Cache Creek to the Rockies Program
Roth Creek to Brake Check

Functional Planning Report
Apr. 2001

Consultants Ltd.
FUNCTIONAL PLANNING REPORT

FOR

CACHE CREEK TO THE ROCKIES PROGRAM

ROTH CREEK TO BRAKE CHECK

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April 2001
EXECUTIVE SUMMARY

In the fall of 1998, the Ministry of Transportation and Highways (MoTH) retained ND Lea Consultants Ltd. to undertake a study to investigate and evaluate alignment options to improve the Trans Canada Highway from approximately one kilometer east of Roth Creek to Brake Check (LKI 12 to LKI 17); the east section of the Kicking Horse Canyon. The limits of the Study Area are shown on the cover of this report. The purpose of all options were improvements that upgraded the Highway from its existing two lane condition, with auxiliary lanes, to a four lane facility.

From west to east, within the study area, the Highway parallels the west-flowing Kicking Horse River along the Canyon floor. The Highway then crosses the River and the Canadian Pacific Railway tracks on the deteriorating Ten Mile (Park) Bridge, before ascending Ten Mile Hill on a curvilinear alignment for approximately two and a half kilometers at a constant eight percent gradient. On this hill, the Highway is constrained to the North by the Canyon walls and to the south by concrete roadside barrier, beyond which lies a steep slope down to the river. The Highway then levels off at the study's east limit, site of a Brake Check for westbound tractor trailers, and continues east toward Yoho National Park.

Traffic operation is generally slow within the study area, in particular on Ten Mile Hill where tractor-trailers ascend at crawl speed. Sharp horizontal curves and steep grades over this section of Highway also have the effect of reducing tractor-trailer speeds to 30 km/h in both the uphill and downhill directions. Cars unimpeded by slow moving trucks travel over this section of the highway at a speed over 80 km/h. This is over 50 km/h faster than the measured speeds of the trucks on the steep grades. The climbing lane on Ten Mile Hill provides overtaking opportunity for vehicles on the ascent. However, there is no passing lane in the downhill direction. Vehicles that have enjoyed good Highway geometry and operating speeds for a long distance east of the Brake Check are suddenly restricted and constrained as they platoon behind slow moving tractor trailers, and other vehicles, upon entering the Kicking Horse Canyon.

Traffic volumes in 1996 averaged approximately 4,655 (AADT) vehicles per day for the year as a whole, climbing to 9,175 (SADT) vehicles per day in peak summer months. These volumes are expected to grow to 6,760 and 12,990 for annual and summer daily travel over this section of the Highway at a speed over 80 km/h. This is over 50 km/h faster than the measured speed of the trucks on the steep grades. The climbing lane on Ten Mile Hill provides overtaking opportunity for vehicles on the ascent. However, there is no passing lane in the downhill direction. Vehicles that have enjoyed good Highway geometry and operating speeds for a long distance east of the Brake Check are suddenly restricted and constrained as they travel over this section of the Highway at a speed over 80 km/h.

From documented accident records, the Accident Rate within the study limits for the years 1991 through 1995 inclusive is double the Provincial Average, while the Accident Severity Index is slightly lower than the Provincial Average

The Accident rate, however in the area of the Park Bridge (LKI 13.8 -LKI 15.2), is 22 times occurring within the study area. The CMP performance measure is set at 1.5 times the Provincial average Accidents are concentrated in this area with lower geometric standards and posted speed, indicating that road geometry plays a significant part in accidents occurring within the study area.

EXECUTIVE SUMMARY

The Park Bridge and Ten Mile Hill section of the Trans Canada Highway is set in an area of complex geological terrain that limits options and increases costs for highway reconstruction.

The study area runs through steeply sloping terrain. The stratigraphy consists of a thin layer (~2m) of topsoil and gravelly silt underlain by limestone or shale bedrock of poor quality with variable competence and structure. Existing rock slopes are 65-70 degrees and severe erosion has taken place at many locations. Steep slopes in this poor rock have a high potential for failure. The gravelly silty soil is susceptible to surface erosion, and with high groundwater conditions, deep-seated landslides are probable. Two such slides have been identified. The first slide is close to the east approach to the existing park bridge and the second one is on the Ten Mile Hill. Both of these slides drastically reduce the choices for alignment options without incurring high costs and high geotechnical risks.

The snowpack in this area seldom exceeds one meter. However, because of the steep terrain, typically weak snowpack structure and smooth ground surface, small snow avalanches occasionally block the existing highway.

A variety of structural defences, including snow retaining fences, terraces, enlarged ditches, and roadside walls, are proposed to keep avalanches off the highway and eliminate the need for closures.

The key environmental issues within the study area are recreational, wildlife, fisheries and archaeological.

The Kicking Horse River is ideal for commercial white water rafting and kayaking. These activities are however likely to be affected primarily by construction activities during the rafting season.

Wildlife movements are concentrated along the river with little or no movement across the River or the Highway. Mountain goats use the bluffs on the south side of the River located above the west abutment of the existing 10 Mile Bridge. Limited potential impacts are expected to wildlife and wildlife habitat.

The River is the only fish-bearing stream crossed by the Highway within the study area. However, limited potential impacts to fish and fish habitat are likely to be mitigated by the proposed clear span bridge across the River, and the provision of ‘No Disturbance Zone’ set back from the river to the proposed surplus material disposal site below or south of the Brake Check.

Based on the background review and field assessment, the possibility of impacts to intact archaeological resources within the study area and the proposed surplus material disposal site is considered low.

To address the poor existing condition of the Highway, several alignments were investigated that employed a range of horizontal and vertical geometry elements within an 80 km/h to 100 km/h design speed envelope, all of which incorporated a four lane divided cross section. Quantities and cost estimates for the various scenarios were developed and, through an iterative and refinement process, a preferred option was identified.
 EXECUTIVE SUMMARY

Under the preferred option, west of the Kicking Horse River crossing, both eastbound and westbound traffic generally follows the existing alignment with minor geometric improvements that raise the design speed to 100 km/h, and cross-section improvements to a four lane facility. Immediately west of the River crossing, the two eastbound and westbound alignments diverge with the eastbound alignment generally following the Highway's existing alignment and crossing the River and CPR tracks on a new 140 meter long bridge. For the westbound alignment, an 1160 meter viaduct is proposed to cross the River and the CPR tracks. This proposal not only minimizes the costs and the risks by reducing the volume of rock cut on the west side of the River, but it also offers enhanced construction staging opportunities for traffic management. East of the River crossing, two lanes of eastbound traffic will travel on the Highway's existing alignment (with horizontal geometry improvements to 80 km/h) while two lanes of westbound traffic will travel on a new, two kilometer roadway (with improvements to allow for a 90 km/h roadway) located uphill and separate from the eastbound travel lanes. At an estimated total cost of $101.3 million, this preferred option is the lowest cost alternative that was developed, while still providing the necessary safety and operational improvements required in the east section of the Kicking Horse Canyon.

If both the Yoho (5 Mile) and approaches and the Park Bridge/10 Mile projects are constructed then the upgrading of the short (1 km ±) four lane section, just east of Rafters Pullout is recommended. This upgrading would cost in the order of $5 million and would provide a consistent cross section and driving experience through this area.
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1.0 INTRODUCTION

This report is part of a series Functional Planning Reports for the Trans Canada Highway - Cache Creek to the Rockies Program. The highway has been studied to determine the scope of potential improvements.

LIMITS OF STUDY AREA

The Trans Canada Highway through the Kicking Horse Canyon, located in southeastern British Columbia, has its western boundary approximately two kilometers east of Golden. Within its confines travels the west flowing Kicking Horse River, the Canadian Pacific Railway (CPR) mainline and the Trans Canada Highway. This functional planning study focuses on the eastern one-third of the Highway's fifteen kilometer length through the Canyon, from Roth Creek to the Brake Check.

The start of the project is located approximately 12 km east of Golden. The limits of the Study Area extend from Roth Creek (LKI 11.8) to approximately 300 m east of Brake Check (LKI 17.4).

The Study Area is shown in Figure 1.1.

STUDY AREA

The Trans Canada Highway within the Kicking Horse Canyon was built to arterial standards in the early 1960's. West of its River and CPR crossing at Ten Mile (Park) Bridge, the Highway is located south of the River along the Canyon floor. The alignment here is relatively good, posted at 80 km/h and includes a short four lane section, approximately 1.5 km in length, adjacent to the Rest Area. From the end of the four lane section to the bridge, the Highway is two lanes wide. The River and railway crossing consists of a seventy one meter long steel truss and concrete deck bridge that was originally built in 1956. Its condition is poor, and is in need of repairs to improve its deck, superstructure and bearings. East of the River, the Highway climbs Ten Mile Hill at approximately eight percent over two and a half kilometers before levelling off at the Brake Check, some 200 meters above the River and Canyon floor. The Highway is posted under an advisory speed of 60 km/h on the Hill, with a serpentine alignment consisting of horizontal curves associated with, generally, 80 km/h design speeds. Two lanes are provided for eastbound, or uphill, traffic, while only one lane accommodates westbound, or downhill, vehicles. At the Brake Check the climbing lane tapers out and the Highway proceeds east on a good, two lane alignment.

OBJECTIVES

The main objectives for this study were to identify the Highway's existing deficiencies and problems, and to determine the optimum four lane alignment through the section recognising total project cost, constructability and the environment.

1.1 REPORT SECTIONS

The report is divided into three main components. The first, containing Chapters 2 through 5, assess the existing conditions of the Highway with respect to the Roadway, Structural elements, Geotechnical and Avalanche issues, and the Environmental parameters. The second component, comprising Chapter 6, presents the preferred alignment option, and is complete with drawings. Finally, Appendix A, discuss the development and analysis of all other alternatives considered by ND Lea during the course of the assignment.

1.2 DATA COMPILATION

The data used in this report is as follows:

- Trans Canada Highway Existing Conditions Report. This report has 1:10,000 unrectified mosaics, Geotechnical Conditions, Agriculture, Archaeology, Fisheries and Wildlife
- Trans Canada Highway, Corridor Management Plan, 1998 (CMP)
- Traffic Data (MoTH data for Count Station P-37-1)
- Reliability Data (MoTH, June 2000)
- Field visits
- Additional References listed in the Geotechnical & Environmental Sections
- Base mapping (compiled from aerial mapping and ground survey (1998 and 2000))
2.1 PREAMBLE

The existing conditions of the highway have been extracted from the "existing conditions" report, a document that was prepared by ND Lea for this section of the Highway in 1998. The information extracted from this report is supplemented with observations from site visits conducted by ND Lea and others between 1998 and 2000. The accompanying 1:10,000 photo mosaics present the existing conditions in tabular form (refer to Figures 2-1.1 and 2-1.2 at the back of this chapter), and identify deficiencies and problems that are discussed in detail throughout this chapter.

In order to establish benchmarks against which existing Highway conditions could be assessed, the Ministry adopted a set of Performance Measures, discussed below, as identified in the Trans Canada Highway's 1998 Corridor Management Plan. In addition to these Measures, Highway deficiencies are noted relative to the posted speed and desired design speed (100 km/h).

2.2 CMP PERFORMANCE MEASURES

The CMP performance measures assess specific parameters of the highway with respect to traffic and geometry.

2.2.1 Running Speeds

Limited observations of truck running speeds were measured during site visits in May 2000. The running speed through this section was difficult to measure as the vehicle mix affected the running speed.

In two lane sections with steep grades, trucks slow down dramatically. (See Figure 2.2.3). In a number of these locations there are no passing opportunities. Slow moving trucks affect the speed of the vehicles following them. As the volume of traffic increases, this increases the probability of lower running speeds as vehicles capable of higher speeds are more likely to be platooned behind slow moving trucks. As a result the running speed varies depending on the volume of traffic on the facility at any given time.

The running speed is estimated to be less than the posted speed of 80 km/h and less than the rural performance measure of 90 to 100 km/h.

2.2.2 Passing Opportunities

There are no passing opportunities on the highway where there are only two lanes as a double yellow line is present. The highway is a two lane facility with the following exceptions.

- In the eastbound direction
  - two lanes from LKI 12 to LKI 13
  - eastbound climbing lane LKI 14.5 to LKI 16.9

Due to the curvilinear alignment, the above exceptions are the only opportunities for faster moving vehicles to pass slower moving vehicles.

In the sections adjacent to the study area, passing opportunities occur at the following locations:

- West of the study area
  - In the eastbound direction: 2.0 kilometers west
  - In the westbound direction: 3.5 kilometers west

- East of the study area
  - In the eastbound direction: 0.5 kilometers east
  - In the westbound direction: 0.5 kilometers east

The lack of passing opportunities in this section negatively affects average running speed, safety and traffic operations in general. If passing opportunities are desired, additional lanes will be needed.

2.2.3 Truck Speeds

Climbing lanes are warranted when the truck speed drops more than 15 km/h below the average running speed.

Truck speeds drop in areas of steep grades both in the uphill and downhill directions. Tight horizontal curves also affect truck speeds.

This corridor has both steep grades and tight horizontal curves. The maximum grade on this section of the highway is 7.8 % over two kilometers. The truck speeds drop off dramatically due to the very steep grade in both the uphill and downhill directions.

Truck speeds were measured in the field for two trucks in both the uphill and downhill directions. It was noted that the lowest speed was 30 km/h, over 50 km/hr lower than the posted speed. The truck speeds were measured during a May 2000 field visit and are shown on Figure 2.2.3.

Cars unimpeded by slow moving trucks travel over this section of the highway at a speed over 80 km/h. This is over 50 km/h faster than the measured speed of the trucks on the steep grades.
2.0 HIGHWAY ASSESSMENT

2.2.4 Reliability

The definition of reliability as stated in O.G.E.S. Section 2.2 states "The performance measure for reliability of the highway reflects the degree to which the highway is closed during the year due to incidents such as avalanches, slides, major accidents and highway maintenance..."

The basis for rating the reliability of the highway is to compare it to the critical closure rate for the Provincial average. The average rate of closures for the Provincial numbered highways is 5.23 hrs/km/yr. The Trans Canada Highway from Kamloops to the Alberta border has a rate of 6.04 hrs/km/yr. The Kicking Horse segment has an average of 7.21 hrs/km/yr.

This segment of the highway has closures. Most of them are as a result of avalanches and whiteouts. Some of the closures are related to adjacent sections that are closed for similar reasons.

There is a road closure gate located at the eastern end of this segment of the highway (LKI 17). Except for the toilet facility at the Brake Check, there is no nearby facility to accommodate people during a closure should drivers encounter a closed gate during their travels.

2.2.5 Pavement Quality Index

The pavement condition performance measure used for highways on the CCRRP is the Pavement Quality Index.

The Pavement Quality Index (PQI) measures the required treatment for the road pavement. The Pavement Quality Index is a combination of the pavement distress index (PDI)(40%) and the ride comfort index (RCI)(60%). The CMP gives the following performance measure for the pavement quality index:

- 6.4<PQI: Does not need resurfacing
- 5<PQI<6.4: Needs resurfacing
- PQI<5: Will need rehabilitation

Table 2.2.5 shows the locations and the extent of PDI, RCI and PQI on the existing highway as reported in the Existing Conditions Report (1998). A review of the data indicates that most sections of the highway do not require any treatment and only a short segment requires rehabilitation.
Table 2.2.5

<table>
<thead>
<tr>
<th>LKI Stationing (km)</th>
<th>Pavement Distress Index (PDI)</th>
<th>Riding Comfort Index (RCI)</th>
<th>Pavement Quality Index (PQI)</th>
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<tbody>
<tr>
<td>11.90 to 13.25*</td>
<td>9</td>
<td>7</td>
<td>4.56</td>
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<td>13.25 to 14.20</td>
<td>8.2</td>
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<td>7.48</td>
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<td>14.20 to 14.30</td>
<td>8.3</td>
<td>7</td>
<td>7.88</td>
</tr>
<tr>
<td>14.30 to 14.40</td>
<td>8.3</td>
<td>7</td>
<td>7.88</td>
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<td>14.40 to 14.60</td>
<td>6.7</td>
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<td>16.70 to 17.00</td>
<td>6</td>
<td>7</td>
<td>6.6</td>
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<td>17.00 to 17.10</td>
<td>7.6</td>
<td>7</td>
<td>7.3</td>
</tr>
<tr>
<td>17.10 to 18.00</td>
<td>5.5</td>
<td>7</td>
<td>6.4</td>
</tr>
</tbody>
</table>

*These segments have undergone asphalt rehabilitation.

2.3 POSTED SPEED

The posted speed is 80 km/h. Curves immediately before and after Park Bridge have an advisory posted speed of 60 km/h due to sharp horizontal curves immediately before and after the bridge.

The objective design speeds set by MoTH are 100 km/h in rural conditions. Where highway upgrading is warranted, consideration should be given to designing to the 100 km/h design speed.

2.4 HIGHWAY GEOMETRY

2.4.1 Horizontal Geometry

The highway in this study area appears to use the horizontal design curves based on a maximum super elevation rate of 8%. Current practice limits the maximum super elevation to 6% and does not recommend a greater value for rural highways.

Using the MoTH Design Manual Table, 330.C (max. super elevation = 8%) the minimum radius for the posted speed of 80 km/h is 250 meters. The minimum radius for 60 km/h is 120 meters. Using MoTH Table, 330.F (max. super elevation = 8%) the minimum radius for the preferred CMP performance measure relating to a 100 km/h design speed is 440 meters. The posted speed within the study area is 80 km/h. A short section located in the vicinity of Park Bridge has an advisory speed posted at 60 km/h. All of the existing vertical curves meet the minimum k values for the posted speed.

2.4.2 Consistency of Curvature

Research indicates that when most of the curves along a corridor show a small deviation from the average curvature for the corridor, the accidents are distributed evenly throughout the corridor. Driver expectations are related to the average curvature. When there are curves that are much less than the average curvature, an increase in the accident rate can be expected in these areas. Within the study area the curves along the alignment deviate significantly from the average in the area of Park Bridge. The accident rate in this area is considerably higher than the rest of the study area (see section 2.8.4). In addition, compared to adjacent sections, the curve radii within the study area are also much less.

2.4.3 Vertical Geometry

The minimum k value for headlight control for a sag curve is 32 at 80 km/h, 17 at 60 km/h (49 for 100 km/h). The minimum k value for taillight control for a crest curve is 36 at 80 km/h, 22 at 60 km/h (74 for 100 km/h). All of the existing vertical curves meet the minimum k values for the posted speed.

2.5 CROSS SECTION

2.5.1 Shoulder Widths

The existing shoulder widths throughout the corridor vary from 0.5 meters to 2 meters. MoTH Table 430.A states the required shoulder width for an arterial undivided highway with less than 450 for the design hour volume is 2.0 meters and is 2.5 meters for a design hour volume exceeding 450.

The existing shoulder width does not meet the MoTH requirements for the current 30th highest hourly traffic flow of approximately 1000 vehicles. The required shoulder width is 2.5 meters.

2.5.2 Clear Zone

The clear zone in this section is generally only the width of the 0.5 to 2 meter shoulder plus the varying recoverable slope widths ranging from 0.5 to approximately 10 meters. Non-recoverable slopes start immediately outside these areas. MoTH technical bulletin DS960001 states a 6 meter clear zone is required for a 6000 Design AADT for a 90 km/h posted speed. This requirement is only partially met now. Most sections of the highway have clear zone widths less than 6 meters.

2.5.3 Median

The warrants for a median barrier are shown in the MoTH Design Manual, section 630.02. Current AADT volumes are less than 5000 vehicles and a median is not warranted. The design year of 2021 is forecast to have an AADT of 6,755, at which volume a median barrier is optional.

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2.6 INTERSECTIONS AND ACCESSES

The highway travels through a rural setting and there is only one intersection within the study area. The intersection is located at LKI 12 and accesses the Rest Area. Brake Check also acts as an access to Glenogle Forestry Road for eastbound vehicles, which are mainly logging trucks. There are other accesses that appear to have very little traffic (less than 5 vehicles per day).

Table 2.6 shows the locations and descriptions of the existing intersection, accesses and other ancillary facilities along this stretch of the highway.

<table>
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<th>Kilometer</th>
<th>Description</th>
<th>Notes</th>
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<td>Rest Area</td>
<td>12.5, 12.7</td>
<td>The rest area is accessed by a westbound right turn deceleration lane and an eastbound left turn lane</td>
<td></td>
</tr>
<tr>
<td>Informal Accesses</td>
<td>13.1, 13.5</td>
<td>Accesses that serve no specific facility and do not appear to be used very often. They may be utility accesses</td>
<td></td>
</tr>
<tr>
<td>CPR Access</td>
<td>14.4</td>
<td>A rough gravel access road to the CPR tracks located immediately east of Park Bridge</td>
<td></td>
</tr>
<tr>
<td>Runway Lane</td>
<td>14.7</td>
<td>Gravel runway lane located just east of the existing 60 km/h curve before Park Bridge</td>
<td></td>
</tr>
<tr>
<td>Informal Accesses</td>
<td>15.6, 15.9</td>
<td>Gravel access to the Hydro power line pole line off the existing eastbound side of the road.</td>
<td></td>
</tr>
<tr>
<td>Brake Check and Glenogle Forestry Road</td>
<td>16.8, 17.0</td>
<td>The Brake Check has an ingress and egress separated by 200 meters. Access to Glenogle Forestry road is via the Brake Check Area.</td>
<td></td>
</tr>
<tr>
<td>Weather Station</td>
<td>16.95</td>
<td>A weather station is located on the south side of the highway, opposite the Brake Check.</td>
<td></td>
</tr>
</tbody>
</table>

2.6.1 Deceleration/Acceleration Lanes

For the eastbound traffic, there is a channelized left turn lane into the Rest Area. However, there are no acceleration or deceleration lanes for other movements. The Brake Check has substandard acceleration and deceleration lanes. There are no other acceleration/deceleration lanes within the study area.

2.6.2 Approach Grades

The approach grades on the intersections and accesses are less than 6%. These grades are acceptable.

2.6.3 Intersection Sight Distance

Sight distances were reviewed for Stopping Sight Distance and Crossing Sight Distance at the Rest Area. The required minimum distances are 160 meters for an 80 km/h design speed (200 meters for 100 km/h) for both the Stopping Sight Distance and the Crossing Sight Distance. The Rest Area has sight distances in excess of the minimum distances.

2.7 TRAFFIC

Based on data supplied by the Ministry, supplemented by on-site observations, existing traffic conditions were analysed and forecasts prepared of future traffic volumes and operational conditions. This will provide essential input to the planning of improvements. In 1996 the annual average daily traffic flow (AADT) was 4,655 vehicles per day. Summer average daily traffic (SADT) 9,175 vehicles per day. and truck volumes about 850 per day.

2.7.1 Traffic Data Collection

The main source of data was the Ministry’s permanent count station no. P-37-1, located to the east of Golden. Since there is very limited activity adjacent to the Highway between the outskirts of Golden and Yoho, and hence limited movements onto or off the Highway, traffic volumes are essentially the same along this entire section of road.

Two half-hour manual classified counts were carried out during a recent site visit by ND Lea Consultant Ltd.'s staff to provide a check on assumptions regarding vehicle classification.

2.7.2 Vehicle Classification

Truck volumes along the entire corridor (Cache Creek to the Rockies) were fairly consistent at between 700 and 900 per day, with seasonal variation generally being quite small. A truck volume of 850 vpd (18% of AADT) has been used. This may be slightly conservative, as some recent data shows truck percentages at 20% or more.

A classified count conducted by the Ministry in August 1996 at Blackwall Bluffs, in the Kicking Horse Canyon, some distance to the west of the section under review, but within the same segment of the Trans Canada Highway and with very little difference likely in traffic flow, indicated that 86.3% of traffic was light vehicles (cars / pick-ups / SUVs / motorcycles), and 13.7% trucks. (A more detailed breakdown of trucks is available for use in determining pavement design parameters.)

A more recent classified traffic count was conducted in August 1999 at Blackwall Bluffs. This count would be indicative of the traffic expected in this section. The data collected provides a breakdown of the vehicle sizes as follows:

<table>
<thead>
<tr>
<th>Vehicle Size</th>
<th>Volume/24 hours</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0m – 6m</td>
<td>7550</td>
<td>78.2%</td>
</tr>
<tr>
<td>6m – 12.5m</td>
<td>955</td>
<td>9.9%</td>
</tr>
<tr>
<td>12.5m – 22.5m</td>
<td>978</td>
<td>10.1%</td>
</tr>
<tr>
<td>22.5m – 35m</td>
<td>178</td>
<td>1.8%</td>
</tr>
<tr>
<td>&gt;35m</td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

Note that there are 1,156 vehicles per day over 12.5 m long, which includes all trucks and heavy RVs representing 23.6% of the AADT, and considering an allowance for heavy RVs supports the use of an 18 – 20% truck percentage.
2.0 HIGHWAY ASSESSMENT

Two half-hour counts conducted at 09:30 and 14:00 on May 25, 2000 in the section covered by this report, gave truck percentages of 16% to 21%, whilst RV’s accounted for 8% in both time periods.

There is one school bus that transports students from Field to the schools in Golden each school day.

Local forestry activity, including logging and the transport of processed timber accounts for approximately 20 truck trips per day.

RV volumes are strongly seasonal, being highest between May and September, but fairly low during the winter months. Classified counts east of Revelstoke gave RV flows at around 7% of summer average daily traffic (SADT).

Rafting also generates a certain amount of seasonal traffic. A detailed discussion concerning traffic generated by the rafting community is presented in Chapter 5.

2.7.3 Seasonal Variation in Traffic Flow

Traffic on this section of the Trans Canada Highway is very strongly seasonal. Local traffic is very limited, and truck traffic is a fairly consistent volume throughout the year. However, recreational traffic, which is a major component of summer traffic, drops to a very low volume in mid-winter. Monthly average daily traffic (MADT) in January is only 15% of July MADT. In relation to AADT, January MADT is 29% of AADT, whilst July MADT is 190% of AADT.

Figure 2.7.3 shows the variation of traffic by month.

Monthly Average Daily Traffic, MADT
2.5km East of Junction with Route 95, Golden

<table>
<thead>
<tr>
<th>Month</th>
<th>% of AADT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jan</td>
<td>20%</td>
</tr>
<tr>
<td>Feb</td>
<td>25%</td>
</tr>
<tr>
<td>Mar</td>
<td>30%</td>
</tr>
<tr>
<td>Apr</td>
<td>35%</td>
</tr>
<tr>
<td>May</td>
<td>40%</td>
</tr>
<tr>
<td>June</td>
<td>45%</td>
</tr>
<tr>
<td>July</td>
<td>50%</td>
</tr>
<tr>
<td>Aug</td>
<td>55%</td>
</tr>
<tr>
<td>Sept</td>
<td>60%</td>
</tr>
<tr>
<td>Oct</td>
<td>65%</td>
</tr>
<tr>
<td>Nov</td>
<td>70%</td>
</tr>
<tr>
<td>Dec</td>
<td>75%</td>
</tr>
</tbody>
</table>

Source: MTP37 Count Station F-27-1

2.7.4 Annual Average Daily Traffic (AADT)

Annual average daily traffic (AADT) in 1996 was 4,655 vpd. The hourly distribution is shown in Figure 2.7.4, based on three count periods of at least sixteen days each in June, August and November 1999.

Highest average hourly flow was 8.4% between 15:00 and 16:00, and 8.3% the preceding hour, as shown in Figure 2.7.4. Clearly, daily traffic variation on this section of the Trans Canada Highway is very different to patterns found in urban areas, with hourly volume climbing steadily during the day until mid-afternoon, then dropping gradually during the evening.

2.7.5 Summer Average Daily Traffic

The summer average daily traffic (SADT) is defined as the average daily traffic flow during the months of July and August. In 1996 the observed SADT was 9,175 vpd. Growth in SADT between 1963 and 1996 is shown in Figure 2.7.5.
2.7.5 Traffic Growth to 2021

Population growth in Golden has been modest, and this rate is not likely to increase much, if at all, during the design period. The redevelopment of Golden Peaks Ski Resort (now re-named Kicking Horse Mountain Resort), could contribute to traffic growth in the area as a whole, but its impact on average daily traffic on the Trans Canada Highway east of Golden will be modest, and can be taken as part of the overall traffic growth discussed below. It should also be noted that peak demand at this facility would be in winter, when daily traffic on the Trans Canada Highway is at its lowest.

Whilst there is likely to be some development in the Beaverfoot Road/Lodge area (located in the Brake Check to Yoho National Park section) and in Field, this will be limited. Beaverfoot Road may have some increase in holiday homes, whilst in Field a modest increase in tourist accommodation and in accommodation for service contractors working in Yoho National Park or on the CP Rail line is possible. Local growth will therefore have little effect on traffic volumes. In the Community Impact and Development Study Summary Report (Urban Systems, May 1998), the Recommended Growth Scenario adopts traffic growth rates of 1.5% p.a. for AADT and 1.4% p.a. for SADT. Applying these rates gives the following forecast daily flows in the design year (2021):

<table>
<thead>
<tr>
<th></th>
<th>AADT</th>
<th>SADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>6,755 vpd;</td>
<td>12,990 vpd.</td>
</tr>
</tbody>
</table>

2.7.7 Forecast Design Hour Volumes

The design hour volume (DHV) is usually taken as the thirtieth highest hourly flow in the forecast year. The Traffic Forecast Report for the corridor indicated a DHV range of 10 to 12% of SADT or 15 to 22% of AADT on two rural segments of the route, and recommended that a figure of 10% of SADT be generally used for calculating DHV. This gives a DHV of 1300 vph.

2.7.8 Traffic Distribution

Nearly all traffic on this section of the Trans Canada Highway travels through the entire section.

2.7.9 Level of Service

The operational capacity of a road or roadway element is generally expressed in terms of its level of service (LOS), using the letters from A to F to indicate LOS. LOS A indicates free-flow traffic, with vehicles unconstrained by other traffic. As traffic increases, the LOS goes to B, C and D, with E being at or close to capacity. LOS F indicates congestion, sub-optimal operation, and the volume of traffic wishing to use the road being in excess of what it is able to accommodate. Lengthy delays may be experienced at LOS F.

Determining the LOS for the Rest Area to Brake Check section of the TCH is not easily definable. Specific LOS values are related to homogenous sections of roads. The road is not homogeneous. The highway has 4 lane, 2 lane and 3 lane sections. It has rolling and mountainous terrain. It has varying lane, shoulder and clear zone widths. All of the factors lend themselves to different values for the LOS for that particular section. In the worst area, the one lane westbound downhill, 2 kilometer stretch form the Brake Check to Park Bridge, the LOS according to HCM would be classified as F. Factors that contribute to the LOS for this section are the percentage of heavy vehicles, and the steep gradient. These contribute to very slow travels speeds that create long platoons with no passing opportunities.

Such sections slow down the overall travel speed of the vehicles. Directly after Park Bridge the overall westbound travel speed is observed to increase due to the rolling rather than the mountainous terrain. Just 1 kilometer west of Park Bridge, the LOS can be classified as C/D because a 4 lane level section, with passing opportunities, is encountered.

As well, different drivers will experience different travel speeds at different times due to the irregular traffic mix. This translates to different LOS values. Within the same quarter hour period, different drivers may experience levels of service ranging from A to F. In the case of drivers experiencing LOS F, his average travel speed (and hence his level of frustration) may be considerably higher than that of a driver experiencing LOS C/D conditions.

The significant volume of trucks (850 per day), which travel at or close to the speed limit on level or rolling terrain, but slow down dramatically on steep inclines where passing opportunities are limited, is a major contributor to delay, and to poor levels of service in places.
2.0 HIGHWAY ASSESSMENT

Taking all these factors into account, and recognizing that the level of service for the section as a whole is a composite of the different road characteristics through the section and differing traffic conditions at different times, the overall level of service is likely to be in the D to E range.

2.8 SAFETY

2.8.1 Overall Accident Statistics

The Ministry of Transportation and Highways provided accident statistics for the five year period from 1991 to 1995 inclusive. The location of each accident is identified to the nearest 100 m in terms of the Ministry's Landmark Kilometer Index (LKI).

For the 5.4 km section from the Roth Creek (LKI 12.0 of Segment 990) to Brake Check (LKI 17.4), a total of 54 accidents were recorded during this five year period. These were classified as fatal, injury, or property damage only, as listed in Table 2.8.1.

Table 2.8.1: Accident Statistics: 1991 to 1995
Highway 1: LKI 12.0 (Roth Creek) to 17.4 (Brake Check)

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal</th>
<th>Injury</th>
<th>Property Damage Only</th>
<th>Total Accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>0</td>
<td>8(16)</td>
<td>13</td>
<td>21</td>
</tr>
<tr>
<td>1992</td>
<td>1(1F+5I)</td>
<td>6(7)</td>
<td>8</td>
<td>15</td>
</tr>
<tr>
<td>1993</td>
<td>0</td>
<td>0</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>1994</td>
<td>0</td>
<td>2(4)</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td>1995</td>
<td>0</td>
<td>2(2)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>1(1F+5I)</td>
<td>18(29)</td>
<td>35</td>
<td>54(1F+29I)</td>
</tr>
</tbody>
</table>

Note: Figures in brackets indicate numbers of persons killed (F) or injured (I)

The locations of the accidents listed above are shown in Section 11 of the Existing Conditions Report.

2.8.2 Comparison with Provincial Accident Frequency and Severity Rates

In order to provide for comparison between accident rates on different roads of similar type (e.g., rural arterial, urban freeway), accident rates are generally expressed in terms of accidents per million vehicle kilometers (mvk) of travel. The Provincial average accident rate for rural arterials is 0.7 acc/mvk, but where volumes are lower, rates are slightly higher, with roads carrying less than 5,000 vpd have an average accident rate closer to 0.8 acc/mvk. The accident rates for the section of Trans Canada Highway between Roth Creek and the Brake Check are shown in Table 2.8.2.

An Accident Severity Index has also been developed which weights accidents by severity, with fatal, injury and property damage only accidents having respective weightings of 100, 10 and 1. The Provincial average Accident Severity Index (ASI) for rural arterials is 6.07.

Table 2.8.2: Accident Rate per mvk and Accident Severity Index (ASI): 1991 to 1995
Trans Canada Highway: LKI 11.8 (Roth Creek) to 17.4 (Brake Check)

<table>
<thead>
<tr>
<th>Year</th>
<th>AADT</th>
<th>Accidents</th>
<th>mvk</th>
<th>Acc/mvk</th>
<th>ASI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1991</td>
<td>3475</td>
<td>21</td>
<td>6.8</td>
<td>3.1</td>
<td>4.4</td>
</tr>
<tr>
<td>1992</td>
<td>3566</td>
<td>15</td>
<td>7.0</td>
<td>2.1</td>
<td>11.2</td>
</tr>
<tr>
<td>1993</td>
<td>3795</td>
<td>6</td>
<td>7.5</td>
<td>0.8</td>
<td>1.0</td>
</tr>
<tr>
<td>1994</td>
<td>4147</td>
<td>7</td>
<td>8.2</td>
<td>0.9</td>
<td>3.6</td>
</tr>
<tr>
<td>1995</td>
<td>4400 (est.)</td>
<td>5</td>
<td>8.7</td>
<td>0.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Av.1991-95</td>
<td>3877</td>
<td>10.8</td>
<td>7.6</td>
<td>1.4</td>
<td>5.8</td>
</tr>
</tbody>
</table>

As may be seen from Table 2.8.2, the number of accidents per million vehicle kilometers for this section over the five years from 1991 to 1995 inclusive is double the Provincial average for rural arterials (1.4 compared with a Province-wide rate of 0.7), and nearly double the norm of 0.8 for low volume roads. This exceeds the desirable performance measure of not more than 1.5 times the Provincial average (1.05, or for low volume roads, 1.2). Accident severity, however, is marginally lower, being 5.8 compared with a Provincial average of 6.07.

Table 2.8.2 indicates a decreasing trend in accident rates, from 3.1 in 1991 to 0.6 in 1995. However, a longer period would need to be considered to determine if this is a definite and sustained downward trend.

2.8.3 Nature and Causes of Accidents

The main contributing factor, as well as surface conditions and weather were examined for the 54 accidents between 1991 and 1995. The findings were as follows:

- 34 accidents (63%) were single vehicle accidents;
- Unsafe speed was given as "first contributing factor for first vehicle" in 18 cases (33%); 16 of these were single vehicle accidents. The advisory speed in this area is 80 km/h. This is 20 km/h below the posted speed of 80 km/h for the rest of the study area. This reduction in the road geometrics leading to the lower posted speed is likely a major contributing factor to the accident rate in this area.
- Weather and weather-related road conditions (snow, slush, icy) were a factor. Traffic being much less means that there are fewer vehicles are slowed down by other traffic, requiring drivers to select a speed appropriate to the conditions. Clearly, the consequences of not doing so are serious;
- Driver-related factors (inattention, inexperience, fatigue or alcohol) were the primary factor in 7 accidents (13%);
- Road-related factors (obstructions or debris, maintenance/construction or roadside hazards) were contributory factors in 5 accidents (9%);
- Wild animals were the primary cause of 4 accidents (7%).

As of April 30, 2001 10:37:27 AM
2.0 HIGHWAY ASSESSMENT

2.8.4 Accident Concentrations

Based on the MoTH accident records for 1991 to 1995, the following observations may be made:

- 35 accidents (17.7/mvk) occurred in the vicinity of the bridge (LKI 13.8 – 15.2). This is 22 times the Provincial average of 0.8 accidents/mvk for <5000 AADT. The CMP performance measure is 1.5 times the Provincial average, or 1.2 accidents/mvk
- Within the above section of the road, 22 accidents involved vehicles leaving the road, of which about two thirds were travelling westbound (i.e. down the hill). While unsafe speed and surface conditions (snow, ice) were given as contributing factors in many cases, the road geometry and condition is likely to have been a significant factor in many of these accidents.
- At the first bend to the east of the bridge (LKI 14.4 – 14.5), 9 accidents occurred during the 5-year period. The severity index was 4.0 (the Provincial average is 6.07).
- 7 accidents occurred at LKI 15.0.

Accidents are concentrated in the area with lower geometric standards and posted speed, indicating that road geometry plays a significant part in accidents occurring within the study area.

2.9 DRAINAGE AND UTILITIES

2.9.1 Drainage

The existing drainage consists of open ditches and cross culverts, none of which have had condition surveys. There are no enclosed drainage systems on the existing highway.

West of Park Bridge, the two largest culverts are a 1200 mm diameter CSP and a 1750 mm diameter CSP. East of the bridge, the largest culvert is a 900 mm diameter CSP and most culverts are carried right to the base of the hillside slope. It is surmised that this is done in order to reduce erosion.

2.9.2 Utilities

There are only two utilities in the immediate vicinity of the highway.

- HYDRO POWERLINE. The power line essentially parallels the existing highway.
  - West of Park Bridge, the power line is located primarily on the left hand side of the existing road and its offset from the road varies from 10 to 30 meters. A significant number of poles will have to be relocated to accommodate the new design.
  - East of Park Bridge, the powerline is located primarily right of the highway south of the Brake check and left of the highway from the Brake check onwards. Its offset varies from 7 to 70 meters. Most of the poles that need to be relocated will be from the Brake check area eastwards.

- FIBRE OPTICS LINE. There is a fibre optics line located within the CPR right of way. It is not anticipated that this line will be impacted, as the design does not involve construction within the CPR right of way.
<table>
<thead>
<tr>
<th>Intersection/Accesses</th>
<th>0990</th>
<th>12.0</th>
<th>13.0</th>
<th>14.0</th>
<th>15.0</th>
</tr>
</thead>
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<tr>
<td>Cut/Fill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder Zone (Left)</td>
<td>7.0</td>
<td>CRB 0.8</td>
<td>2.0</td>
<td>4.0</td>
<td>2.5</td>
</tr>
<tr>
<td>Right Turn Lanes (Length)</td>
<td>0.8</td>
<td>1.9</td>
<td>0.8</td>
<td>1.9</td>
<td>0.5</td>
</tr>
<tr>
<td>Shoulder Width (Right)</td>
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<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
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<tr>
<td>Median Width (Type)</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Left Turn Lanes (Length)</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Lane Width (Number)</td>
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</tr>
<tr>
<td>Clear Zone (Right)</td>
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<td>0.5</td>
<td>0.5</td>
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</tr>
<tr>
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<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Horizontal (°)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical (%)</td>
<td>+2.0%</td>
<td>+1.0%</td>
<td>+1.0%</td>
<td>+1.0%</td>
<td>+1.0%</td>
</tr>
<tr>
<td>Posted Speed (Advisory)</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>ADT (SADT)</td>
<td>4278</td>
<td>4278</td>
<td>4278</td>
<td>4278</td>
<td>4278</td>
</tr>
<tr>
<td>Electrical</td>
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<td></td>
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<tr>
<td>Drainage</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
<td>1200</td>
</tr>
<tr>
<td>Structures (RCI)</td>
<td></td>
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<tr>
<td>R/W (Total)</td>
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<td>34</td>
<td>34</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>PS/RCI</td>
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<td>A</td>
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<td>A</td>
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<tr>
<td>Geotechnical Issues</td>
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<tr>
<td>Archaeology</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Fishery</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Wildlife (WARS)</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
<td>Low</td>
<td>Moderate</td>
</tr>
</tbody>
</table>

**Figure 2-1.1**

Scale 1:10,000
3.7(1)  

Posted Speed (Advisory) 80
AADT (SADT) 4276 (8760)

<table>
<thead>
<tr>
<th>Intersections/Accesses</th>
<th>Segment/LKI</th>
<th>C</th>
<th>16.0</th>
<th>17.0</th>
<th>18.0</th>
</tr>
</thead>
<tbody>
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<td>C</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clear Zone (Left)</td>
<td>C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder Width (Left)</td>
<td>1.0</td>
<td>2.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Turn Lanes (Length)</td>
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<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder Width (Right)</td>
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<td>1.5</td>
<td></td>
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<tr>
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<tr>
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<tr>
<td>Accidents</td>
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<td>Natural Hazards</td>
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<td>Geotechnical Issues</td>
<td></td>
<td></td>
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</tr>
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<td>Archeology</td>
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<td></td>
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</tr>
<tr>
<td>Wildlife (WARS)</td>
<td>Low</td>
<td></td>
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</tbody>
</table>
3.1 In this section of the highway, there is only one bridge, the 10 Mile (Park) Bridge, and two retaining walls.

3.1.1 The 10 Mile (Park) Bridge

The existing bridge is a three-span, structural steel deck-truss structure with a reinforced concrete deck supported on reinforced concrete piers and abutments. The piers are relatively tall rectangular shafts of reinforced concrete construction, which support the 71m long main span of the bridge. The abutments consist of reinforced concrete walls, which are arranged, in a closed-box, cellular configuration. The reinforced concrete deck has a curb-to-curb width of 7.2m which is appreciably narrower than current standards dictate.

3.1.2 Condition Assessment

The bridge was last inspected by the Ministry in early May 2000. The inspection report, which presents a numerically based assessment of each inspected component of the bridge, indicates that the bridge is in need of repairs to remain in service. The bridge has been assigned an Adjusted BCI (Bridge Condition Index) of 2.57. An index of 1 would indicate a bridge in excellent condition and an index of 5 signifies very poor condition.

The most deteriorated element of the bridge is the reinforced concrete bridge deck, although there are also some problems in the steel superstructure and its supporting bearings.

The bridge has been assigned a Repair Urgency Index of 4 on a scale of 5 in which a score of 5 would indicate a high priority for structural repairs associated with significant safety concerns.

3.1.3 Structural Capacity

The bridge was originally built in 1956, and it is understood that no load rating has been subsequently carried out to determine if the structural capacity of the bridge meets current highway bridge design requirements.

3.2 OTHER STRUCTURES

3.2.1 Retaining Walls

Two steel bin walls are located in the Ten Mile slide area and support the existing highway. Although the bin wall structures themselves appear to be in generally sound condition, their overall stability is being compromised by ongoing soil instability. Further discussion of these structural elements with suggestions for their future service is contained in Chapter 4 Geotechnical Assessment.
4.0 GEOTECHNICAL AND AVALANCHE ASSESSMENT

4.1 GENERAL CONDITIONS

The Park Bridge and Ten Mile Hill section of the Trans Canada Highway is set in an area of complex geological terrain that limits options and increases costs for highway reconstruction.

The study area runs through steeply sloping terrain composed of glaciolacustrine with interbedded colluvium deposits and occasional glacial drift. The stratigraphy typically is compromised of a thin layer of topsoil over compact to dense, gravelly silt underlain by limestone or shale bedrock. Depth to bedrock is typically very shallow, less than 2.0 meters.

The snowpack in this area seldom exceeds one meter. However, because of the steep terrain, typically weak snowpack structure and smooth ground surface, small avalanches frequently block the existing highway.

Geotechnical and Avalanche Investigation:
- Review of historical information.
- Air photo interpretation to identify potential natural hazards, waste sites and aggregate sources.
- Site reconnaissance on several occasions.
- Drilling along the Park Bridge alignment and approaches and within the Ten Mile Slide to investigate subsurface conditions. Geophysics within the Ten Mile Slide to help define the soil/bedrock interface.
- Evaluation of the acid rock generating potential of the rock types likely to be excavated and used for fill materials and the metal leaching potential of the McKay Group 5 Calcareous Slates and Glenogle Shales.
- Laboratory analysis of soil and rock samples and logging of rock core.
- Application of avalanche dynamics models to determine defence structure requirements.

4.2 ENGINEERING EVALUATION

4.2.1 Natural Hazards

Two landslides have been identified within the project area, the Park Bridge and Ten Mile Slides. These are constraints on the alignment options.

4.0 GEOTECHNICAL AND AVALANCHE ASSESSMENT

Park Slide:

The Park Slide is comprised of western and eastern slope movements. Movement was first observed during the original construction of Park Bridge in 1954. A drainage adit was placed within the western slope sliding mass to reduce internal water pressures, since then there has been no record of further movement. However, sloughing and tension crack development above the steep cut slope was noted after the completion of construction in the late 1950’s.

An assessment of the slide was completed by Golder Associates Ltd. and is summarized in the report ‘Geotechnical Assessment of Park Bridge Slide’ dated October 1999.

The slide is a low risk hazard but because it appears to be sensitive to groundwater elevation the condition of the drainage adit needs to be determined. The Park Slide can essentially be ignored if the slope drainage is maintained.

The presence of the slide precludes constructing an alignment to the northwest of the existing bridge.

Ten Mile Slide:

The Ten Mile Slide was first noticed in the spring of 1999 when 1.0 m of downslope movement resulted in the appearance of a large tension crack below the existing highway on the Ten Mile Hill.

Slide movement is driven by high water pressures created during spring melt. Surface drainage improvements are required to maintain stability by stopping water from seeping into the slide area and increasing groundwater elevations and by reducing surface erosion of the slope. Improvements such as enclosing drainage from the highway over the fill slopes and increasing the number of culverts should be considered. Additionally, work should be done at the toe to prevent further erosion by the Kicking Horse River.

Slope inclinometers and pneumatic peizometers have been installed within the sliding mass and on the existing highway to determine the extent of the slide. The instrumentation has shown that the slope is failing along the bedrock contact at the headscarp, below the steel bin walls, and through the soil further down the slope. In addition, the instrumentation has shown that the slide is a minimum of 15 m thick.

The slide is a risk to the present alignment and any future alignments at the same location. Remedial measures to be considered for alignments through the area should encourage unloading through top-down excavation. The use of viaducts would require stabilization or removal of slide material.

Avalanches

Avalanches from four paths block this section of the existing highway several times during an average winter. These paths shown in Drawing 81432-SK-147 and numbered 14.2, 14.5, 14.7 and 15.3 in the Ministry Avalanche Atlas, are responsible for most of the highway avalanche control closures in the Kicking Horse Canyon.
4.0 GEOTECHNICAL AND AVALANCHE ASSESSMENT

Since 1974 there have been six avalanche incidents on this section of the highway. Three private vehicles were hit by avalanches and on three occasions Ministry loaders were hit while removing snow. There were no injuries.

Since 1992, when a reliable record of avalanche size begins, 52 of the 103 natural avalanches that affected this section of the highway were large enough to bury a person but none were large enough to seriously damage a car.

Although the avalanches tend to be small the associated hazards are still significant. A vehicle stopped by a small avalanche may be hit by a following vehicle or, a line of stopped vehicles may extend under an adjacent path and expose stopped vehicles and occupants outside those vehicles to increased risk.

Ministry Snow Avalanche Programs staff from Revelstoke manage the hazard by closing the highway and helicopter bombing when avalanches are expected. Since 1992 the average annual closure time for avalanche control in the Kicking Horse Canyon has been 12.7 hours. The median annual closure time has been 4.8 hours.

Recent logging has created an opening in the steep forest between avalanche Paths 14.7 and 15.3. This opening may produce avalanches that will affect the highway in the future. If necessary, on-slope structures can be constructed to prevent avalanching at this site.

A variety of structural defences, including snow-retaining fences, terraces, enlarged ditches, and roadside walls, should be employed to keep avalanches off the highway and eliminate the need for closures.

4.2.2 Geotechnical Issues

Rock Cuts:

McKay Group 6 Limestone is present on the western approach to Park Bridge. Local instabilities encountered during blasting can be mitigated through bolting. A catch fence or a post and mesh system will be required at the crest of the cut slope to deal with boulders from rock slopes above.

McKay Group 5 Calcareous Shale is present on the eastern side of Park Bridge. This rock is much less competent than the limestone and is comparable to a silty soil in terms of strength parameters.

The rock structure and degree of alteration varies along the existing cuts. Existing rock cuts sit at 65-70 degrees, however in areas where discontinuities dip into the highway the cut has eroded back.

At steep cut angles there is the risk that unstable areas will be daylighted and failure will occur. The greatest risk is during construction.

The rock is not conducive to bolting, however if required, very long double corrosion protected anchors could be applied with low tension to hold in unstable areas.

To reduce the risk of failures during and after construction, the rock should be cut at 45 degrees. This will generate large quantities, expose long cuts and increase surface erosion and avalanche potential.

Due to its poor quality the rock may be removed through ripping, however it is felt that harder zones may be encountered which will require removal through blasting.

Ditch geometry will be based on both rockfall and avalanche concerns.

Soil Cuts:

The soil within the project area is predominantly a silty gravel, the silty matrix makes it prone to surface erosion.

MSE Walls:

For some of the alignment options, MSE retaining walls up to 30 m in height were considered on 30 – 40 degree silt slopes prone to erosion. The preferred option includes walls with heights up to 15 meters in height.

Soil nailed excavations may be required at the back of wall excavations to hold up the cut face and to provide sufficient room for traffic and construction equipment. Tie back anchors would be required to transfer the tieback load into the soil and they must be long enough to resist possible rotational failure of the slope due to the load of the wall. Where bedrock is close to the ground surface the wall should be founded on rock.

Due to the proposed high heights and complex foundation conditions the construction of walls will be both challenging and costly. For alternatives other than the preferred option, retaining walls approximately 30 m high with surcharge were employed in the designs. These surcharged heights, however, exceed the known heights for these type of walls and are not recommended. For stability concerns and constructability reasons the recommended MSE walls are not to exceed height restrictions of 20 m and 30 m imposed respectively for east and west sides of the Kicking Horse River. These wall heights exceed any known for permanent MSE retaining walls.

Viaducts:

Viaducts are a preferred option because through slide areas the unstable material can be unloaded and because it reduces the use of high MSE retaining walls.

Piled foundations are required to be installed into bedrock.

Steel Bin Walls:

Two steel bin walls located at the head of the Ten Mile slide, under the existing highway, are being undermined due to surface erosion. Based on previous erosion rates...
4.0 GEOTECHNICAL AND AVALANCHE ASSESSMENT

replacement within five years will be required. The replacement structures will have to be
founded on deeper bedrock and may include remedial measures below the walls such as
bio-remediation and/or a shotcrete and anchoring system.

Avalanche Defence Structures

In most cases, the design avalanche will stop in the proposed enlarged ditches behind the
roadside walls. Where sufficiently large ditches and roadside walls are not feasible, slopes
should be broken with terraces to reduce avalanche size and provide additional catchment
capacity. If it is not feasible to mitigate avalanche with enlarged ditches (catchment
areas), stopping walls and/or terraces then it may be feasible to use snow retaining
structures such as Brugg net. However, these structures are expensive, and are therefore
generally not the preferred option. Alternatively, if structural mitigation is not feasible,
permanent active control tools such as Gaz Ex could be implemented.

Risks:

The Kicking Horse River below existing fill slopes is causing toe erosion. This leaves the
river vulnerable to landslide activity which may block or change water flow. Rip-rap may
be required at certain locations to mitigate these problems.

The CPR below the existing highway east of Park Bridge is vulnerable to landslide activity
and rockfall and avalanche debris. Mitigation may require the installation of catch fences.

During the construction of an MSE wall and/or a viaduct the existing highway may be
undercut.

There is the possibility of the presence of unidentified deep-seated landslide movement
triggered by changes to slope geometry.

Disposal Sites:

Six potential disposal sites have been previously identified. However, the disposal site
chosen for alignment option 58 has not been evaluated.

Site development will require survey, foundation investigation, laboratory work and design
to determine foundation stability and dump design. Drainage will be very important to the
long-term stability of the disposal pile.

Aggregate Sources:

Due to its poor quality the McKay Group 5 Calcareous Shale excavated from east of Park
Bridge can only be used as fill. Rock excavated from west of Park Bridge, McKay Group
6 Limestone, is suitable as base course, sub-base and retaining wall backfill material.

Paving aggregate, base course and sub-base material can be produced from the large
proposed dolomite rock cut east of Yoho Bridge and/or a quartzite outcrop across from the
rafters pullout, west of the alignment boundary.

Testing by Golder Associates Ltd. has indicated that rock in the project area has no
potential to generate acidity metal mobilization under low pH (<4.2).

4.3 EXISTING PAVEMENT

Pavement Distress Index (PDI) and Riding Comfort Index (RCI) values, as reported in the
Existing Conditions Report 1998, are as follows:

<table>
<thead>
<tr>
<th>LKI Stationing</th>
<th>Pavement Distress Index (PDI)</th>
<th>Riding Comfort Index (RCI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>km</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.90 to 13.25</td>
<td>9.0</td>
<td>7.0</td>
</tr>
<tr>
<td>13.25 to 14.20</td>
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<td>14.20 to 14.30</td>
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<td>7.6</td>
</tr>
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<td>14.30 to 14.40</td>
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<td>7.6</td>
</tr>
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<td>14.40 to 14.60</td>
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<td>15.20 to 15.30</td>
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<td>15.30 to 16.45*</td>
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<td>16.45 to 16.70</td>
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<td>16.70 to 17.00</td>
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<td>17.00 to 17.10</td>
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<td>7.1</td>
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<tr>
<td>17.10 to 18.00</td>
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</table>

*These segments have undergone asphalt rehabilitation.

A very preliminary review of existing pavement distortions verifies the above PDI and RCI
values. West of Park Bridge there are a minimal number of transverse cracks of low
severity. East of Park Bridge there are frequent longitudinal and transverse joint cracks of
moderate severity, two small sections of longitudinal wheel cracks of moderate severity
and frequent rutting of moderate to high severity. The ruts are of the greatest severity on
the inside of corners where shoving by heavy trucks occurs.

Low and moderated severity frost heaves have been located between LKI stations 15.15
and 15.30 and 17.10 and 17.50 respectively. The frost heaves cover all lanes of traffic.
5.0 ENVIRONMENTAL ISSUES

This section describes existing environmental conditions, potential impacts and impact mitigation at a conceptual level for the alignments described in Chapter 6 of this report. Key impacts will be to commercial recreation, with limited potential impacts to fish and fish habitat, and to wildlife and wildlife habitat. Commercial and recreational use of the river is likely to be affected, primarily by construction activities during the rafting season and is addressed as a social impact in this section of the report. Forestry access may also be affected. No agricultural land use takes place adjacent to the Trans Canada Highway in this area.

Wildlife, fisheries and archaeological consultants conducted field assessments of environmental resources specific to the proposed corridor. Acres International conducted a background review of commercial rafting, with additional contacts with the rafting community during December 2000 and February 2001.

5.1 WILDLIFE

5.1.1 Background Information

Information on wildlife habitat and movements between the Trans Canada Highway corridor between Roth Creek and Brake Check have been compiled from a number of sources including:

- Habitat mapping (Harvey Research 1994);
- Wildlife Accident Reporting System (WARS) database (MoTH, 1998);
- Wildlife tracking projects (LGL, 1998 and Central Rockies Wolf Project, 1998);
- Environmental overview assessment (Acres, 1998);
- Existing conditions report and Appendix 6: Wildlife (MoTH/ Manning Cooper and Associates 1998);
- Memos from to MoTH CCRP Environmental Coordinator (Manning Cooper and Associates 1999);
- Habitat mapping (Manning Cooper and Associates 2000); and
- Mountain goat monitoring (Timberland Consultants Ltd. 2000)

All of the above-noted reports have been submitted previously on an informational basis to the Ministry of Environment, Lands and Parks.

Due to the condition of the alignment and bridges in the Kicking Horse Canyon, it has long been anticipated that highway improvements would be required in this area. The environmental studies listed above dated 1998 or earlier were commissioned by the regional environmental coordinator or by headquarters in anticipation of these improvements. Since the outset of the CCRP program in September 1998, additional studies were conducted to address information needs at the various stages of highway planning and design.

5.1.2 Wildlife Habitat

Mountain goats, moose, elk, deer and black bear are the key species encountered along this portion of the corridor from a management perspective. In response to concerns expressed by MELP staff regarding potential impacts to goat populations as a result of upgrades to the TCH, goat monitoring and impact assessment was commissioned by MoTH. During the study, goat and other wildlife were monitored at the 10 Mile Bridge and environs to determine patterns and types of use and to identify wildlife access routes. In addition, the biologists were requested to assess potential impacts of Options 5, 5a and 5b, identify effects to the goat population and propose appropriate mitigation measures.

Mountain goats are known to use the area to the north of the river between Roth Creek and Glenogle Creek. Most visibly however, goats use the bluffs on the south side of the river located above the west abutment of the 10 Mile Bridge. These bluffs "appear to contain a source of minerals that is an attractant to goats in the area, including nannies with 2-3 week old kids... The relative importance of this lick to the goat population... is unknown but is likely high... Only one other lick has been identified within the region..." (Timberland Consultants Ltd. 2000:15). Based on observations here and what is known about populations elsewhere, the primary period of use is May and June.

Habitat mapping was conducted by Manning Cooper and Associates based on aerial photo interpretation, background research and ground-truthing a small sample of plots, plus winter-tracking, and reconnaissance of all potential high use areas. Separate mapping was produced for deer, elk, moose, bear and goats.

Isolated patches of Class 3 habitat (moderate) for moose, elk and deer are located between Roth Creek and the 10 Mile Bridge to the north of the river. Otherwise habitat values are Class 4 or 5 (moderately poor to poor). Wildlife habitat values are poor south of the river in this area. East of the 10 Mile Bridge, the reverse is true with the best habitat values (Class 3) for ungulates located primarily south of the river.

5.1.3 Wildlife Movements

Moose, elk, deer and bear are rarely sighted adjacent to or crossing the TCH in this area. Mountain goats apparently avoid crossing the highway. Therefore, wildlife crossings of the highway are unlikely to constitute a highway safety issue within the study area.

Wildlife movements tend to be concentrated along the Kicking Horse River with little or no movement across the river or the highway in this area. Studies (LGL, 1998) indicated that elk were the primary species utilizing the north-facing slopes during winter. WARS data for the period 1978 to 1997 (MoTH 1998: Segment 990 – LKI 11 to 17) indicates movements of mostly deer and some elk across the highway during summer and winter periods. Based on the WARS data (see Table 5.1 below), elk were common prior to 1983 but have not been reported recently, suggesting a change in elk population distribution in this area.
Table 5.1: Wars Data for Segment 990, LKI 11 TO 17 (MoTH 1998)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>MONTH</th>
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<th>LKI</th>
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<td>GOLDEN</td>
</tr>
<tr>
<td>1993</td>
<td>7</td>
<td>DEER</td>
<td>1</td>
<td>12</td>
<td>GOLDEN</td>
</tr>
<tr>
<td>1995</td>
<td>6</td>
<td>DEER</td>
<td>1</td>
<td>14</td>
<td>GOLDEN</td>
</tr>
</tbody>
</table>

5.1.4 Wildlife Mortality and Accident Data

The Wildlife Accident Reporting System (WARS) records animals struck and killed on British Columbia highways. Some caution is required in interpretation of the data as the location (LKI) data provided is often suspect. Based on the data as presented for the period from 1978 to 1987 (MoTH 1998), the WARS database recorded 26 wildlife mortalities in the study area, primarily at LKI 16 (n=10) and LKI 14 (n=5) (see Table 5.1 below). LKI 16 is located at the slide area just west of Brake Check; LKI 14 is just west of the 10 Mile Bridge. Fourteen deer, 6 elk, 4 unidentified animals, 1 moose and 1 porcupine were recorded in the database.

The Highway Accident Statistics (HAS) database records when wild animals are the primary cause of an accident. The current database lacks a species identification for the animal struck, but the location data tends to be more reliable than the WARS data. Between 1991 and 1995, wildlife-vehicle collisions were attributed as the primary cause of three accidents. Wildlife exclusion fencing is therefore not warranted in this area.

5.2 FISH AND AQUATIC

5.2.1 Background Information

A comprehensive fish habitat assessment and sampling program was completed in 1998 by ENKON Environmental Ltd. Coast River Environmental Services Ltd. conducted additional sampling and assessment in 1999. Seasonal programs of fish sampling were conducted by ENKON in October 1997, May 1998 and July 1998, and by Coast River Environmental Services Ltd. in June and August 1999.

The reports summarizing this work have been previously submitted to the Ministry of Environment, Lands and Parks.

5.2.2 Fish Habitat

The Kicking Horse River is the only fish-bearing stream crossed by the Trans Canada Highway in the study area. The Kicking Horse River is a very turbid system with high levels of glacial fines typically from early May to early October. High velocities, low average water temperatures and steep gradients also affect fish productivity in this system.

At the Yoho Bridge, about 5 km downstream of the 10 Mile Bridge, river velocities range from 3.6 m/s during mean annual flood to 3.0 m/s during July and August. ENKON (1998) identified a velocity barrier to fish passage at this site. Fifty percent of the time, flows are less than 18 m3/s, with average velocities of 1 m/s or less. Flow characteristics are likely to be similar in the study area.

ENKON (1998) measured water temperatures in the mainstem river as well as tributaries. Temperatures peaked in July (13 degrees C.) and were lowest in October (4 degrees C.). This is to be expected in a system that receives most of its flow from snowmelt.

Glencoe Creek, a tributary on the north side of the Kicking Horse River, is also fish-bearing. The study area falls within Reach 3 and Reach 4 as classified by ENKON 1998. Reach 3 is characterized as _"...a riffle/run/rapid series throughout the reach with some large pools located in the rapid sections... The bed material consists of boulders, bedrock and large cobbles. During lower flows, cobbles/boulder bars are exposed... The large pools are suitable resting and feeding habitat for adult fish and the deep channel offers cover while swimming."_ (ENKON 1998). Similar to Reach 3, Reach 4 is riffle/run/rapid. Bed material is boulder with some cobble. Cover is provided by boulders, pools adjacent to bedrock banks and LOD logjams. ENKON (1998) notes that "Patches of spawning habitat are located... in shallow riffle areas. This habitat would be suitable for fall spawning species (kokanee salmon, bull trout and brook trout since the river is clear in the fall. Spring spawners (rainbow trout) would not likely spawn here due to the highly turbid water during their spawning season."

At the Yoho Bridge, about 5 km downstream, river velocities range from 3.6 m/s during mean annual flood to 3.0 m/s during July and August. Fifty percent of the time, flows are less than 18 m3/s, with average velocities of 1 m/s or less. Flow characteristics are likely to be similar in the study area.
5.0 ENVIRONMENTAL ISSUES

5.2.3 Species Distribution

Fish species found in the Kicking Horse River or its tributaries between Park Bridge and Yoho National Park West boundary are kokanee, bull trout, brook trout, rainbow trout, torrent sculpin and pygmy whitefish. ENKON (1998) found that most fish appeared to be concentrated in the first reach of each tributary, where turbidity levels tended to be lower than in the mainstream river. Spawning kokanee were observed adjacent to the CPR in September 1997 opposite the west end of the Rest Area (ENKON, 1998). Bull trout, which are provincially blue-listed (vulnerable), have been found at the confluence of and in Reach 2 of Gienoglock Creek. They have also been found at the confluence of Roth Creek (ENKON, 1998).

5.3 ARCHAEOLOGY AND HERITAGE

5.3.1 Overview

The following information is based on an archaeological overview and subsequent impact assessment conducted by G. Prager of Points West Heritage Consulting Ltd. (Prager, 2000a; Prager 2001). The entire highway corridor in this section crosses from the south side to the north side of the Kicking Horse valley at the 10 Mile Bridge. Level benches or terraces in the immediate vicinity of the Kicking Horse River represent the best archaeological potential within this study area. Little is known of the past use of the Kicking Horse valley and virtually no archaeological research has occurred. As the Kicking Horse River is fish-bearing and there is ungulate habitat in the vicinity, some human use likely occurred in pre-contact times. Unfortunately, considerable historic and more recent disturbance has also occurred in the valley and, given the constrained nature of much of the terrain, this disturbance likely obliterated evidence of earlier cultural activities. This lends even greater importance to the undisturbed remnants of level benches or terraces because they provide the only opportunities to find intact cultural remains. Such remains represent important components of the cultural history of this area, given the scarcity of archaeological sites on which to base such interpretations.

5.3.2 Archaeological Inventory and Investigations

Areas within the study area identified as having moderate to high potential for containing intact archaeological remains were investigated. In 1999, visual reconnaissance and where warranted, subsurface (shovel) testing were conducted under Permit #1999-105. Areas examined in detail were the Rest Area, Sta. 12+400 to 13+700, LKI 14.4 to 14.6, Sta. 15+600 to 16+800, and Sta. 16+900. In addition, post-assessment was conducted on several geotechnical boreholes located at the base of the slope around LKI 15.0. In 2000, additional investigation in the study area was conducted under Permit #2000-172. This investigation included foot traverses and shovel tests in the waste site identified below Brake Check (see Drawing 81432-SK-151) and a bench landform between Brake Check and the Glenogle FSR. Reports describing the investigations and results have been submitted to the Archaeology Branch, as partial fulfillment of permit requirements.

Finds of archaeological or historical significance included a small cultural flake found approximately 50 m east of the 10 Mile Bridge east abutment. This flake was found in a previously disturbed area, was out of context and the potential for disturbance of intact cultural deposits was considered low (Prager, 1998). Several culturally modified birch trees were found in the vicinity of Brake Check. Due to the relatively short lifespan of birch, it is unlikely that they would come under the auspices of the Heritage Conservation Act. Birch bark is commonly used to make containers, to provide tinder for fires, or to make moose or elk calling horns. West of Park Bridge, all possible routes for the approach have been assessed previously and no further archaeological concerns are associated with these options. East of the bridge, no evidence of archaeological deposits was found within the study area during investigations of moderate to high potential areas along the proposed alignment, notably between Brake Check and the Glenogle FSR.

Based on the assessment of proposed alignments under consideration, the potential for disturbance to intact cultural deposits was considered low within 50 m of the existing highway. West of Park Bridge, all possible routes for the approach have been assessed previously and no further archaeological concerns are associated with these options. East of the bridge, no evidence of archaeological deposits was found within the study area during investigations of moderate to high potential areas along the proposed alignment, notably between Brake Check and the Glenogle FSR.

5.4 RECREATION

The steep gradient of the Kicking Horse River and the rugged landscape of the canyon are ideal for exciting whitewater and other outdoor adventures. Rafting, kayaking and scenic viewing are the primary activities taking place in the study area. Commercial rafting is the primary activity that could be affected by highway improvements in the study area.

5.4.1 Background Information

Commercial rafting on the Kicking Horse River is of particular economic importance to the area and an understanding of where and when the use occurs will assist in high way design and stakeholder consultation. Jon Wilsgard (MoF Recreation Officer), Gordon Eisenhuth (MoTH), and Geoff Freer (BCTFA) (formerly of Glacier Rafting Co.) provided much of the following information. Table 5.2 shows operators, contact information, trip offerings, and schedules. In addition, Ron Taphorn (MoTH Area Manager) contacted George McLaren, then president of the rafting association in Golden in December 1998 and that information is also presented. In addition, Drawing 81432-SK-167 shows access points and landmark names along the river. Half-day and full-day trip locations for one rafting company are also shown.

5.4.2 Rafting Operations

Data from 1998 indicated that 14 operators were licensed to operate on the Kicking Horse River. Rafting companies are represented officially by the Kicking Horse Rafting Outfitters' Association. According to one operator, nine companies are actively offering trips on the Kicking Horse River. Based on information from two operators, at least 20,000 visitors rafted the Kicking Horse River each year in 1998 and 1999. Extrapolating from average ticket prices shown in Table 5.2, gross revenues to these operators likely exceed $1.5 Million.
5.0 ENVIRONMENTAL ISSUES

More than half of the visitors originate from Banff. Hydra River Guides, located in Banff, are responsible for approximately 40% of the business. Two operators out of Golden, Wet 'N Wild and Glacier Rafting Company appear to be responsible for another 50%, with the remaining volume split between the other operators. Clients are transported to the put-in points via vans, school buses or charter-type coaches.

The operating season extends from May 15 to September 15 with the peak between June 1 and Labour Day. Rafts hold 8 clients plus a river guide. Rafts are spaced on the river to enhance the sense of adventure, as well as for safety. During the 90 day operating season, an average of 28 boats a day raft the Kicking Horse. However, as most of the trips occur on the weekends, weekend boat traffic is higher than this average.

5.4.3 Trip Logistics

The rafting operators originate from Golden, Banff or Radium and conduct full-day or half-day trips from several put-in points upstream of the canyon. Full-day trips run the Upper Canyon (Hoodoos to Glenogle Pullout (Rafters' Pullout) or the Upper and Lower Canyon (Beavermouth area to Rafters' Pullout, CPR Access to Golden). Trips originating in Banff are typically full day trips whereas those from Golden are half-day trips, putting in at 10 am or 1 pm. However, Golden operators all offer full day trips as well. Half-day trips begin at the Mt. Hunter Creek pit area or the put-in point (CPR Access) for the Lower Canyon.

The Lower Canyon can only be run within a certain range of water levels, usually in August and early September. Some companies offer a double run of a portion of the Upper Canyon if the Lower Canyon is unavailable.

The Glenogle or Rafters' Pullout is the universal take-out point. The Kicking Horse Rafting Outfitters Association has a road access permit from MoTH for this site. It is critical that rafters make this pullout, as there are no other accesses between here and the dangerous rapids at the Yoho Bridge. The CPR Access road just at LKI (west limit of the 10 Mile Bridge and approaches project) is the universal put-in point for rafting the Lower Canyon. However, rafters have no authorization from CPR regarding use of this access or for crossing the CPR tracks adjacent to the river.

Two companies use the Kicking Horse Pit access at Vacation Creek to put into the river. Six companies use the Beaverfoot Bridge area.

Typically, rafts put into the river around 10 am. All trips pass under the Park (10 Mile) Bridge and pullout at Glenogle (Rafters’ Pullout). Glenogle is used by some of the companies as a lunch stop. Pullout areas along the beach at Glenogle are spread along the entire base of the surplus disposal site, so that groups are reasonably dispersed. Due to the dangerous Class VI water at the Yoho Bridge site and Glenogle's function as a mandatory pullout point, Glenogle tends to be very congested in the afternoon, particularly between 3 and 4 pm, when rafts are pulling out every 5 to 10 minutes. Depending on water levels, trips may then portage downstream of the Yoho (5-Mile) Bridge to put in again at approximately LKI 8.6 via the CPR access road. If water levels are unacceptable for running the Lower Canyon, trips may put in further upstream for full day trips or may run the most exciting section of the Upper Canyon twice. Only 2-3 groups a day may do a run after 3 pm.
5.0 ENVIRONMENTAL ISSUES

- Prior to construction, additional spot monitoring of goat populations should be conducted to increase understanding of goat use and determine best locations for alternative licks. Alternative lick sites should be provided by MoTH during the course of construction.

- A wildlife biologist should review locations of avalanche mitigation measures in the field to minimize potential disruption of goat trails.

- Where possible, modify the timing of construction activity to avoid sensitive period for goat use (late May to mid-July).

- If any access roads are constructed in the vicinity of the bluffs, their use should be strictly controlled during construction and they should be decommissioned immediately following construction.

- The surplus material site should be recontoured, reclaimed and revegetated for wildlife habitat. Reclamation should be phased so that most of the site will be available for wildlife by the end of the construction period. Recontouring and revegetation of the site should be guided by the Reclamation and Environmental Protection Handbook (MoTH 1995).

- Suggested mitigation could include reclamation of existing borrow sites along the Kicking Horse Valley bottom or enhancement of critical elk winter range east of Brake Check.

5.5.2 Fisheries and Aquatic Resources

Potential Impacts

Proposed highway improvements for the Roth Creek to 10 Mile Brake Check area are unlikely to involve in-stream work or loss of in-stream habitat. Roadway improvements will be primarily along or near the existing highway alignment, located 100 m or more above the Kicking Horse River. Proposed design for providing a new 4-lane crossing of the Kicking Horse River to replace the existing bridge will be a clear span configuration. Some impacts to riparian vegetation are anticipated. The Kicking Horse River is the only fish-bearing watercourse to be crossed. Other drainages crossed are too steep to support fish populations, but may provide backwater refuge habitat at their confluences with the Kicking Horse River at certain times of the year.

Impacts will primarily be associated with sediment and drainage due to construction of access roads and staging areas, excavation and placement of overburden and rock, and losses of vegetated buffers due to clearing, grubbing, and silver fills.

Mitigation of Impacts

A bridge design which clears spans the fish-bearing watercourses is the most effective mitigation measure to avoid potential impacts to fisheries habitat. The proposed design has piers located outside the 200-year flood limit.

Well-planned and -implemented sediment and drainage management will be important to minimizing construction-related impacts. In addition, timing of construction during the drier summer and fall months will limit sediment and erosion generation.

5.5.3 Archaeology

Potential Impacts

All the drainages crossed by the highway in this section have been visually assessed for potential for intact cultural deposits by Prager (2000b). In most cases, the terrain adjacent to the highway is either steeply sloping or previously disturbed. Consequently, within the 50 m strip to either side of the highway, there are few archaeological concerns. Several remnant benches were identified as having moderate potential for intact cultural deposits. These were in the vicinity of LKI 15+600 to 15+800 and 16+900. Shovel testing was conducted in these areas. Several birch trees with bark stripping were encountered south of the highway at 16+900 but these were not considered old enough to warrant protection under the Heritage Conservation Act.

The area identified for surplus disposal below Brake Check was foot traversed and several shovel tests were conducted. No archaeological sites were located and the potential for conflict between use of the area as a disposal site and intact cultural deposits is considered low.

Areas for ancillary developments, such as quarries, stockpiling or work staging, should be identified as far in advance of construction as possible to provide sufficient lead time to conduct archaeological assessments.

Mitigation of Impacts

Prager (2000) considers it very unlikely that any large or intensively utilized intact archaeological sites are located in the sections subjected to archaeological ground reconnaissance adjacent to the highway. There is always the chance that a small archaeological site may have been missed, therefore, if ground disturbance activities uncover any cultural or human remains, all work should cease in the immediate vicinity and the Archaeology Branch contacted. Timely archaeological investigations incorporated into the design process will minimize chances of delays during construction.

If any excavation is required to prepare the surplus material disposal site, archaeological monitoring should be conducted in conjunction with the excavation, to minimize disturbance of any deeply buried cultural remains.
5.0 ENVIRONMENTAL ISSUES

5.5.4 Recreation

Impacts

Commercial rafting activities will potentially be affected by traffic delays and closures on the highway, as well as construction activities limiting movements on the river at the 10 Mile Bridge. Traffic delays may also affect winter recreation, particularly snowmobilers, skiers and other outdoor enthusiasts attracted to the Golden area from Alberta. Traffic management will need to be cognizant of the potential economic impact of delays, particularly on weekends during the prime winter recreation periods.

During the summer, recreation impacts will consist of vehicular traffic delays for rafting operations during highway and bridge construction, as well as potential vessel traffic closures during bridge construction. In addition, there will be visual/aesthetic impacts for those parts of the alignment visible from the river for the rafting clientele. This is likely to be especially of concern regarding the potential impact of the surplus disposal site. Visual / aesthetic quality will also be affected for the driving public during the construction period.

Mitigation of Impacts

Traffic management should consider the prime recreational travel periods for both the peak summer and winter periods. If possible, bridge construction requiring river closures should be scheduled during weekdays, and outside of the June to September rafting season.

Visual setbacks ranging from 30 m at the upstream end of the site to 15 m at the downstream end of the site will likely provide an adequate visual screen for the rafting public, depending on the final height of the waste pile.

Due to the rugged terrain and sparse natural vegetation currently existing adjacent to the highway, impacts will be low to moderate in severity. Roadside signage which assists the travelling public in understanding the need for the project will offset negative perceptions of the visual impacts.
INTRODUCTION

To meet the objective of determining an optimum 4 lane alignment for this section of the highway, numerous options were studied. Assessment of the options led to the selection of Option 5B as the preferred basically because of:

- horizontal and vertical alignment aspects
- geotechnical and risk considerations
- costs

Option 5B has been chosen as the preferred option following a review of numerous alternative options. Appendix A, Other Alternatives Studied, describes the pros and cons of numerous options and the evaluation criteria used to select Option 5B as the preferred option.

Appendix A, “Other Alternatives Studied”, describes the pros and cons of numerous options and the evaluation criteria used to select Option 5B as the preferred option.

6.0 PREFERRED OPTION

6.1 PROPOSED GEOMETRY

The preferred option is essentially split alignment for approximately four kilometers (Sta. 117+00 to Sta. 155+00) of its overall approximate length of five kilometers (Sta. 111+00 to Sta. 157+00). There is approximately 200 meters of 4 lane divided alignment at either end of the split alignment that ties into the existing road.

At this western end, the preferred option ties into a 4 lane cross section. The existing highway has acceptable geometric standards and has not been considered necessary to upgrade according to the CCRPMT.

The uphill, eastbound leg of the split alignment is largely located on the existing road only deviating from the existing highway where the existing design speed is less than 80 km/h. The existing road, constructed to the standards of the day, is essentially an 80 km/h, 8% super elevation design with a maximum grade of 7.8%. As a result the new uphill alignment has been designed to 80 km/h, 7.8% maximum grade design standards. Park Bridge will have to be replaced, as it is part of the existing alignment that is designed to 60 km/h and it will also be due for major rehabilitation. A new 140 meter long bridge will be required and Park Bridge will be removed.

The downhill, westbound leg of the split alignment is located away from the existing road. It has been designed to 90km/h, 6% maximum grade design standards. A new bridge (viaduct structure), approximately 1160 meters long, is required to cross over the Kicking Horse River.

6.2 TYPICAL CROSS SECTIONS

The four lane divided typical cross section consists of:

- 2-2.5 m shoulders with concrete roadside barriers
- 4-3.7 m lanes
- 1-2.6 m median

The 2.6 meter median was chosen to allow for a future median barrier with an offset of 1 meter to the lane line. The 2.8 meter median also allows for shying distance between opposing traffic prior to the future median barrier being installed.

The two lane leg of the split alignment consists of:

- 2-3.7 m lanes
- 1.0 m left shoulder plus concrete roadside barrier
- 2.5 m right shoulder plus concrete roadside barrier

The proposed typical cross sections are shown on Drawing 81432-SK-164.

6.3 ACCESSES AND ANCILLARY FACILITIES

Listed below are accesses and ancillary facilities:

- REST AREA (Sta. 109+00 to Sta. 110+00): To the west of the tie-in to the existing highway, there is a rest area between the highway and the River. The rest area is not affected as the new design ties into the existing highway east of the rest area. The
6.0 PREFERRED OPTION

rest area is currently accessed from the highway by a westbound right turn deceleration lane and an eastbound left turn lane. This access, although outside of the Project limit, can be upgraded to the standards used in other sections to the east or west. There is a widened gravel shoulder opposite the rest area beside the eastbound lane. This area may be used as an informal chain up area for eastbound vehicles. A river rafting access is located approximately 500 meters west of the rest area.

- INFORMAL ACCESSSES (Sta. 114+00 and Sta. 117+50): There are gravel accesses on the riverside of the existing highway. They access no specific facility and do not appear to be used very often. If they are utility accesses, the one at Sta.114+00 can be reconnected to the new road. However, the one at Sta.117+50 cannot be maintained due to the proposed high fill and a retaining wall. It is an informal hygiene access and the pole will need to be relocated in any case. Only right in right out movements should be accommodated in the new design.

- CPR ACCESS (Sta. 127+00): There is a rough gravel access road to the CPR tracks located immediately east of Park Bridge on the right hand side of the existing road. This access road does not appear to be used very frequently. There has been no specific plan to include this access in the detailed design, however it may be advisable for the Ministry to discuss this matter with Canadian Pacific (CP) Railway should CP desire this access to its facility below. However, it should be noted that it could be retained with right in and right out movement only.

- RUNAWAY LANE (Sta. 130+00): There is a gravel runway lane for the westbound, downhill lanes located just east of the existing 60 km/h curve before Park Bridge. There is no recorded information on any vehicles using this runway lane. The new design does not connect to the runway lane due to the horizontal and vertical constraints. Although an initial review indicates that such a runway lane is not required on the new alignment, this can be revisited during the detailed design. In which case, consideration can be given to constructing an arresting bed utilizing surplus material.

- INFORMAL ACCESSSES (Sta. 239+00 and Sta. 242+00): There are gravel accesses to the Hydro power line pole line off the existing eastbound side of the road. A right in and right out movement can be maintained in the proposed design.

- BRAKE CHECK AND GLENOGLE FORESTRY ROAD (Sta. 150+00 and Sta. 153+00): The Brake Check has ingress (including left turns for eastbound traffic originating in Golden) at Sta. 153+00, and an egress as Sta. 151+00. Access to Glenogle Forestry road is via the Brake Check area.

- WEATHER STATION (Sta. 153+00): The weather station is located on the south side of the highway, opposite the eastern end of the Brake Check. There is an access to a pullout at this station.

- AVALANCHE GATES (Sta. 157+00): This gate closes off access to through traffic on the highway in case of avalanches in the Kicking Horse Canyon.
6.0 PREFERRED OPTION

In view of the proposed significant height of the viaduct above the existing highway and river valley, and of the pronounced curvature of the superstructure in plan, it is suggested that segmental concrete box construction utilizing the balanced cantilever method would produce a viable form of construction for the structure. This form of construction can accommodate significant (60 – 250 m) span lengths which will allow the pier foundations to be optimally placed to avoid the main crossing constraints while maintaining overall structural efficiency. The construction of the superstructure at points where the existing road is crossed can be readily carried out by this method since no ground-level structural support is required for the superstructure.

Given the significant length of the structure and the range of permissible span lengths and configurations, other forms of construction, including structural steel, are also feasible and potentially cost competitive with concrete. In order to obtain competitive prices, alternative designs in concrete and steel should be considered.

Preliminary investigations indicate that the varying height piers will require piled support, with piles extending to the underlying bedrock at approximately the elevation of the Kicking Horse River bed.

Drawing 81432-SK-220 shows the general arrangement of this bridge.

Replacement for the Existing Park Bridge

Following the construction of the new viaduct and the westbound road works, and the detouring of all traffic on to it, the existing highway lanes and Park Bridge can be reconstructed on the proposed new alignment.

The existing Park Bridge will have to be removed in an environmentally acceptable manner and will be replaced with a new structure, which will be constructed at approximately the same elevation.

The existing bridge is a three-span, structural steel deck-truss bridge with a reinforced concrete deck supported on reinforced concrete piers and abutments. The piers are relatively tall shafts of reinforced concrete construction, which support the 71m long main span of the bridge. The abutments consist of reinforced concrete walls, which are arranged in a closed-box, cellular configuration.

This structure will have to be demolished and removed prior to the construction of the new crossing of the Kicking Horse River. The west abutment of the new structure occupies the location of the west abutment of the existing bridge. The east abutment of the new structure will be located northeast of the existing bridge and abutment in order to avoid cutting into the existing slide area.

The new bridge will, however, be reoriented to match the proposed new alignment for the highway. With a length of approximately 140 m (Sta. 225+38 to Sta. 226+78), a number of feasible span configurations could be investigated for this structure. Precast, prestressed concrete construction could be readily utilized for the superstructure of this bridge, and piled support will also be required for the reinforced concrete piers and abutments.

Drawing 81432-SK-221 shows the general arrangement of this bridge.

6.7 GEOTECHNICAL CONSIDERATIONS

West of Park Bridge the rock is considered competent and any local instabilities can be mitigated through bolting.

East of the Bridge the rock is of such poor quality that it may be removed through ripping rather than blasting. The structure and degree of alteration of the rock varies significantly along the existing cut. Limited structural mapping and no drilling or geophysical exploration, has been completed. The ability to confidently predict what will happen beyond and above the existing cuts is limited without further extensive geotechnical investigations.

A recommended cut slope of 70 degrees, for cuts less than 30 meters in height, poses some risk that unstable areas will daylight. Instabilities will occur where unfavourable structural geology or intense alteration is encountered. These areas will slough locally.

Ditches constructed 5 m wide and 2.25 m deep will contain most slide material but there is a moderate risk that larger slides will cover the highway. Reducing the cut slope to a 45 degree angle will reduce the risk but produce significantly larger quantities.

Rock remediation may be required at the recommended cut slope of 70 degrees. However the rock is not conducive to remediation due to its poor quality, and therefore associated costs will be high. The probability of remediation being required increases as the area and height of the cut increases.

The existing 10 Mile slide creates a risk to the present alignment and any future alignments that use the same location. To achieve long-term stability surface drainage will have to be improved and maintained. As well, existing downslope steel bin walls will require replacement by founding a new wall on rock well below the existing wall. It is very difficult to forecast the behaviour of the slide and to quantify the risk to the proposed alignment.

The following parameters have been used in the development of the preferred option.

- No rock excavation from the western limits of the project to stations 119+60 on the westbound alignment and 222+40 for the eastbound alignment.
- Cut slopes/ditches west of the river:
  - 1.5:1 for OM excavation from the western limit to Sta. 222+40
  - 0.75:1 for rock excavation, from Sta. 222+40 to Sta. 224+60
  - 0.25:1 for rock excavation, from Sta. 224+60 to the Start of the proposed bridge
  - Ditch width 5 m, depth 2.25 m between Sta. 221+20 and the proposed bridge, 3 m width with variable depth everywhere else
- Cut slopes east of the river:
  - 0.3:1 for rock cuts less than 30 m
  - 0.62:1 for rock cuts between 30 and 50 m
  - 1:1 for rock cuts greater than 50 m
  - Ditch width 5 m, depth 2.25 m for the westbound alignment.
Avalanches from four avalanche paths (14.2, 14.5, 14.7 and 15.3) block the existing highway several times during an average winter. Drawing 61432-SK-147 shows the avalanche paths. These paths are responsible for most of the avalanche closures in the Kicking Horse Canyon. MoTH Snow Avalanche Programs Revelstoke staff manage the hazard by closing the highway and helicopter bombing the starting zones to release the avalanches. The alignment will require snow-retaining structures in avalanche starting zones.

Avalanche hazard mitigation measures, including snow-retaining structures in avalanche starting zones, enlarged ditches, terraces, and roadside avalanche-stopping walls, are proposed to protect the travelled portion of the highway from 10-year avalanches. With these measures in place there will no longer be a need for active avalanche control.

**Mitigation Measures to Protect Option 5B Westbound Alignment**

- **Sta. 132+80 - Sta. 135+20:** 240m 1.75m wall
- **Sta. 144+75 - Sta. 145+25:** 50m 1.75m wall
- **Total:** 290m 1.75m wall

The westbound alignment crosses Path 15.3 (Sta. 132+80 - Sta. 135+20) upslope from the existing highway. The extent of the path above the highway is thus reduced, and the volume of snow on the slope, which depends on slope length, is also reduced. The avalanches threatening the highway will therefore be smaller than those affecting the existing highway. The mitigation measures recommended for Path 15.3 are based on calculations indicating that it will be possible to stop these smaller avalanches with a 5 m wide ditch and 1.75 m high wall, and that snow-retaining structures in the path will not be required.

**Mitigation Measures to Protect Option 5B Eastbound Alignment**

- **Sta. 218+00 - Sta. 220+60:** terracing and 260m 1.0m wall

The existing highway has not been affected by avalanches from the cut slopes in this area. However, if the proposed new cuts are smoother than the existing they will be more likely to produce avalanches. These new cut slopes must be terraced or roughened to retain snow and prevent or reduce the size of these avalanches. Four 4 m wide cat-tracks across the slopes will reduce the volume of snow reaching the ditch so that it can be contained with a 1.0m high wall. These tracks need not be horizontal and should be accessible for periodic maintenance.

- **Sta. 222+60 - Sta. 225+00:** 280m 1.25m wall and 3ha netting
- **Sta. 229+20 - Sta. 230+60:** 1 ha netting and 140m 1.25m wall (starting at Sta. 230+60 and extending westward up the outside edge of the runway lane)

**Total:**
- 260m 1.0 m wall
- 420m 1.25m wall
- 4 ha netting

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**6.9 ENVIRONMENTAL CONSIDERATIONS**

Environmental issues concern the following resources: Wildlife, Fisheries and Aquatic, Archaeological and Recreation. The assessments consider both the alignments and the spatial requirements at the associated surplus material disposal site. The surplus material disposal site is located about 2 kilometers east of Park Bridge on a bench adjacent to the river.

The impact on wildlife is considered in terms of the amount and quality of the habitat affected, as well as potential disturbance of wildlife during construction. Key impacts will be to mountain goat habitat located adjacent to the west end of the existing bridge. This habitat includes a mineral lick which is likely quite important to the local goat population and is used by nanny goats and kids in spring and early summer. Human activity within the habitat as well as loud and unpredictable noise generated during construction will likely have the most potential to cause goats to avoid this critical habitat. Otherwise, impacts to ungulate habitat east of the bridge are anticipated to be low.

Low to moderate value ungulate habitat will be affected by the new westbound alignment east of the bridge and therefore impacts are anticipated to be low. Suggested mitigation could include reclamation of existing borrow sites along the Kicking Horse Valley bottom or enhancement of critical elk winter range east of brake check.

About 12 ha of moderate value ungulate habitat will be affected by the surplus material disposal site. Impacts can be mitigated by contouring, reclaiming and revegetating the site for ungulate habitat as per the Reclamation and Environmental Protection Handbook (MoTH 1995). Reclamation should be phased so that the majority of the site is revegetated by the end of the construction period.

Fish and aquatic impacts are considered in terms of harmful effects on fish habitat, loss of riparian vegetation and the amount of work in environmentally sensitive areas. The Kicking Horse River is the only fish-bearing drainage in the project area. Potential fisheries impacts of a new crossing of the Kicking Horse River are largely mitigated by the clear span design proposed. Impacts to riparian habitat are localized to the bridge crossing site. Potential impacts to fisheries or riparian habitat adjacent to the proposed surplus material disposal site below Brake Check are mitigated by provision of 30 m No Disturbance Zone set back from the annual high water level. DFO has suggested that burial of two non-fish-bearing drainages in the proposed surplus site could result in groundwater flows into the Kicking Horse River, which may actually enhance fisheries habitat (Dave Carter, January 25, 2000). A riprapped berm face is recommended for portions of the disposal area located within the 200 year flood limit.
6.0 PREFERRED OPTION

The archaeological assessment is based on the potential for encountering intact archaeological resources within the project area. Based on a review of landforms and field assessment of areas with moderate or high potential, the likelihood of impacts to intact archaeological resources within the project area of the preferred option is considered low.

Based on background review and field assessment, the likelihood of affecting intact archaeological resources in the surplus material disposal site by simply depositing of material on the surface is considered to be low. However, archaeological monitoring should be conducted in conjunction with any excavation required to prepare the surplus disposal site because it is possible that cultural remains could be buried under recent debris flow deposits.

Recreation impacts will consist of vehicular traffic delays for operators during construction, as well as potential vessel traffic closures during bridge construction. In addition, there will be visual/aesthetic impacts for those parts of the alignment visible from the river for the rafting clientele. This is likely to be especially of concern regarding the potential impact of the surplus disposal site. Visual setbacks ranging from 30 m at the upstream end of the site to 15 to 30 m at the downstream end of the site will likely provide an adequate visual screen, depending on the final height of the waste pile.

Visual / aesthetic quality will also be affected for the driving public during the construction period. Due to the rugged terrain and sparse natural vegetation currently existing adjacent to the highway, impacts will be low to moderate in severity.

Roadside signage, which assists the travelling public in understanding the need for the project, will offset negative perceptions of the visual impacts.

6.10 RIGHT OF WAY

The existing right of way varies between 30 meters to 101 meters. It will be necessary to obtain additional right of way to construct the preferred option. All of the additional required right of way is through crown land.

The preferred option does not require placement of any piers within the CPR right of way.

6.11 SURPLUS MATERIAL DISPOSAL SITE

There is estimated to be a surplus of excavation of approximately 450,000 cubic meters.

A potential site has been identified at the base of the mountain, immediately next to the river opposite Sta. 246+00 to Sta. 250+00. Material is anticipated to be moved to the site by a conveyor system. It may be necessary to build a chute over the existing highway in order to facilitate movement of traffic.

Initial environmental assessment indicates that it will be necessary to riprap the riverside face of the berm within the 200 year flood limit. A minimum No Disturbance Zone of 30 meters from the river to the berm face will be required. Any reclamation or partial reclamation of the site will be in accordance with the wildlife habitat guidelines of the Reclamation and Environmental Protection Handbook (MoTH 1995).

6.12 CONSTRUCTABILITY AND STAGING

There are large volumes of material to be excavated relatively close to the existing highway. West of Park Bridge, most of the excavation is OM and should be relatively easy to remove without disturbing existing highway traffic. This was a significant factor in choosing this alignment as the preferred option. Rock removal will have to be done by blasting although it is not anticipated that there is a significant amount of rock excavation west of Park Bridge.

East of the Park Bridge, most of the excavation is anticipated to be undertaken by ripping or blasting. East of Park Bridge, the westbound alignment is located on the adjacent slope next to the existing highway. Appropriate traffic management and construction techniques will have to be employed in order to maintain safety and minimize inconvenience to the public.

Suggested Staging has been shown in four main construction activities or contracts as shown on Drawing 81432-SK-166.

1. The first contract involves the west grading and retaining walls necessary to construct the new alignments west of Park Bridge. Considerable detouring will be required during this contract as the new alignments are located in the immediate vicinity of the existing highway.

2. The second contract involves the grading and retaining wall construction on the westbound alignment east of Park Bridge. Care will have to be taken during this contract to provide safety and avoid inconvenience to traffic on the existing highway.

3. The third contract involves the construction of the viaduct for the westbound alignment. Upon completion of the viaduct, the traffic can then be detoured to this alignment in order to undertake the next contract.

4. The fourth contract involves replacing the existing Park Bridge and repaving/remediating the existing highway. The traffic can then be re-routed accordingly i.e. two lanes eastbound utilizing the new Park Bridge and two lanes westbound on the new alignment utilizing the viaduct.

Construction staging should be revisited during the detailed design phase.

From a traffic management perspective, it is anticipated that traffic would stay on the existing highway while the first three contracts are completed. Traffic will be diverted to the westbound alignment while the fourth contract is constructed.

The contracts have been split based on the construction staging. Building the new 2 lane alignment allows the traffic to use the existing road during non-closure periods. Once the new alignment is constructed, traffic can be diverted to this alignment and the remainder of the construction can be completed.

The most aggressive construction schedule has both the grading and the long bridge for the westbound alignment being constructed simultaneously. It will take two to three years to construct the long bridge. The grading and paving of the associated alignment can be
CONTRACTING STRATEGY

| Contract 1 | West rock, grading and walls | $10.0M |
| Contract 2 | East rock, grading and walls | $24.8M |
| Contract 3 | Long bridge and approaches | $33.9M |
| Contract 4 | Replace existing bridge and remediate highway | $12.6M |
| Subtotal | | $81.3M |
| Engineering | | $7.0M |
| Land | | $0.1M |
| Contingency | | $12.9M |
| Total Estimated Cost | | $101.3M |

Total Estimated Cost: $101.3M
6.0 PREFERRED OPTION

built within the same period. This reflects a total construction period over two to three years. The eastbound alignment, the bridge and the associated road works, paving, existing failing bin wall replacement etc can be constructed within one year. The overall construction schedule would take three to four years.

The least aggressive construction schedule involves constructing all of the grading of the westbound alignment. This would take approximately two to three years, depending on allowable road closures. After this operation, the long bridge could be constructed. This would take another two to three years. After this the associated works with the eastbound alignment could be constructed within one year. The overall construction schedule would take five to seven years.

These construction schedules assume that construction periods are not constrained by limited working hours and necessary traffic closures will be allowed during the construction period.

6.13 QUANTITIES AND COST ESTIMATE

The cost estimate has been developed using the estimating program employed by the CCRPMT. Cost estimates and design assumptions were developed in conjunction with the Regional Geotechnical Branch, Golder Associates and CCRP staff. The DTM was generated from mapping composed of both Aerial Mapping and ground survey. The Cost Summary is shown at the end of this section.

Design Constraints and Costs Used in the Estimate

Geotechnical

Rock and OM excavation:
- Both the MoTH Geotechnical Branch and Golder Associates provided information for the location and extent of rock material. An average depth of 2 m for overburden material (OM) was assumed.
- The unit cost of excavating rock varied by the type and location of the rock material. Based on the recommendations made by Golder, the Ministry Geotechnical Branch and the CCRPMT, the following unit costs were used:
  - West of the river, the cost to excavate the rock was considered to be high given the type of rock (blasting required) and the proximity to the existing road. A cost of approximately $30 per cubic meter was assumed to be reasonable for this type of rock excavation.
  - East of the river, the type of rock was assumed to be less costly to excavate as it could either be ripped or blasted. A good portion of the material can be ripped but there are anticipated to be lenses where blasting is required. A cost of about $20 per cubic meter was assumed for this type of rock excavation.
- The angle of cut slopes required for rock excavation had to meet certain criteria:
  - West of the river, the angle of cut slopes varied, between 0.75:1 to 0.25:1, depending on which rock formation the cut was in. This was based on the criteria set out by Golder.
  - East of the river, the Ministry Geotechnical Branch provided criteria that recommended varying cut slope angles based on the height of the cut achieved.

Rock Stabilization:
- In accordance with the Geotechnical Branch's recommendations, a lump sum cost of $1,500,000 for rock stabilization, west of the river, was recommended as scaling and bolting is required to stabilize the existing rock cuts.

Drainage:
- Based on Geotechnical recommendations, the drainage east of the river has to be enclosed over the existing fill slopes. The estimated cost for this has been estimated at $700,000.

Avalanche Defences:
- The Ministry Snow Avalanche Program provided the location and cost of avalanche netting and stopping walls as noted in Appendix A.

Station Specific Information

Excavation:
- No rock excavation was required from west limit (Sta. 111+00) to the start of the upper bridge (Sta.119+70) for the westbound alignment and to Sta. 222+40 for the eastbound alignment.
- Rock with 2 meters of overburden was assumed for the remaining sections requiring excavation
- Cut slopes west of the river were as follows:
  - 1.5:1 for OM excavation, from west limit to Sta. 222+60.
  - 0.75:1 for rock excavation, from Sta. 222+40 to 224+60.
  - 0.25:1 for rock excavation, from Sta. 224+60 to start of the bridge.
- Cut slopes east of the river for rock excavation varied from 0.3:1 to 1:1 depending on the height of the cut (as per MoTH criteria).
- Proposed ditch widths west of the river were as follows:
  - 5 m wide for the right side between Sta. 221+20 and the bridge.
  - 3 m wide everywhere else.
- East of the river, a ditch width of 5 m was used for left side for all rock cuts along the westbound alignment.
### 6.0 PREFERRED OPTION

**Avalanche Defences:**
- A cost of $1,950,000 was estimated for installing avalanche netting from Sta. 222+80 to Sta. 225+50 and $650,000 from Sta. 229+20 to Sta. 230+60.
- Roadside avalanche-stopping walls were recommended at various locations. The walls were priced as follows:
  - $600/m for 1.0 m high walls
  - $800/m for 1.25 m high walls
  - $1050/m for 1.75 m high walls

**Surplus Material Disposal Site Development:**
- A cost of $600,000 was estimated for developing this site.

**Structural Construction**

**Bridges:**
- Option 58 consists of an 1160 m long bridge for the westbound alignment. This bridge was estimated to cost about $1,900/m² of deck area required.

**Retaining Walls:**
- The proposed maximum heights for the retaining walls are approximately 15 meters.

**Cost Summary:**
- The cost summary by component is shown in Table 6.1. The total cost is estimated to be $101,316,000.

**6.14 UPGRADING THE EXISTING FOUR LANE SECTION**

The existing four lane segment (coincident passing lanes) between Rafters Pullout (LKI 12.0±) and the Park Bridge/10 Mile Hill section (LKI 13 ±) should be considered if the Trans Canada Highway to the west and east are upgraded as part of the Yoho (5 Mile) Bridge and Approaches and Park Bridge/10 Mile Hill Projects respectively.

Upgrading to a consistent cross section with 2.6 m paved flush median for future median barrier and 3.0 m shoulders is recommended and would cost in the order of $5 million.
### Table 6.1: Cost Summary

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Total</th>
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<td>Grade Construction</td>
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<td>Road Grade - Excavating, Place and Fill</td>
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<td><strong>Project Supervision (2.5% of Construction)</strong></td>
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<td><strong>Project Engineering</strong></td>
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<tr>
<td><strong>Total Cost</strong></td>
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</tbody>
</table>

**Notes:**
1. This cost summary was derived using the estimating program employed by the CCRPMT.
2. Costs were developed in conjunction with Golder Associates and the CCRPMT.
APPENDIX A
OTHER ALTERNATIVES STUDIED

INTRODUCTION

In September of 1998, the Ministry of Transportation and Highways (MoTH) retained ND Lea Consultants Ltd. to undertake functional planning and preliminary design of approximately 6 km of the Trans Canada Highway between Roth Creek and the Brake Check through the Kicking Horse Canyon.

ND Lea Consultants Ltd. in their 1992 study had identified the following two alternative routes for the highway improvement from Roth Creek to Yoho Park:

- The “North Side” route crossed the Kicking Horse River from the south side of the river to the north side approximately 2.5 km downstream of the existing Park Bridge and proceeded eastwards utilizing a combination of tunnels, viaducts, and surface grading and tied into the existing road approximately 200 m east of the Brake Check.
- The “South Side” route stayed on the south side of the river entering a short tunnel through the rock knoll at the west approach to the existing Park Bridge and heading eastwards crossing the Kicking Horse River approximately 250 m west of Beaverfoot Road intersection and tied into the existing highway in that vicinity.

In early October 1998, MoTH decided to pursue the feasibility of a Design / Build contract for the construction of a new bridge across the Kicking Horse River and the highway approaches on each side of the new bridge, in the vicinity of the existing Park (10 Mile) Bridge. The project would start on the west side at a suitable location east of the Rest Area, and after crossing the river, tie back into the existing highway at a practical location somewhere near the truck runaway lane on the east side.

At a meeting in Victoria on October 9, 1998, it was discussed that the highway alignment would remain on the south side of the river west of the existing Park Bridge to maximize the use of the existing facility. The river crossing could then be either downstream or upstream of the existing bridge.

In March 1999, ND Lea Consultants Ltd. submitted to the Ministry of Transportation and Highways a draft report titled “Alignment Alternatives – Design / Build Section Sta. 112+00 to Sta. 133+00.” The report addressed the various alignment options which were investigated, their respective quantities and costs, and preliminary geotechnical conditions. The report also identified a preferred alignment for this section.

As part of the on-going preliminary design process, an alignment between the truck runaway lane and the Brake Check to the east was also investigated. This alignment was located between the existing highway and the Kicking Horse River with a design speed of 90 to 100 km/h with a 5% grade.

However, in May 1999, a slide occurred on the south side between the highway and the Kicking Horse River, approximately two kilometers east of the Park Bridge and along the proposed alignment. This event has significantly impacted any potential alignment that would pass through the slide area.

APPENDIX A – OTHER ALTERNATIVES STUDIED

In view of the above, in January 2000, MoTH requested ND Lea Consultants Ltd. to investigate other possible options to improve the highway in this section.

This chapter covers the Pre-Slide and the Post-Slide alignment investigations.

A.1 PRE-SLIDE INVESTIGATIONS

ND Lea Consultants Ltd. carried out conceptual route location investigations for possible river crossing sites. Figure 2 shows three potential options, which were studied. A brief description of these options is as follows:

Option “A”

For this option, the proposed route crossed the river approximately 400 m downstream from the existing bridge and utilized the railway right of way to accommodate a viaduct and connect back into the existing highway on the east side going up the hill towards the Brake Check. However during a site reconnaissance visit October 15 and 16, 1998 with the Project Team (MoTH and ND Lea staff, environmental and geotechnical subconsultants), geotechnical concerns were expressed about the stability of the existing slopes north of the railway tracks. Also due to a very confined railway corridor at that location, it would have been difficult to straddle the rail tracks with a viaduct structure without encroaching into the river. For these reasons, and the potential high cost of such a viaduct, the option was not pursued any further.

Option “B”

The alignment for this option was located slightly to the south of the existing road requiring up to 70 m high cuts in the rock “knoll” on the west approach and then crossed the river on a 250 – 300 m long bridge approximately 60 m upstream of the existing bridge. The alignment then connected back into the existing highway east of the truck runaway lane.

Option “C”

For this option, a variation of the SNC – FENCOS “Southside Route,” the proposed route remained on the south side of the river, tunnelled through the existing rock knoll near the west abutment of the existing bridge and then crossed the river on a bridge located approximately 400 m upstream of the existing bridge. This alignment would require an approximately 520 m long tunnel and a 500 m long bridge. Therefore due to high cost implications, no further work was carried out on this option.

Preferred Option

Option “B” was the preferred option selected and further investigations were subsequently carried out to refine the proposed horizontal and vertical alignments within this “corridor” or band.

With respect to the required lanning and cross-section, staged construction was initially considered – for example: build two lanes now and build an additional two lanes in the future. However, recognizing the difficulties of highway construction and in particular traffic management during construction (detour routes not locally available) in a narrow canyon,
APPENDIX A – OTHER ALTERNATIVES STUDIED

the Project Team opted in favour of constructing the four-lane cross-section in one successive construction operation in order to eliminate a second period of construction and traffic disruption.

The west limit of the advance contract was established at Station 112+00 where the new four-lane roadway would tie into the existing four-lane section. The rationale for terminating the western limit of the proposed construction approximately 1.3 Km west of the bridge was to eliminate retaining a short section of existing two-lane road. On the east side of the river, Station 133+00 was established as the limit of the contract where the new roadway would be temporarily tapered from four lanes down to three lanes to tie into the existing cross-section. In future, the alignment, with minor modifications, would then continue eastwards to the Brake Check.

Review of Design Speed Implications

Several horizontal alignments for design speeds of 80, 90, and 100 km/h were prepared. East of the bridge, however, all three alignments temporarily utilized an existing grade of up to 8% going up the hill to the Brake Check.

For each of the three design speeds, order of magnitude earth works quantities were prepared for comparative purposes. Following the review of the alignments and the required earthworks, the Project Team selected the 90 km/h design speed. ND Lea subsequently carried out further investigations and alignment optimizations based on the 90 km/h design speed.

For the proposed design speed, in order to provide standard stopping sight distances around cuts and concrete barriers in this confined terrain, it would have required flattening the curves and widening the cross-section. This would have resulted in unreasonably high construction cost due to large quantity of cuts and fills. Therefore the Project Team decided that no additional widening would be provided on curves with barriers to meet stopping sight distance requirements. It was the Consultants understanding that MoTH would apply the above standards to all the CCRP project sections with similar constraints on the premise that the higher design standards and improved natural hazard control measures would mitigate the absence of widening on curves.

Typical Cross Sections

During the early stages of the alignment development, the parameters shown in Figure 3 were used to generate preliminary quantities and costs. This section was based on a typical section used by the Ministry's Region 3 in their previous studies.

- 4 x 3.7m wide lanes
- Median width/type – 2.6m / paved
- Shoulder widths – 3.0m paved shoulder
- Fill Slope – 1.5:1
- OM cut slope/ditch – 1.5:1 back slope with typical MoTH ditch section
- Rock cut slope/ditch – 0.25:1 back slope with 5.0m wide ditch

Typically use 0.25:1 back slope with 5.0m wide ditch for rock cut
- Where avalanche hazards exist, use 0.25:1 back slope with 10.0m wide ditch, including a 5.0m wide bench along the top of rock cut
- For overburden, use 0.58:1 back slope

Typically use 0.47:1 back slope with 6.0m wide ditch for rock cut
- For overburden, use 0.58:1 back slope

Figure 4 shows the revised sections, which were used to estimate the earthworks and the construction costs.

Retaining walls were proposed as and where required to prevent fill encroachment into the river and onto the CPR track. On the east side of the river, pending further geotechnical input as to the optimum location, retaining walls could be located along the shoulders or at the toes of the fills. For the purpose of this exercise, the retaining walls were offset 20.0m from the centreline of the CPR track.

Alignment Alternatives

For the Design/Build section, the horizontal and vertical alignments were originally tied to existing highway on the east side on the premise that the rest of the highway would be realigned horizontally for a 90 km/h design speed within the existing highway corridor. However since the traffic had to be accommodated during construction, the vertical alignment had to be close to the existing 8% grade. Any major improvements to the profile uphill would require a new corridor. For this reason and for reasons of safety and reduced vehicle operating costs, new alignments east of the Design/Build section and between the existing highway and the river for a 90 km/h design speed, and 0%, 5.5% and 5% grades were also investigated.

APPENDIX A – OTHER ALTERNATIVES STUDIED

In November 1998, the median and shoulder widths were revised as follows:

- Median width/type – 4.0m/paved (Ref: MoTH Highway Engineering Design Manual, Page 630–1, August 1995)
- Shoulder widths – 2.5m if no barriers are used or 3.0m to the face of the barriers where barriers are used
- Bridge – 4x3.7m lanes, 4m median and 2.5m shoulder to the face of the bridge barrier

During the post-slide investigations, in order to minimize earthworks and construction costs, the above shoulder and median widths were revised to those shown in Chapter 6, section 6.2.

In January 1999, Golder Associates provided preliminary geotechnical investigations and recommendations, and the following rock cut parameters were used:

a) West of Bridge
- Typically use 0.25:1 back slope with 5.0m wide ditch for rock cut
- Where avalanche hazards exist, use 0.25:1 back slope with 10.0m wide ditch, including a 5.0m wide bench along the top of rock cut
- For overburden, use 0.58:1 back slope

b) East of Bridge
- Typically use 0.47:1 back slope with 6.0m wide ditch for rock cut
- For overburden, use 0.58:1 back slope

Figure 4 shows the revised sections, which were used to estimate the earthworks and the construction costs.
CUT & FILL TYPICAL SECTION
SHOWING PAVEMENT & GRANULAR DETAIL

4 LANEING WITH MEDIAN
CUT AND FILL TYPICAL SECTION
WEST APPROACH TO PARK BRIDGE

CUT AND FILL TYPICAL SECTION
EAST APPROACH OF PARK BRIDGE
APPENDIX A – OTHER ALTERNATIVES STUDIED

Due to the location of these alignments and the steep side slopes between highway and the river, the new alignments would have to be built almost entirely on side hill fills. Overall, any new alignment on the east side would require a substantial amount of borrow material. The 5% alignment would have required the least amount of fill material and pending further investigations, had been used for the future improvements between this section under consideration and the Brake Check.

In view of the steep terrain and the presence of Canadian Pacific Railway, it was necessary to confine all alignments within a very narrow corridor. Although the maximum separation between the most extreme alignments was only 25 meters, earthwork quantities varied by approximately 400,000 m³. Figure 5 shows the various alignments investigated and their relative close proximity.

The following is a brief description of each alignment. The referenced Figures 6 to 12 are included at the end of this section and titled "Drawings For Pre-slide Investigations".

Alternative #1 (Figure 7)
This alignment was the result of refinement of an original alignment established earlier following field reconnaissance by the Project Team. This alignment provides approximately 10m of lateral clearance between the existing and the new bridge structures on the west side. This provided some working room for the contractor for the construction of the west approach and the abutment.

With this alignment, extensive rock excavation and retaining walls up to 22m high were required. Quantities and cost estimates were initially prepared using the original cross sections as shown in Figure 3.

Alternative #2 (Figure 9)
This alignment was established to eliminate or reduce the excavation in the north rock face, by shifting the alignment approximately 25m southward, east of the bridge. Alignment of the west approach and the bridge crossing remained the same as Alternative #1. Although, the southward shift in the alignment decreased the volume of excavation, it required higher and longer retaining walls along the CPR track. Overall there were no cost advantages over Alternative #1. However, on the down side, the wall height increased by approximately 10m.

Quantities and cost estimates were initially prepared using the original cross sections as shown in Figure 3.

Alternative #3 (Figure 7)
This alignment is identical to Alternative #1. However, the revised cross sections as shown in Figure 4 were used to update the quantities and costs.

Alternative #3A (Figure 8)
This alignment was established in an attempt to combine the best features of Alternatives #1 and #7 as described below, by combining the western section of Alternative #1 with the eastern section of Alternative #7.

Earthworks were quantified using the revised cross sections as shown in Figure 4.

Alternative #4 (Figure 9)
This alignment is identical to Alternative #2. However, the revised cross sections as shown in Figure 4 were used to update the quantities and costs.

Alternative #5 (Figure 10)
Alternative #5 was based on an 80 km/h design speed to determine if there was appreciable difference in quantities and costs relative to Alternative #1. Due to variations in both tangents and curves, the cost for Alternative #5 was estimated to be approximately $0.5M more than Alternative #1, due to increased wall requirements on the east side.

Quantities and cost estimates were initially prepared using the original cross sections as shown in Figure 3.

Alternative #6 (Figure 10)
This alignment is identical to Alternative #5. However, the revised cross sections as shown in Figure 4 were used to update the quantities and costs.

Alternative #7 (Figure 11)
Due to large rock cuts and geotechnical concerns about natural hazard risks, the west approach and the bridge centreline were shifted 10m to the northwest. New quantities and costs were then prepared for this alignment using the revised cross sections shown in Figure 4.

This alignment generated the least amount of earthwork and reduced the geotechnical and avalanche concerns on the west approach.

Alternative #8 (Figure 12)
This alignment was established in an attempt to eliminate or minimize retaining walls on the west approach between the highway and the river. The Alternative #7 alignment between Sta. 112+00 to Sta. 118+00 was shifted 10m to the south. Alignment at the bridge crossing and eastward remained the same as Alternative #7.

This alignment did reduce the retaining wall quantities west of the bridge, but did not eliminate the walls completely. Also, the shift of the alignment increased the earthworks quantities by about 330,000 m³ when compared to Alternative #7.

Earthworks were quantified using the revised cross sections as shown in Figure 4.
APPENDIX A – OTHER ALTERNATIVES STUDIED

Profile
With the close proximity of all the alignments, there were only minor differences between the profiles. Figure 6 shows the typical profile and grades of an alignment.

Field Survey
The Request for Expression of Interest and Request for Proposal for the Design/Build section were originally scheduled for the spring of 1999. Therefore a field survey for this section, authorized by MoTH, was carried out in the fall of 1998.

Quantities and Costs
For comparison purpose, only the quantities and cost estimates generated using the revised cross sections will be presented in the final analysis, namely Alternatives 3, 3A, 4, 6, 7, and 8. Therefore, quantities and cost estimates for Alternative #1, #2 and #5 were not reported.

The following criteria were used in estimating the earthwork quantities for all alignments:
- Golder’s recommended rock cut sections were used
- OM excavation bulking factor = 1.15
- Rock excavation bulking factor = 1.3
- Fill shrinkage factor = 1.15
- West and east bridge abutments were assumed to be Sta. 124+90 and Sta. 127+50 respectively.

Table A.1 summarized the construction costs, including 40% contingencies and 15% engineering, for each of the pre-slide alignment. These cost estimates did not account for the additional 1km (approximately) of the highway improvements from Roth Creek to just east of the Rest Area, and also the 2.3 km on the 10 Mile Hill towards the Brake Check.

Table A.1:
<table>
<thead>
<tr>
<th>TCH – Roth Creek to Brake Check Design/Build Section (Station 112+00 to Sta. 133+00)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alignment #</td>
</tr>
<tr>
<td>-------------</td>
</tr>
<tr>
<td>ALT. #3</td>
</tr>
<tr>
<td>ALT. #3A</td>
</tr>
<tr>
<td>ALT. #4</td>
</tr>
<tr>
<td>ALT. #6</td>
</tr>
<tr>
<td>ALT. #7</td>
</tr>
<tr>
<td>ALT. #8</td>
</tr>
</tbody>
</table>

APPENDIX A – OTHER ALTERNATIVES STUDIED

CONCLUSIONS AND RECOMMENDATIONS
Based on the above evaluations, Alternative #7 was the most economical one for the Design/Build section. It was therefore recommended that this alternative be fine tuned to optimize the locations of the bridge abutments and retaining walls, and then proceed to the detailed design phase.

However, in May 1999, a slide occurred on the south side between the highway and the Kicking Horse River, approximately two kilometers east of the Park Bridge and along the proposed alignment. This event has significantly impacted any potential alignment that would pass through the slide area.

Further post-slide investigations for other alignment options were carried out starting in early 2000. These investigations and options development are described below.

A.2 POST-SLIDE INVESTIGATIONS

Alignment Investigations
ND Lea developed a number of rough conceptual alignment options to avoid the slide area. They are as follows:
- **Option 1** is a 90 km/h design west of the bridge at a 0 to 4% grade. The bridge profile has a 6% grade. East of the bridge the alignment heads eastward at a 100 km/h, and a 6% grade until it reaches the brake check. East of the river, the alignment is located uphill of the existing road.
- **Option 1A** is a variation of Option 1 designed for 100 km/h for the entire section. It has a short 500 meter length of 8% grade to help minimize the excavation quantities.
- **Option 1B** is a 100 km/h and 6% grade alignment which attempts to achieve the same reduction in quantities as Option 1A by shifting the alignment out of the sidehill and utilizing more retaining walls.
- **Option 2** is a 90 km/h alignment with a maximum 6% grade. West of the bridge it is similar to Option 1. It crosses the river on a 4% grade and is located below the existing road east of the river. It traverses the slide area. In order to traverse the slide area, extensive and expensive geotechnical remediation is required.
- **Option 3** is a 90 km/h design using a maximum grade of 8% that attempted to minimize the excavation quantities by optimizing the horizontal and vertical alignments. The alignment traversed both below and above the existing highway.
- **Option 4** is a 90 km/h design based on widening the existing road to a four lane cross section. By utilizing the existing road it has a 2 kilometer stretch of approximately 8% grade.

The plan and profile for each of these alignments are included at the end of this section and titled “Drawings for Post-Slide Investigations”.
In order to reduce construction costs, the shoulder and median widths originally used in the Pre-Slide investigations (3 m and 4 m respectively) were reduced to 2.5 m and 2.6 m respectively as shown in Drawing 81432-SK-164 included in Chapter 6.

“Order of Magnitude” costs for major construction items were calculated and are shown in Table A.2.

Table A.2: Order of Magnitude Costs for Major Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit Prices</th>
<th>1</th>
<th>1A</th>
<th>1B</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>W of Structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavation (m³)</td>
<td>669,075</td>
<td>1,047,072</td>
<td>1,537,286</td>
<td>751,075</td>
<td>735,240</td>
<td>940,085</td>
<td></td>
</tr>
<tr>
<td>Fill (m³)</td>
<td>85,133</td>
<td>125,459</td>
<td>157,509</td>
<td>69,971</td>
<td>65,839</td>
<td>44,000</td>
<td></td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>$20,012,300</td>
<td>$31,289,232</td>
<td>$46,186,600</td>
<td>$22,050,300</td>
<td>$22,050,300</td>
<td>$28,292,200</td>
<td></td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>$7,945,000</td>
<td>$10,115,000</td>
<td>$8,400,000</td>
<td>$9,467,000</td>
<td>$9,467,000</td>
<td>$7,490,000</td>
<td></td>
</tr>
<tr>
<td>River Bridge Length (m)</td>
<td>400</td>
<td>500</td>
<td>400</td>
<td>400</td>
<td>450</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>River Bridge Cost</td>
<td>$2,000</td>
<td>$20,000,000</td>
<td>$25,000,000</td>
<td>$20,000,000</td>
<td>$22,500,000</td>
<td>$5,000,000</td>
<td></td>
</tr>
<tr>
<td>E of Structure</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavation (m³)</td>
<td>4,088,264</td>
<td>951,575</td>
<td>740,000</td>
<td>2,352,944</td>
<td>4,775,783</td>
<td>1,525,955</td>
<td></td>
</tr>
<tr>
<td>Fill (m³)</td>
<td>86,283</td>
<td>953,033</td>
<td>853,734</td>
<td>425,900</td>
<td>264,687</td>
<td>31,754</td>
<td></td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>$122,643,900</td>
<td>$28,547,200</td>
<td>$22,200,100</td>
<td>$70,088,500</td>
<td>$143,305,900</td>
<td>$46,176,000</td>
<td></td>
</tr>
<tr>
<td>Reinforced Slopes</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$4,175,000</td>
<td>$4,175,000</td>
<td>$1,100,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slide Area L.S.</td>
<td>$190,000</td>
<td>$190,000</td>
<td>$105,000</td>
<td>$200,000</td>
<td>$151,200</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excavation (m³)</td>
<td>4,757,339</td>
<td>1,954,546</td>
<td>2,277,230</td>
<td>3,104,619</td>
<td>5,512,022</td>
<td>2,468,560</td>
<td></td>
</tr>
<tr>
<td>Fill (m³)</td>
<td>175,410</td>
<td>688,492</td>
<td>1,033,243</td>
<td>495,901</td>
<td>325,526</td>
<td>75,784</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The Design Criteria, Quantities and Costs, Constructability and Staging, Geotechnical Risk, CPR concerns, Avalanche concerns, Environmental concerns, Waste disposal sites, Tie-in of a possible Advance Bridge were all broadly considered and compared. (See Table A.3.) All of these alignments were considered expensive but Options 1B and 4 were considered superior to the other alignments and considered worthy of developing and analyzing further.

Table A.3: Evaluation Matrix

<table>
<thead>
<tr>
<th>Design Criteria</th>
<th>Alignment 1</th>
<th>Alignment 2</th>
<th>Alignment 3</th>
<th>Alignment 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design speed</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Bases</td>
<td>90</td>
<td>90</td>
<td>90</td>
<td>90</td>
</tr>
<tr>
<td>Max grade</td>
<td>6</td>
<td>8</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>7.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Constructability</td>
<td>Good</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Good</td>
</tr>
<tr>
<td>Staging</td>
<td></td>
<td>Moderate</td>
<td>Moderate</td>
<td></td>
</tr>
<tr>
<td>Geotechnical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risk</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CPR concerns</td>
<td>Best</td>
<td>Best</td>
<td>Best</td>
<td>Worst</td>
</tr>
<tr>
<td>Avalanche</td>
<td>Middle</td>
<td>Best</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>Tie-in</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Waste disposal</td>
<td>4.5 Million</td>
<td>1.3 Million</td>
<td>1.3 Million</td>
<td>2.6 Million</td>
</tr>
<tr>
<td>Environmental</td>
<td>Moderate</td>
<td>Minimal</td>
<td>Minimal</td>
<td>Minimal</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Options 1C and 4A, variations of 1B, and 4, were developed and costed using the estimating program employed by the CCRPMT and refined geotechnical and avalanche input. The quantities and costs for Options 1C and 4A are shown in Table A.4.
APPENDIX A - OTHER ALTERNATIVES STUDIED

Table A.4
Roth Creek to Brake Check
(From existing four lanes to brake check)
Station 113+00 to 157+00
Functional Draft Quantities and Costs Summary April 25, 2000

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Option 1C</th>
<th>Option 4A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quantity</td>
<td>Quantity</td>
</tr>
<tr>
<td>Project Management</td>
<td>$ 9,340,745</td>
<td>$ 8,854,619</td>
</tr>
<tr>
<td>Engineering</td>
<td>$ 9,135,385</td>
<td>$ 9,465,234</td>
</tr>
<tr>
<td>Land Acquisition</td>
<td>$ 93,750</td>
<td>$ 93,750</td>
</tr>
<tr>
<td>Grade Construction</td>
<td>$ 65,890,404</td>
<td>$ 76,049,401</td>
</tr>
<tr>
<td>Major Items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock Excavation West of River</td>
<td>220,000 @ $50</td>
<td>160,000 @ $50</td>
</tr>
<tr>
<td>Rock Excavation East of River</td>
<td>887,000 @ $20</td>
<td>1,395,000 @ $20</td>
</tr>
<tr>
<td>Rock Remediation</td>
<td>10,000 @ L.S.</td>
<td>10,000 @ L.S.</td>
</tr>
<tr>
<td>Overburden Treatment</td>
<td>6,100 @ L.S.</td>
<td>7,500 @ L.S.</td>
</tr>
<tr>
<td>Avalanche Walls and Fencing</td>
<td>5,592 @ L.S.</td>
<td>3,485 @ L.S.</td>
</tr>
<tr>
<td>Road Side Construction</td>
<td>$ 710,000</td>
<td>$ 710,000</td>
</tr>
<tr>
<td>Other Construction (Environmental Mitigations)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Construction</td>
<td>$ 33,194,438</td>
<td>$ 17,291,110</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Items</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridge</td>
<td>$ 19,000,000</td>
<td>$ 10,700,000</td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>$ 14,100,000</td>
<td>$ 6,500,000</td>
</tr>
<tr>
<td>Paving Construction</td>
<td>$ 1,476,954</td>
<td>$ 1,563,858</td>
</tr>
<tr>
<td>Operational Construction</td>
<td>$ 737,125</td>
<td>$ 785,324</td>
</tr>
<tr>
<td>Utility Construction</td>
<td>$ 124,300</td>
<td>$ 132,600</td>
</tr>
<tr>
<td>Resident Engineering</td>
<td>$ 11,736,652</td>
<td>$ 11,736,642</td>
</tr>
<tr>
<td>Total Construction</td>
<td>$ 113,869,928</td>
<td>$ 108,105,945</td>
</tr>
<tr>
<td>Tender Contingency</td>
<td>$ 20,016,061</td>
<td>$ 18,975,085</td>
</tr>
<tr>
<td>Management Reserve</td>
<td>$ 7,672,824</td>
<td>$ 7,273,783</td>
</tr>
<tr>
<td>Project Total (as of April 4, 2000)</td>
<td>$ 161,125,234</td>
<td>$ 182,749,436</td>
</tr>
<tr>
<td>Reductions to reflect April 25 recommendations:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock Remediation</td>
<td>$ 14,000,000</td>
<td>$ 14,000,000</td>
</tr>
<tr>
<td>Overburden Treatment</td>
<td>$ 8,540,000</td>
<td>$ 11,000,000</td>
</tr>
<tr>
<td>Avalanche Walls and Fencing (Assumed)</td>
<td>$ 3,885,750</td>
<td>$ 3,885,750</td>
</tr>
<tr>
<td>Total Reductions</td>
<td>$ 26,426,750</td>
<td>$ 25,000,000</td>
</tr>
<tr>
<td>Project Total (less reductions)</td>
<td>$ 134,702,544</td>
<td>$ 127,692,436</td>
</tr>
</tbody>
</table>

These costs were still considered high. A split alignment was suggested at this point. It had promise of costing less by utilizing the existing road for one of the travel directions.

FURTHER INVESTIGATIONS

ND Lea then investigated split alignment options, separated two lane directional roadways.

APPENDIX A - OTHER ALTERNATIVES STUDIED

- Option 5 utilized the existing road for the westbound downhill direction resulting in a 2 lane 80 km/h, 8% design. The eastbound uphill traffic direction was based on a new 90 km/h, 6% design.
- Option 5A used the same basic alignments but reversed the traffic flow on the two alignments. The westbound downhill alignment became the new 90 km/h, 6% design. The eastbound uphill traffic direction was based on utilizing the existing road in an 80 km/h, 6% design.
- Upon further review, it was determined while these options were less expensive than the previous options, there were still significant cost, geotechnical, constructability and staging issues associated with the rock cut immediately west of the river. ND Lea then prepared Option 5B, a variation of Option 5A, which avoided a large rock cut by introducing an 1100 meter bridge.
- Options 1C, 4A, 5, 5A and 5B were then evaluated using an evaluation matrix that considered Geotechnical risk, Constructability and Staging, Functionality and Safety, Operations and Maintenance and Cost. Option 5B scored the highest rating. Except for option 1C, all of the options costs were within $12 million of each other. Option 5B was considered to be the preferred as it had the least geotechnical risk and was the easiest to stage and construct. Option 5B, utilizing a very long bridge for the westbound direction avoided a difficult rock cut immediately west of the Park Bridge. This greatly improves constructability and staging and reduces the geotechnical risk.

This chapter covers the evaluation of the preferred Alignments 1C, 4A, 5, 5A and 5B in greater detail.

Evaluation Criteria

The criteria for evaluating the Study Alignment Options have been divided into five main categories:
- Cost
- Geotechnical Risk
- Constructability and Staging
- Functionality and Safety
- Operations and Maintenance

The factors considered in each category are as follows:

Cost

The costs are shown in Table A.5 - Evaluation Matrix. A detailed cost breakdown for each option is shown in Table A.6.

Geotechnical Risk

- Larger volumes result in higher risks
- Longer cut faces result in higher risks
APPENDIX A – OTHER ALTERNATIVES STUDIED

- High retaining walls result in higher risk

Constructability and Staging
- Larger volumes result in longer construction periods
- Rock cuts immediately adjacent to the existing highway result in more difficult traffic management
- Road closures

Functionality and Safety
- Higher design speed is more desirable
- Maximum 6% grade is more desirable
- High speed, lower grade downhill alignment is more desirable for overall safety
- Low grade uphill alignment is more desirable for trucks
- Ability to accommodate run-away lane if required

Operations and Maintenance
- Snow removal and storage provisions
- Longer bridge will require more maintenance to mitigate potential icing conditions

Evaluation of Study Alignment Options

Geotechnical Risk
Alignment 1C (Drawing 81432–SK–101)
- Large west side rock volume with up to 80 meter high cut faces
- Large east side rock volume with up to 80 meter high rock faces
- East side rock difficult to remediate
- Extensive retaining walls up to 30 meters high throughout the project

Alignment 4A (Drawing 81432–SK–104)
- Large west side rock volume with up to 80 meter high cut faces
- Large east side rock volume with up to 80 meter high rock faces
- East side rock difficult to remediate
- Least amount of retaining walls all less than 20 meters high

Alignment 5 (Drawing 81432–SK–118)
- Lower west side rock volume with up to 50 meter high rock faces
- Lower east side rock volume with all cut faces less than 30 meters high
- Less exposed cut faces will reduce remediation cost on east side
- Extensive retaining walls on west side up to 20 meters high
- Extensive retaining walls on east side all less than 20 meter high

Alignment 5A (Drawing 81432–SK–125)
- Large west side rock volume with up to 50 meter high cut faces
- Lower east side rock volume with all cut faces less than 30 meters high
- Less exposed cut face will reduce remediation risk on east side
- Extensive retaining walls on west side up to 20 meters high
- Extensive retaining walls on east side all less than 20 meters high

Alignment 5B (Drawing 81432–SK–136)
- Negligible rock cut on west side
- Lower east side rock volume with all cut faces less than 30 meters high
- Less exposed cut face will reduce remediation risk
- Extensive retaining walls on west side up to 20 meters high
- Extensive retaining walls on east side all less than 20 meters high

Constructability and Staging
Alignment 1C
- Largest rock and OM volumes
- Extensive detouring associated with new grade and retaining walls
- Extensive double handling required to implement staging with reasonable traffic management
- Extensive day closures required to construct west rock cut

Alignment 4A
- Large rock and OM volumes
- Constructing immediately adjacent to existing traffic lanes will result in difficult and risky traffic management
- Extensive day closure required to construct east and west rock cuts.
Alignment 5
- Lower rock and OM volumes
- Extensive day closures required to construct west rock cut
- Generally not constructing immediately adjacent to existing traffic lanes

Alignment 5A
- High rock and OM volumes compared to Alignment 5
- On east side, generally not constructing immediately adjacent to existing traffic lanes
- On west side, high, difficult rock cut immediately adjacent to existing traffic lanes
- Extensive day closure required to construct west rock cut

Alignment 5B
- Lowest rock and OM volumes
- On east side, generally not constructing immediately adjacent to existing traffic lanes
- On west side, negligible rock cut
- Closures for bridge construction will be shorter and less risky when compared to west side rock cuts in Alignments 5 and 5A

Functionality and Safety
Alignment 1C
- 100 km/h design up and downhill except for 90 km/h curve immediately west of the Kicking Horse River
- Maximum 6% grade up and downhill
- Difficult to provide run-away lane

Alignment 4A
- 90 km/h design speed up and downhill
- Maximum 8% grade up and downhill
- able to incorporate existing run-away lane

Alignment 5
- 90 km/h design speed eastbound uphill on new alignment
- 80 km/h design speed westbound downhill on existing alignment
- Maximum 6% grade uphill on new alignment
- Maximum 8% grade downhill on existing alignment

Operations and Maintenance
Alignment 1C
- snow removal and storage will follow normal procedures
- long bridge may require more winter maintenance

Alignment 4A
- snow removal and storage will follow normal procedures
- short bridge on flat grade may require less winter maintenance

Alignment 5
- short east side crossover bridge may require special snow removal techniques to avoid dumping snow on road below
- long bridge may require more winter maintenance

Alignment 5A
- west side crossover bridge will require special snow removal technique to avoid dumping snow on road below
- long bridge may require more winter maintenance

- driver perception of “wrong side” traffic will be mitigated
- able to incorporate existing run-away lane

Alignment 5A
- 90 km/h design speed downhill on new alignment
- 80 km/h design speed uphill on existing alignment
- Maximum 6% grade downhill on new alignment
- Maximum 8% grade uphill on existing alignment
- Difficult to provide run-away lane

Alignment 5B
- 90 km/h design speed downhill on new alignment
- 80 km/h design speed uphill on existing alignment
- Maximum 6% grade downhill on new alignment
- Maximum 8% grade uphill on existing alignment
- Difficult to provide run-away lane
APPENDIX A – OTHER ALTERNATIVES STUDIED

Alignment 5B

- long west side crossover bridge will require significant special snow removal techniques to avoid dumping snow on road below
- very long bridge may require more winter maintenance.

Alignment 5B rated the highest score and additional work proceeded on this option.

Table A.5
Evaluation Matrix

<table>
<thead>
<tr>
<th>Alignment</th>
<th>Option</th>
<th>Score</th>
<th>Cost $ Millions</th>
<th>Risk</th>
<th>Geotechnical</th>
<th>Constructability</th>
<th>Functionality</th>
<th>Maintenance</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1C</td>
<td>$167</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
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<tr>
<td>4A</td>
<td>$126</td>
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<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>5A</td>
<td>$114</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>165</td>
<td></td>
</tr>
<tr>
<td>5B</td>
<td>$116</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>275</td>
<td></td>
</tr>
</tbody>
</table>

Weight: 50% 5% 5% 25% 15% 5% 5% 5% 100%

0 Points - Least Effective
3 Points - Most Effective

Table A.6
Detailed Cost Breakdown

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Option 1C</th>
<th>Option 4A</th>
<th>Option 5</th>
<th>Option 5A</th>
<th>Option 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade Construction</td>
<td>$321,000</td>
<td>$374,000</td>
<td>$382,000</td>
<td>$336,000</td>
<td>$298,000</td>
</tr>
<tr>
<td>Road Grading - Excavation, Place and Fill</td>
<td>$38,378,000</td>
<td>$40,171,000</td>
<td>$18,783,000</td>
<td>$34,642,000</td>
<td>$13,053,000</td>
</tr>
<tr>
<td>Rock Stabilization (West of River)</td>
<td>$1,500,000</td>
<td>$1,500,000</td>
<td>$1,500,000</td>
<td>$1,500,000</td>
<td>$1,500,000</td>
</tr>
<tr>
<td>Rock Removal (East of River)</td>
<td>$10,000,000</td>
<td>$10,000,000</td>
<td>$ -</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Drainage</td>
<td>$1,150,000</td>
<td>$935,000</td>
<td>$1,153,000</td>
<td>$1,148,000</td>
<td>$1,116,000</td>
</tr>
<tr>
<td>GC $0</td>
<td>$505,000</td>
<td>$686,000</td>
<td>$778,000</td>
<td>$727,000</td>
<td>$726,000</td>
</tr>
<tr>
<td>CBC</td>
<td>$703,000</td>
<td>$752,000</td>
<td>$616,000</td>
<td>$590,000</td>
<td>$639,000</td>
</tr>
<tr>
<td>Avalanche Fencing and Retaining Structures</td>
<td>$3,300,000</td>
<td>$3,400,000</td>
<td>$2,500,000</td>
<td>$2,700,000</td>
<td>$2,300,000</td>
</tr>
<tr>
<td>Waste Pit Development</td>
<td>$600,000</td>
<td>$600,000</td>
<td>$600,000</td>
<td>$600,000</td>
<td>$600,000</td>
</tr>
<tr>
<td>General</td>
<td>$1,605,000</td>
<td>$2,005,000</td>
<td>$1,012,000</td>
<td>$1,468,000</td>
<td>$834,000</td>
</tr>
<tr>
<td>Total Grade Construction</td>
<td>$62,262,000</td>
<td>$65,208,000</td>
<td>$30,956,000</td>
<td>$46,725,000</td>
<td>$25,438,000</td>
</tr>
</tbody>
</table>

Structural Construction

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Option 1C</th>
<th>Option 4A</th>
<th>Option 5</th>
<th>Option 5A</th>
<th>Option 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge</td>
<td>$21,644,000</td>
<td>$7,368,000</td>
<td>$20,896,000</td>
<td>$22,818,000</td>
<td>$31,043,000</td>
</tr>
<tr>
<td>Demolition of Existing Bridge</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>Retaining Walls</td>
<td>$20,438,000</td>
<td>$6,494,000</td>
<td>$14,963,000</td>
<td>$10,429,000</td>
<td>$11,992,000</td>
</tr>
<tr>
<td>General</td>
<td>$2,177,000</td>
<td>$421,000</td>
<td>$3,091,000</td>
<td>$1,468,000</td>
<td>$1,203,000</td>
</tr>
<tr>
<td>Total Structural Construction</td>
<td>$43,899,000</td>
<td>$14,763,000</td>
<td>$37,450,000</td>
<td>$34,759,000</td>
<td>$44,641,000</td>
</tr>
</tbody>
</table>

Paving Construction

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Option 1C</th>
<th>Option 4A</th>
<th>Option 5</th>
<th>Option 5A</th>
<th>Option 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Utility Construction</td>
<td>$1,401,000</td>
<td>$1,580,000</td>
<td>$1,498,000</td>
<td>$1,445,000</td>
<td>$1,351,000</td>
</tr>
<tr>
<td>Environmental Mitigations</td>
<td>$1,184,000</td>
<td>$873,000</td>
<td>$790,000</td>
<td>$859,000</td>
<td>$905,000</td>
</tr>
<tr>
<td>Resident Engineering</td>
<td>$12,268,000</td>
<td>$3,651,000</td>
<td>$7,722,000</td>
<td>$9,469,000</td>
<td>$7,877,000</td>
</tr>
<tr>
<td>Total Construction</td>
<td>$121,808,000</td>
<td>$95,252,000</td>
<td>$79,647,000</td>
<td>$94,444,000</td>
<td>$81,180,000</td>
</tr>
</tbody>
</table>

Total Construction Cost based on further refining of 1C, 4A and 5A.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>Option 1C</th>
<th>Option 4A</th>
<th>Option 5</th>
<th>Option 5A</th>
<th>Option 5B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project Management</td>
<td>$9,676,000</td>
<td>$7,298,000</td>
<td>$6,592,000</td>
<td>$7,052,000</td>
<td>$6,711,000</td>
</tr>
<tr>
<td>Engineering</td>
<td>$10,629,000</td>
<td>$8,939,000</td>
<td>$7,770,000</td>
<td>$7,740,000</td>
<td>$7,921,000</td>
</tr>
<tr>
<td>Land Acquisition</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
<td>$100,000</td>
</tr>
<tr>
<td>Tender Contingency (15%)</td>
<td>$20,050,000</td>
<td>$15,775,000</td>
<td>$14,110,000</td>
<td>$15,050,000</td>
<td>$14,380,000</td>
</tr>
<tr>
<td>Management Reserve</td>
<td>$8,260,000</td>
<td>$6,490,000</td>
<td>$6,750,000</td>
<td>$6,020,000</td>
<td>$5,140,000</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$167,306,000</td>
<td>$126,213,000</td>
<td>$112,016,000</td>
<td>$121,962,000</td>
<td>$115,811,000</td>
</tr>
</tbody>
</table>

Notes:
1. Engineering judgment was used to arrive at the refined costs for Options 1C, 4A and 5A. Actual alignment revisions and earthwork runs have not been calculated.
2. This cost summary was derived using the estimating program employed by the CCRPMT.
3. Costs were developed in conjunction with Golder Associates and the CCRPMT.
4. Option 5B was chosen as the prefered option and refined. The refined cost estimate is shown in Chapter 6.
APPENDIX A – OTHER ALTERNATIVES STUDIED

Two major items, Environmental Assessment and the Railway have not been included in the evaluation matrix. They have been studied but their impact on the evaluation of each alignment has been considered to be approximately the same for all of the Alignment Options.

A review of the Alignments with respect to the Railway indicates that there should be little concern except possibly during construction when rockfall may impact the tracks. This can happen during construction of all the alignment options so the railway impact has not been considered in the evaluation matrix.

Costing and Design Assumptions

Various cost estimates were generated throughout the functional planning exercise. Order of magnitude costs were initially produced for alignment options 1, 1A, 1B, 2, 3 and 4. The major items used as the basis for comparison included earthwork quantities (excavation and fill), length of bridge structure, retaining wall and reinforced slope requirements options. As the study developed complete cost estimates, based on the estimating program employed by the CCRPMT, were used for all the options.

The parameters and the constraints used in the design calculations and costs varied as the project developed. As a result, there was also variability in the unit costs assigned to the various construction items. The following describes some of the major cost components and the criteria used in estimating their costs:

Geotechnical

Rock and OM Excavation:

- Both the MoTH Geotechnical Branch and Golder provided information for the location and extent of rock material. An average depth of 2 m for overburden material (OM) was assumed to overlay the rock material.
- The unit cost of excavating rock varied by the type and location of the rock material. Based on the recommendations made by the Geotechnical consultants and the CCRPMT the following unit costs were used:
- West of the river, the cost to excavate the rock was considered to be high given the type of rock (blasting required), the proximity to the existing road and the large cut volumes estimated in this area. A cost of approximately $30 per cubic meter was assumed to be reasonable for this type of rock excavation.
- East of the river, the type of rock was assumed to be less costly to excavate. In this area the rock could either be ripped or blasted. A good portion of the material can be ripped but there are anticipated to be lenses where blasting is required. A cost of about $20 per cubic meter was assumed for this type of rock excavation.
- The angle of cut slopes required for rock excavation had to meet certain criteria:
- West of the river, the angle of cut slopes varied, between 0.75:1 to 0.25:1, depending on which rock formation the cut was in. This was based on the criteria set out by Golder.

Retaining Walls:

- Retaining walls were not to exceed certain heights:
  - East of the river – approximately 30 meters
  - West of the river – approximately 30 meters
- Unit costs ($/m2) for constructing retaining walls varied depending on the height, constructability of the wall, and the global stability (or instability) that the wall implied. The cost for structural backfill was accounted for in the unit costs. The MoTH Geotechnical staff provided the unit costs for retaining walls.
- The height of the allowable retaining walls east of the river was initially 15 meters with no surcharge. As additional investigation was undertaken the final parameters listed above were reached.

Reinforced Slopes:

- A maximum slope of 1:1 was recommended with a maximum height of 40 meters.
- Reinforced slopes were used in lieu of retaining walls that exceeded the maximum permissible heights.
- Also used in areas where flatter slopes (1.5:1) needed to be avoided.

Rock Remediation:

- A provisional cost of $10,000,000 for rock remediation was recommended by the Ministry to be included in the four-lane options (1C and 4A). Anticipation of irregularities in the rock cuts account for this provisional sum.

Rock Stabilization:

- A lump sum cost of $1,500,000 for rock stabilization, west of the river, was recommended by the Geotechnical Branch for options 1C, 4A, 5, 5A and 5B as scaling and bolting is required to stabilize the existing rock cuts.

Bin Wall Replacement:

- Bin walls along the existing highway are failing and are required to be replaced for those options that will maintain operation on the existing highway (4A, 5, 5A and 5B).
- This cost was estimated to be about $1,000,000.
APPENDIX A – OTHER ALTERNATIVES STUDIED

Drainage:

- Based on Geotechnical recommendations, the drainage east of the river has to be enclosed over the existing fill slopes. The estimated cost for this has been estimated at $700,000.

Avalanche Defences:

The Ministry Avalanche department provided the location and cost of avalanche netting and stopping walls for each option. Refinement of the necessary measures was only undertaken for the later developed options.

Base Mapping:

The quantities were developed from base mapping constructed from aerial mapping and ground survey. At the completion of the study MoTH surveyed the remaining unsurveyed portions of the study area. The extents of the survey are shown in Drawing 81432-SK-162.

A.3 DRAWINGS

The proposed geometric improvements for Roth Creek to Brake Check are shown on the following drawings:

DRAWINGS FOR PRE-SLIDE INVESTIGATIONS:

Figure 6 Typical Profile
Figure 7 Alternatives #1 & #3 - Plan
Figure 8 Alternatives #3A - Plan
Figure 9 Alternatives #2 & #4 - Plan
Figure 10 Alternatives #5 & #6 - Plan
Figure 11 Alternatives #7 - Plan
Figure 12 Alternatives #8 - Plan

DRAWINGS FOR POST-SLIDE INVESTIGATIONS:

81432-SK-62 Study Alignment 1 - Plan
81432-SK-63 Study Alignment 1 - Profile
81432-SK-65 Study Alignment 2 - Plan
81432-SK-66 Study Alignment 2 - Profile
81432-SK-68 Study Alignment 3 - Plan
81432-SK-69 Study Alignment 3 - Profile
81432-SK-91 Study Alignment 1b - Plan
81432-SK-92 Study Alignment 1b - Profile
81432-SK-94 Study Alignment 1a - Plan
81432-SK-95 Study Alignment 1a - Profile
81432-SK-97 Study Alignment 4 - Plan
81432-SK-98 Study Alignment 4 - Profile
81432-SK-101 Study Alignment 1c - Plan
81432-SK-102 Study Alignment 1c - Profile
Drawings for

Post-slide Investigations

NDLEA