Preliminary Design Report for Cheekye Fan Deflection Berms

Final Report
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KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

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EXECUTIVE SUMMARY

The Cheekye River drains a steep watershed on the west flank of Mount Garibaldi, north of Squamish. The Cheekye Fan comprises approximately 8.3 km^2 of gently sloping land within the District of Squamish. The fan is subject to debris flow and flood hazards from the Cheekye River. The southern part of the fan is occupied by residential Brackendale. The northern part of the fan is undeveloped except for the Squamish Airport, the Cheekye Substation, and scattered residential development. There is a need to construct mitigative works in order to protect existing and future development on the fan.

An extensive study was completed by Thurber Engineering and Golder Associates in 1992. This study provided estimates of the design debris flow magnitude on the Cheekye River. The District of Squamish and the Ministry of Water, Land and Air Protection (MWLAP) subsequently proposed a series of deflection berms on the fan.

The present study reviews the feasibility of the deflection berm concept, provides preliminary designs for the various berm sections, and identifies key issues associated with implementation of the deflection berm concept. The study concludes that the deflection berm concept is feasible in principle, with no significant transfer of risk to other facilities, and would protect residential Brackendale from debris flow damage.

MWLAP specified a 10,000-year return period as the design criteria for this study, with a volume of 7 million m^3 and a peak discharge of 1,700 m^3/s. Following review, KWL concluded that this magnitude may be too high in volume, but far too low in peak discharge. An updated estimate of the largest event in the past 10,000 years was suggested as a volume of 5.4 million m^3 and a peak discharge of 15,000 m^3/s. For the purpose of this study, MWLAP advised the design event magnitude to be a volume of 7 million m^3 and revised the peak discharge to 15,000 m^3/s.

FLO-2D modelling was performed to simulate debris flow deposition on the Cheekye Fan. Model runs were completed for existing conditions, and with the proposed deflection berms in place. The modelling work provides an updated assessment of the debris flow risk on the fan, and also provides a basis for establishing preliminary design heights of the various deflection berm sections.

The large magnitude of the design event translates into very large deflection berms. The berm sections vary in height from about 12 m at the upstream end to a minimum of about 3 m. The associated construction cost estimate varies between $13.6 million and $22.7 million, depending primarily on whether imported or local fill material is used. A significant component of the cost pertains to regrading of Highway 99.

Detailed design would need to address environmental issues, such as the berm crossing of Dryden Creek and tree removal. Stakeholder consultations have occurred with MWLAP, the BC Ministry of Transportation, the Squamish Nation and BC Hydro, but further discussion will be needed with these and other stakeholders during detailed design. Some design variations have been identified for consideration prior to detailed design.

Section 1

Introduction

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1. INTRODUCTION

1.1 PURPOSE OF REPORT

The District of Squamish (the District) and the BC Ministry of Water, Land and Air Protection (MWLAP) propose a series of deflection berms to protect the Brackendale area of the District against damage from debris flows and flood avulsions on the Cheekye River. The berms would also protect other fan assets, such as the Squamish Airport, Waiwakum I.R. No. 14 and the Cheekye Substation (which is already protected by a perimeter berm). The original deflection berm concept proposed by the District and MWLAP is illustrated by Figure 1-1.

The purposes of this report are as follows:

- review and assess the feasibility of the deflection berm concept plan;
- provide preliminary design for the constituent berm sections; and
- identify key issues associated with the deflection berm plan.

MWLAP specifies a 10,000-year return period debris flow as the design event. On the basis of this report, the District will be positioned to make decisions regarding possible implementation of the deflection berm plan, with or without modification.

1.2 BACKGROUND

The Cheekye Fan is one of the largest fans in BC, and is subject to periodic large debris flows. In the absence of mitigative measures, development on the fan has been restricted.

The Cheekye Fan has been intensively studied. Key documents are noted in the References section at the back of this report. Thurber-Golder (1993) provided a comprehensive assessment of the debris flow hazards, with an estimated design debris flow magnitude of 7 million m^3, correlating to a return period of 10,000 years. Thurber-Golder also delineated the fan into zones of varying degrees of hazard.

The District commissioned this study to initiate protection of existing developed areas, and possibly provide some additional development area.

Careful consideration needs to be given to the issue of transfer of risk associated with construction of the proposed deflection berms. Key assets are to be protected by deflection berms, but not to the detriment of other facilities. It also needs to be recognized that the berms will not fully protect several linear developments on the fan: Highway 99, the BC Hydro transmission lines, several District roads, and the BC Railway tracks. There needs to be a rationalization of the risk situation for these assets and unimproved land on the upper fan.

1.3 SCOPE OF WORK

The work program was completed in two stages: concept review, and preliminary design. The scope of work for these two stages is generally summarized in Table 1-1 and Table 1-2 respectively.

Table 1-1
Work Program for Concept Review

Item	Description
1.1 Project Initiation	▪ Obtain and review background information, including: - digital base map information; - topographic data and maps; - previous reports; and - survey control. ▪ Project Initiation Meeting with District and MWLAP: - review proposed work program; - establish communication protocol for project; - discuss historic activities; - confirm District's information requirements; and - establish stakeholder contacts and review stakeholder consultation process. ▪ Perform overview inspection of fan area. ▪ Walk proposed berm alignments. ▪ Discuss key project aspects with District and MWLAP.
1.2 Hazard Review	▪ Review and summarize recent research by M. Jakob, P. Friele, and J. Clague. ▪ Review previous debris flow magnitude estimates for Cheekye Fan. ▪ Review available information on large-scale volcanic debris flows in other parts of the world. ▪ Recommend design (10,000-year return period) debris flow volume and discharge. ▪ Discuss recommended debris flow volume and discharge with District and MWLAP, get direction for proceeding with study. ▪ Discuss merits of using return period less than 10,000 years.
1.3 Debris Flow Modelling	▪ Obtain some initial topographic survey data and field measurements to facilitate set-up of FLO-2D model. ▪ Calibrate FLO-2D model using knowledge about past debris flows. ▪ Set up FLO-2D model for existing conditions, incorporating available topography. ▪ Run FLO-2D model for existing conditions with design debris flow magnitude, and other lower magnitude scenarios. ▪ Remodel design debris flow with proposed berms. ▪ Establish preliminary design berm heights.

Item	Description
	▪ Produce model result maps to identify any areas potentially subject to a transfer of risk from the proposed berms. ▪ Identify facilities that would not be protected by proposed berms (Highway 99, hydro towers, telecommunication lines, development areas, etc.).
1.4 Concept Review	▪ Review proposed berms in view of modelling results and field investigation. ▪ Assess feasibility of proposed deflection berms. ▪ Consider logistics of berm crossings at Dryden Creek and Highway 99. ▪ Consider potential berm issues with respect to Waiwakum I.R. No. 14, Poquiosin & Skamain I.R. No. 13, and Cheakamus I.R. No. 11. ▪ Prepare brief report to document concept review. Include results of FLO-2D modelling and a comprehensive plan. Provide recommendations for dealing with any significant transfer of risk identified. Identify design issues associated with each proposed berm. Also provide a recommendation for proceeding to preliminary design. ▪ Meet with District and MWLAP to present draft report. Finalize main berm alignment and initiate field survey. ▪ Obtain feedback on draft report. ▪ Report to be incorporated into preliminary design report in second stage of work.

Table 1-2
Work Program for Preliminary Design

Item	Description
2.1 Field Survey	▪ Perform detailed topographic survey for proposed main berm. ▪ Reduce survey notes and plot base plans. ▪ Survey for proposed deflection berm, highway relocation, airport berm and substation berm will be separate future activities.
2.2 Geotechnical Investigation	▪ Undertake geotechnical (subsurface) investigation for main berm. - excavate up to 10 test pits by back-hoe; - log test pit results; and - perform soil gradation tests. ▪ Perform stability analysis based on preliminary design berm geometry. ▪ Investigate seismic stability, particularly potential liquefaction of any fine grained soils identified. ▪ Provide geotechnical recommendations for detailed design. ▪ Limit scope to main berm. ▪ Document geotechnical investigation for inclusion in report.
2.3 Preliminary Design	▪ Establish berm design criteria in consultation with District and MWLAP (freeboard, impact forces, berm geometry, etc.), addressing both debris flow and flood avulsion hazards.

Item	Description
	▪ Meet with Land and Water BC and other land interests to discuss project. ▪ Meet with Sea to Sky Highway Corridor Technical Liaison Committee for Urban Squamish to discuss issues associated with berm crossing of Highway 99. ▪ Meet with Squamish Nation to discuss project issues. ▪ Meet with BC Hydro to discuss issues associated with berm crossing of transmission lines. ▪ Update FLO-2D model to assist in refining berm alignments and crest elevations. ▪ Use field survey information to prepare preliminary design drawings for main berm (between Highway 99 and Government Road). ▪ Use available mapping and survey information to prepare preliminary design drawings for upper berm (2 or 3 alternatives), Waiwakum berm (1 alternative) and airport berm (one alignment). ▪ Field review of preliminary design by project team. ▪ Field review with environmental consultant. Obtain letter report on environmental issues that could affect project feasibility (deflection berm crossing of Dryden Creek, impact of tree removal on raptors and other wildlife). ▪ Delineate existing property boundaries and proposed right-of-way boundaries on drawings. ▪ Present partial preliminary design to District, MWLAP and any other stakeholders selected by the District. ▪ Obtain feedback, update drawings for inclusion in preliminary design report. ▪ Prepare preliminary design report documenting the preliminary design, providing a Class C construction cost estimate, and including an implementation plan to address construction logistics, such as materials management and staging. Also incorporate preliminary geotechnical and environmental assessments.
2.4 Design Review	▪ Present draft report to District Council. ▪ Obtain input, finalize preliminary design drawings and report. ▪ Submit final documents to District.

1.4 PROJECT TEAM

This report was prepared under the direction of Mike V. Currie, M.Eng., P.Eng., with input from the following senior KWL team members:

- Nigel Skermer, M.Sc., P.Eng. – Geotechnical Engineer;
- Matthias Jakob, Ph.D., P.Geo. – Senior Geoscientist;
- Ken Ferraby, P.Eng. – Senior Civil Engineer; and
- Hamish Weatherly, M.Sc., P.Geo. – Fluvial Geomorphologist.

Pierre Friele, P.Geo., assisted KWL by providing background information for Section 2.1. Mike Nelson, R.P.Bio., of Cascade Environmental Resource Group provided input on environmental resource values.

Input was also provided by Mick Gottardi, P.Eng., and Rod Fleasance, P.Eng. of the District and Ron Henry, P.Eng., of MWLAP.

Section 2

Cheekye River Debris Flows

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2. CHEEKYE RIVER DEBRIS FLOWS

2.1 RECENT RESEARCH ON FAN EVOLUTION

OVERVIEW OF GEOMORPHOLOGY

The Cheekye River drains a steep, deeply incised watershed on the west flank of Mount Garibaldi, a large Quaternary stratavolcano. This volcano was active at the end of the last glaciation but is now dormant. Volcanic materials on the west flank of the volcano originally deposited against ice, were debuttressed as the ice thinned, and collapsed. The debris was subsequently reworked by glacial meltwater. These materials compose the upper Cheekye fan, a deeply incised, raised fan deposit lying between 320 m and 400 m elevation. During the late stages of deglaciation, stagnant ice lay in the middle fan area between 320 m and 200 m elevation. By 11,500 years ago, the middle fan was completely ice free and the Cheekye River had downcut to its present grade, controlled by a rock sill downstream of Stump Lake (Friele and Clague, 2002).

The lower Cheekye Fan is the product of reworking of the upper and middle fan deposits, continued debris flow activity from the flanks of Mount Garibaldi, and fluvial processes. The lower fan extends from its apex at 190 m elevation to the Squamish River floodplain between 10 and 25 m. A secondary avulsion point is located on the northern sector of the fan at an elevation of 120 m (the secondary fan apex).

Friele et al. (1999) developed a Holocene sediment budget for the lower fan based on radiocarbon, test pit, and geophysical (ground penetrating radar) data. The sediment budget indicates that 90 percent of the material stored in the lower fan was deposited before about 7,500 years ago, and that sediment supply has declined exponentially through the Holocene. Thus, the lower fan is largely a product of the geologic past. Other relevant findings include:

- the majority of the mid to late Holocene sedimentation has occurred in the central and northern sectors of the lower fan;
- less than 1 m of aggradation has occurred in the south sector since 8,700 years ago;
- a ground penetrating radar survey across the southern fan margin revealed deltaic facies at 9 m below sea level, indicating that this fan sector had built out to its present extent during the regional marine lowstand 10,200 years ago;
- dating of wood fragments in exposures on the southern fan margin indicate that the lower southern fan sector had completely formed by 10,200 years ago; and

- a 10 m to 15 m deep channel extended westward from the secondary apex to the Squamish River between 5,600 to 7,500 years ago.

The proximal portion of the fan below the primary apex is truncated by the fan portion below the secondary apex indicating that the fan emanating from this point is younger than that from the primary apex. This truncation and the lack of abandoned channels across the southern sector suggests that the fan head above 120 m elevation had become entrenched between 8,700 and 7,500 years ago. At some point, the channel was captured in its present position and flowed west across the central sector of the fan, entrenching the previously noted deep channel. The river occupied this channel for at least 2,000 years, starting about 7,500 years ago. Following a large debris flow about 6,900 years ago, the Cheekye River resumed this position. Ultimately, this channel was filled by a series of debris flows after 5,600 years ago, diverting the channel to its modern position on the northern fan section (Clague et al., 2003, in press).

In summary, there has been a progressive northerly sweep of the active channel and westerly shift of the active apex in response to a sharp decline in sediment supply through the Holocene.

IMPLICATIONS FOR HAZARD ASSESSMENT AND MITIGATION

The analysis of fan geomorphology by Friele et al. (1999), Friele and Clague (2002) and Clague et al. (2003, in press) has important implications for hazard assessment and mitigation:

1. The majority of the debris flow activity on the Cheekye Fan occurred during the early Holocene. Sediment yield during the early Holocene may have been 30 times higher than during the present time. Consequently, the probability and magnitude of debris flows has diminished since that time. This observation implies that debris flow frequencies based on past events may be questionable if extrapolated into the future, and implies that the largest debris flow recorded in the last 10,000 years may have a higher return period than 10,000 years.

2. The configuration of Highway 99, constructed in the late 1970s, has caused changes to the flow direction and increased the likelihood of debris flow avulsions at the Highway crossing. The highway bridge abutments block a portion of the fan-head entrenched channel and will act to deflect large debris flows south. Furthermore, the highway itself forms a graded channel that could convey floods and debris flows toward Brackendale.

These implications need to be considered in any hazard mitigation activities on the Cheekye Fan.

2.2 DESIGN EVENT MAGNITUDE

The design event for this project is defined in the Terms of Reference as a 10,000-year return period debris flow. The event magnitude for this return period was specified by MWLAP on the basis of the Thurber-Golder (1993) report (a total volume of 7 million m^3 and a peak discharge of 1,700 m^3/s). Both the total volume and the peak discharge are important in modelling avulsion and runout on the fan.

This sub-section revisits the design magnitude estimate of Thurber-Golder in view of the recent work by Clague et al. (2003, in press). Research has focussed on two previous large debris flow events on the Cheekye River:

- the Stump Lake debris flow – about 6,900 years ago; and
- the Garbage Dump debris flow – about 800 to 1,000 years ago.

Both events are referenced throughout this section.

DEBRIS FLOW PEAK DISCHARGE

Estimates of the peak discharge of historic debris flow events on the Cheekye Fan have been documented by Clague et al. (2003, in press) and Thurber-Golder (1993). The following is a summary and critique of these estimates.

Clague et al. (in press)

Based on dated lake core sediments, Clague et al. (2003, in press) established that the Stump Lake debris flow partially avulsed from the Cheekye River into Stump Lake about 6,900 years ago. The channel immediately north of the lake has a cross-sectional area of approximately 1,000 m^2. To estimate the velocity of this debris flow event, Clague et al. (2003, in press) used the following equation based on the Newtonian viscous flow model (Sharp and Nobles, 1953; Curry, 1966):

$$v = \gamma S h^2/(k\nu) \qquad \text{(Eq. 1)}$$

where v is mean velocity, γ is the unit weight of the debris, S is the slope, h is the flow depth, k is a cross-section shape coefficient, and ν is the apparent dynamic viscosity of the debris.

Although this equation relates specifically to Newtonian flows, it can be extended to Bingham and pseudoplastic flows (i.e. debris flows) by replacing the dynamic viscosity with an apparent viscosity, which is dependent on two material constants. Equation 1 has shown to be useful at flow depths greater than 2 m, which would clearly be the case at the Cheekye River. The biggest unknown in the equation is viscosity. Clague et al. (in press) used viscosity terms reported by Jordan (1994) ranging from 750 Pas to 2500 Pas, yielding velocities of 108 m/s to 15 m/s. The higher velocity has never been observed for a debris flow and is therefore highly improbable.

There are several uncertainties involved in the use of Equation 1:

- There is no guarantee that the formula yields the correct velocity estimates. An exact error envelope based on the equation cannot be formulated.
- The viscosity of debris flows on the Cheekye River has never been determined directly. Even if that had been done, the viscosity is likely to change during events and will vary for different debris flows (changes in water content and grain size composition of the slurry affect viscosity).

In light of the available information, however, use of Equation 1 is considered a reasonable approach. The velocity estimates of Clague et al. (2003, in press) are reproduced in Table 2-1 based on the published viscosity range. Table 2-1 also includes an estimated velocity based on a Turbid Creek debris flow with a viscosity of 5,300 Pa.s (Jordan, 1994) which not included the analysis of Clague et al.

Table 2-1 considers two cross-sections for the Stump Lake debris flow. While the two cross-sections have similar areas (Clague et al., in press), cross-section B is considerably more confined, resulting in higher velocity and discharge estimates.

Table 2-1
Alternative Scenarios for Debris Flow Velocity and Peak Discharge for the Stump Lake Debris Flow

Viscosity (Pa.s)	Debris Flow Velocity (m/s)		Debris Flow Peak Discharge (m^3/s)	
	XS-A	XS-B	XS-A	XS-B
750	52	108	50,300	114,000
1,500	26	54	25,200	57,000
2,500	16	32	15,100	34,200
3,000	13	27	12,600	28,500
5,300	7	15	7,100	16,100

Table 2-1 suggests that the flow velocity for the Stump Lake debris flow could have ranged from 7 m/s to 108 m/s. Accordingly, the reconstructed peak discharge would range from about 7,000 m^3/s to 114,000 m^3/s. These values illustrate the uncertainty associated with reconstructing peak dischatges of historic creek events. The range, of course, is too broad to develop a reasonable estimate. However, Clague et al. (2003, in press) suggest that a velocity of 15 to 30 m/s is reasonable based on comparable studies of debris flows in the Pacific Northwest.

KWL concurs with this assertion, but has narrowed the velocity estimate to 15 m/s. A higher velocity would indicate a higher water content than is thought to be reasonable. A possible trigger for the Stump Lake debris flow was a rock avalanche that transformed into a debris flow. Rock avalanches do not have enough associated water to lower viscosities to allow a debris flow velocity of 30 m/s. For example, a debris flow at Turbid Creek in 1984 had a velocity of 10 m/s and was indicative of a high viscosity debris flow (5,300 Pas). This debris flow was initiated from a rock avalanche and incorporated most of its water from snowmelt along its path (Evans et al., 2001). Snowmelt will also be a significant source of water for debris flows on Cheekye River. On this basis, a velocity estimate of 15 m/s is thought to be appropriate for the Cheekye River. Multiplying 15 m/s by the cross-sectional area of approximately 1,000 m^2 yields a peak discharge of **15,000 m^3/s** for the Stump Lake debris flow.

No other debris flow avulsions are recorded in the sediments of Stump Lake. The implication is that the 6,900 year old debris flow is the largest event recorded on the lower Cheekye Fan in the last 10,000 years. But this does not necessarily mean that the 6,900 year old debris flow was a 10,000 year return period event. Clague et al. (2003, in press) have correlated the Stump Lake debris flow with the Squamish River unit exposed in a section along the Squamish River and described by the Thurber-Golder report.

Thurber-Golder (1993)

Thurber-Golder based their peak discharge estimate for a 7 million m^3 debris flow on an outbreak flood from a landslide in the upper Cheekye River watershed. In this scenario, a "dry" landslide would dam the creek channel in the headwaters. A debris flow would then result from a breach of the landslide dam. Northwest Hydraulics carried out outbreak modelling using standard software. The results indicated a peak debris flow discharge of 1,700 m^3/s with a flow depth of 7 to 10 m at the apex of the lower fan, prior to lateral spreading of the debris flow surges. However, a complicating factor in the downstream routing of floods from natural dam failures is the bulking and debulking of floodwaters with sediment and debris as the flood moves downstream (Costa and Schuster, 1988). Potential bulking of flood flows appears to be an especially important process in glacial and volcanic terrain (Clague et al., 1985; Scott, 1985). For example, peak discharges from the failure of a moraine dam on the Kumbel River, USSR are well documented (Yesenov and Degovets, 1979). Peak discharge at the dam failure was 210 m^3/s but it bulked to 11,000 m^3/s 15 km downstream.

Several studies have correlated peak discharge to total volume. Of these studies, relations derived by Jakob and Bovis (1996) and Jakob (1996) appear to be most appropriate for the study site.

- Based on work by Mizumaya et al. (1992), Jakob and Bovis (1996) developed a peak discharge – volume relation for clay-rich debris flows. Using this equation, a 7 million m^3 debris flow would have a peak discharge of approximately 20,000 m^3/s.
- Jakob (1996) developed a relation for muddy debris flows in southwestern British Columbia. Using his equation, a 7 million m^3 debris flow would result in a "best fit" estimate of 22,500 m^3/s. His data, however, were based on only eight observations.

The 1,700 m^3/s peak discharge estimate by Thurber-Golder is a significant outlier in both regression equations. Applying Jakob and Bovis' (1996) equation in reverse, a 1,700 m^3/s peak discharge would correspond to a 0.4 million m^3 debris flow, while Jakob's (1996) equation would result in a total debris flow volume of 0.6 million m^3.

Furthermore, using the cross-section of 1,000 m^2, reported by Clague et al. (2003, in press), a debris flow with a 1,700 m^3/s discharge would move at a velocity of only 1.7 m/s. This velocity is approximately an order of magnitude lower than that for other observed volcanic debris flows worldwide (Pierson, 1998).

In summary, although a landslide dam outbreak flood may create a peak discharge of only 1,700 m^3/s, it is unrealistic that a 7 million m^3 debris flow would have a peak discharge of only 1,700 m^3/s. The following sub-section reviews debris flow volumes and explains why a 7 million m^3 debris flow is considered unlikely.

DEBRIS FLOW VOLUME

This section explains how the design debris flow could be initiated in the Cheekye River watershed and also provides a review of previous debris flow volume estimates.

Debris Flow Mechanism and Volume

Thurber-Golder (1993) considered the possibility of spontaneous transformation of a "dry" landslide in the headwaters into a debris flow by incorporating water, but conclude that this process could only lead to a debris flow with a maximum volume of 1 to 2 million m^3. For this reason, they suggested that the design debris flow would be initiated through a landslide dam outbreak scenario.

In reviewing the potential magnitude of a debris flow that results from direct transformation of a landslide (rock slide or rock avalanche), the key issue is whether sufficient pore pressures could be generated in the debris to allow transformation into a debris flow without the necessity of the formation of a temporary debris dam.

Following the logic used in Evans et al. (2001), porous rock with low uniaxial compressive strength, which is the case with the Mount Garibaldi volcanics, may be responsible for pore pressure generation during the collapse of the pore structure of the intact pyroclastic material at the source of the rock slide or rock avalanche (Iverson, 1999). Saturation of the debris mass during travel could be achieved if a large landslide were to occur during a time with substantial amounts of snow and ice on the headwall of Cheekye Valley and along the bottom slopes of Brohm Ridge and Cheekye Ridge. This process would further facilitate transformation of a large landslide into a debris flow.

According to Thurber-Golder (1993) possible water sources are limited to:

* surface water that is incorporated in the debris flow by overrunning (the debris flow will move significantly faster than the streamflow on Cheekye River), and

- melting of snow and ice accumulated in the avalanche gullies of the upper drainage with an assumed melting of 50%.

Thurber-Golder estimated the total volume of these water sources at 430,000 m^3. At a solid concentration (by volume) of 70% (reported in Thurber-Golder, quoting Jordan 1989), this volume of water would translate into a debris flow volume of 1.4 million m^3, which is quoted by Thurber-Golder as the maximum debris flow volume for direct transformation of a landslide into a debris flow. However, concentrations of up to 79% (by volume) have been measured in higher viscosity debris flows elsewhere (Jordan, 1994 and sources quoted in Jordan, 1994). A solid concentration of 79% (concentration by weight of 91%) would result in a total debris flow volume of 2.0 million m^3.

Thurber-Golder assumed that the debris flow initiating landslide would be dry. Since the landslide would likely occur during wet weather, it is likely that the landslide mass would be partially saturated. Assuming one or several partially saturated debris avalanche(s) with a moisture content of 25% totalling 1,000,000 m^3 in volume, the total debris flow volume could amount to approximately 3 million m^3 at a 74% solid concentration by volume.

There are considerable uncertainties involved in the assumptions underlying the above calculations such as:

- the exact water content of the debris flow;
- the amount, and water content of snow in the area overrun by the debris flow;
- the water content of the initiating landslide,
- the volume of the initiating landslide;
- the number of initiating landslides;
- the discharge in Cheekye River at the time of the debris flow; and
- the amount and degree of saturation of debris entrained along the debris flow path.

Making conservative assumptions, it becomes evident that a debris flow exceeding the volume quoted in the Thurber-Golder (1993) report (1.5 million m^3) is possible by direct transformation of a wet (partially saturated) landslide (debris avalanche) into a debris flow. The Garbage dump debris flow described in the following subsection is believed to have occurred as a consequence of this process, rather than through damming and a subsequent outbreak flood of Cheekye River by a large landslide in the Cheekye River canyon as postulated by Thurber-Golder (1993).

Garbage Dump Debris Flow

Prior to Clague et al. (2003, in press) and Thurber-Golder (1993), the largest documented debris flow on the Cheekye Fan was the Garbage Dump debris flow of about 800 to 1,000 years ago, first identified by Baumann (1991). Baumann mapped the Garbage Dump debris flow as a lobe extending west of the secondary fan apex, having an area of

In summary, the association of an event magnitude of 5 to 7 million m^3 to a return period of 6,000 years as reported in the Thurber-Golder (1993) report can be questioned. Since the largest noted debris flow in the Holocene was the Squamish River unit with an estimated volume of 4 million m^3. The 5 to 7 million m^3 event would therefore have a higher than 10,000-year return period. The Squamish River unit is correlated to the Stump Lake event by Clague et al. (2003, in press). In the following section, an attempt is made to improve this estimate by two independent methods.

Stump Lake Debris Flow

Clague et al. (2003, in press) recently cored Stump Lake to reconstruct the frequency of large debris flows reaching the lower Cheekye fan. It was found that following deglaciation, about 11,500 years ago, a large debris flow blocked the drainage of a small kettle allowing Stump Lake to form. The size of this event cannot be reliably reconstructed.

The first anomalous event recorded in the sediment of Stump Lake is a diamicton layer and an associated detrital organic layer capped by clay laminae. The diamicton layer represents a large debris flow from the headwaters of Cheekye basin and has been dated at 6,900 years old. As explained above, Clague et al. (2003, in press) reconstructed a peak discharge of 15,000 m^3/s to 30,000 m^3/s for this event. As discussed before, KWL believes that the lower estimate may be more accurate because of water limitations, which would cause a lower viscosity and therefore a lower debris flow velocity.

Providing that 15,000 m^3/s is a reasonable estimate, the empirical equations of Jakob and Bovis (1996) and Jakob (1996) can be used to estimate a debris flow volume. The results of this are summarized in Table 2-2.

Table 2-2
Debris Flow Volume Calculations for Cheekye River Based on Empirical Equations Relating Peak Discharge to Total Debris Flow Volume for Muddy Debris Flows (Primarily of Volcanic Origin)

Author	Best fit (m^3)	Upper limit[2] (m^3)
Jakob and Bovis (1996)[1]	2.8 million	5.4 million
Jakob (1996)	4.8 million	9.1 million

Based on a discharge of 15,000 m^3/s.
1. Based on work by Mizuyama et al. (1992)
2. Corresponds roughly to the 95% confidence interval

Jakob and Bovis' (1996) data are based on hundreds of observations, while Jakob's (1996) data are based on only eight observations. It is therefore suggested that the former be considered the better estimate. Clague et al. (2003, in press) used the best fit line of the former relation to estimate a volume of about 3 to 5 million m^3 for the Stump Lake event, corresponding to velocity of 15 m/s. To be conservative, the upper limit of the

Section 3

Debris Flow Modelling

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3. DEBRIS FLOW MODELLING

3.1 MODEL DESCRIPTION AND SET-UP

Debris flow modelling for the Cheekye Fan was completed using the commercial software FLO-2D, a two-dimensional flood routing model. Predicting overbank flooding is the most common application for the model, but it is also useful for analyzing unconventional flooding problems, such as unconfined flows over complex topography, debris floods, and debris flows. In the USA, FLO-2D is on the Federal Emergency Management Agency's list of approved hydraulic models for unconfined flow flood insurance studies. Several US federal agency offices are using the model including the Bureau of Reclamation, Fish and Wildlife Service and National Park Service. KWL has previously used FLO-2D for debris flow and debris flood modelling on several creeks in British Columbia and Washington State.

MODEL SET-UP

The FLO-2D model for the Cheekye Fan is summarized as follows:

- The topography was represented by a digital terrain model (DTM) of the fan that was transformed into a 100 m grid. For the Cheekye Fan, a 1 m contour map of the lower fan was obtained from McElhanney Associates. The map was a product of the Thurber-Golder study (1993) and was produced from 1:5,000 air photographs of the fan taken on March 4, 1991. The model was started 100 m upstream of Stump Lake.
- The distance travelled and mobility of debris flows is governed by a number of factors. Viscosity and effective yield stress of the flow are particularly important variables because they determine the dynamics and runout distance of debris flows. The magnitude of these variables is determined by the input of four coefficients. For the Cheekye Fan, these variables were adjusted until the modelled debris flow characteristics resembled the extent of previously mapped debris flow deposits (see Section 2). Volume and peak discharge were then adjusted for the modelled design debris flow scenarios.
- The input debris flow hydrograph was based on the different volume and peak discharge scenarios (see Table 3.1). For the Cheekye River, the design hydrograph was modelled as a series of surges that occur over a period of 30 minutes.

MODEL ASSUMPTIONS AND LIMITATIONS

A major limitation of the FLO-2D model is that each grid element is represented by one value for elevation and one value for flow roughness. For the Cheekye River, the fan topography was overlaid with a 100 m grid, with each grid cell having an area of 1 ha ($10,000\ m^2$). When grid elements are represented by a single elevation, small variations in topography within the grid element are not accounted for in the simulation. These are generally not critical in determining flow paths and depositional zones. Some simulations were attempted with a 50 m grid (2,500 m^2) but the results were not different enough to justify the increased computational and set-up time. An even smaller grid size (5-10 m) may yield more accurate results for small topographic irregularities such as the BC Railway fill, road fills and minor topographic undulations of less than 1 m height. These are not accounted for in the model.

There is some uncertainty in interpreting the model results due to the extreme magnitude of the design event. For example, trees entrained by the debris flow on the fan could cause an increase flow resistance and could create localized blockages or flow constrictions and/or deposition.

MODEL SCENARIOS

By modelling both existing conditions and conditions following the construction of the deflection berms, the model can indicate any transfer of risk arising from the proposed berms. The model can also be used as a basis for determining the berm heights by using flow depth and adding runup or superelevation which can be calculated from estimated debris flow velocities and other known variables.

For existing conditions, the first scenario models the design event (7 million m^3 volume, 15,000 m^3/s discharge). Sensitivity analyses have shown that there is virtually no change in debris flow deposition area, depth or flow velocity up to a peak discharge of 30,000 m^3/s. Existing conditions scenarios were also modelled for two lower magnitude events (5.4 million m^3 and 3 million m^3) to determine the influence of debris flow volume on runout, velocity and flow depth.

All existing conditions scenarios result in a significant avulsion at the primary fan apex. This is due to the fact that the cross-section can not contain the debris flow between the primary fan apex and the Highway 99 bridge, as well as the flow constraint and sharp channel bend posed by the Highway 99 bridge and fill on the north side of the Cheekye River.

The fourth model scenario is for the design event with the proposed deflection berms in place.

These model scenarios are summarized in Table 3-1.

Table 3-1
Cheekye River Debris Flow Model Scenarios

Scenario	Description	Volume (m^3)	Peak Discharge (m^3/s)
1	Existing conditions	7 million	15,000*
2	Existing conditions	5.4 million	15,000
3	Existing conditions	3 million	9,600
4	With proposed deflection berms	7 million	15,000

* Peak discharge could reach 20,000 m^3/s for an event of this volume. However, it was found that there are no significant changes in debris flow runout, flow depth or flow velocity for peak discharges over 15,000 m^3.

The model results for these scenarios are illustrated in Figures 3-1 to 3-4. The figures illustrate maximum flow depth and maximum velocity, which are standard outputs for FLO-2D simulations.

The following sub-sections describe the modelling results for the different scenarios.

3.2 DEBRIS FLOW MODELLING FOR EXISTING CONDITIONS

This sub-section discusses the model results for existing conditions and describes some of the consequences (Scenarios 1 to 4). It is important to note that the results are not precise and may change depending on flow mechanics and random avulsions. They do, however, provide a good sense of areas affected by debris flow and the degree of impact.

SCENARIO 1

In Scenario 1, the majority of the debris flow would avulse at the primary fan apex (Figure 3-1). The model results show that two large debris tongues would extend toward Brackendale, depositing to a depth of up to 4 m in parts of north Brackendale. The flow velocity could reach up to 4 m/s in the Brackendale area. A long section of Highway 99 between the Cheekye River bridge and Brackendale would be inundated.

Debris would flow down the Cheekye River and split into three separate tongues downstream of the secondary fan apex. There would be little impact on the Squamish Airport and the Cheekye Substation. This flow pattern is controlled by the deposit of the Garbage Dump debris flow because it creates a preferential flow path to the northwest. The BC Railway and Squamish Valley Road would probably be severed. Sections of Waiwakum I.R. No. 14 would be inundated with debris up to 0.3 m in depth with a flow velocity less than 2 m/s. Part of the south airport runway would be inundated by up to 0.3 m of debris with a less than 2 m/s. Because random avulsions can not be accurately estimated, it was assumed that some debris may be redirected in westerly direction and may impact the Squamish Airport with a flow depth up to 2 m and a flow velocity up to

2 m/s. This conservative assumption provides the design criteria for the airport berm (Section 6).

The Cheakamus River would be blocked for a period of hours to days depending on the debris flow dam height and discharge of the Cheakamus River at the time of debris flow occurrence. Parts of the debris flow would be diluted by Cheakamus River water and would continue as a debris flood down the Cheakamus River to the Squamish River. Severe and sudden aggradation (several metres) could be expected along the lower Cheakamus River.

SCENARIO 2

Scenario 2 provides a simulation of a smaller debris flow event (see Table 3-1).

The model results, as shown in Figure 3-2, are similar to Scenario 1. As expected, a smaller area of the fan would be inundated by debris and the debris flow consequences at Brackendale would be considerably less. Specifically, the western sections of Brackendale (near Judd Slough) would likely be inundated by a thin layer of muddy water rather than direct debris impact. However, northern portions of Brackendale would still be affected by debris flow inundation up to 2 m depth with a flow velocity of less than 2 m/s. Waiwakum I.R. No. 14 and the Squamish Airport would likely not be impacted by the debris flow.

On the northern sector of the Cheekye Fan, the inundation would be comparable to Scenario 1, with a flow depth of up to 6 m and a velocity ranging from 2 m/s to 8 m/s. Damming of Cheakamus River would very likely occur at the Cheekye River – Cheakamus River confluence.

SCENARIO 3

Scenario 3 (Figure 3-3) provides a comparable simulation of an even smaller debris flow event with the approximate magnitude of the Garbage Dump debris flow (see Section 2). This event was modelled to replicate the last known large debris flow, and compare it with the largest flow that occurred in the last 10,000 years.

The model suggests that Brackendale would not likely be affected by direct debris flow impact. The area inundated by debris flows would be approximately half of that for the design debris flow of 7 million m^3. A large section of Highway 99 would still be inundated with debris but the debris is unlikely to reach developed areas, such as Government Road, the airport, the BC Railway, the Cheekye Substation or Waiwakum I.R. No. 14, except for some muddy water.

At least 50% of the debris flow would still reach the Cheakamus River and likely block it at the confluence with the Cheekye River. The consequence of this blockage would be similar as described for Scenario 1.

Although not modelled with a berm in place, the berm height required to protect Brackendale against the Scenario 3 debris flow would be significantly lower than for the 7 million m^3 design debris flow.

It is possible, although not likely, that the debris flow would remain confined to the upper channel without avulsing at the primary fan apex. This would require that obstructions created by log jams or debris levee deposition would be such that the debris flow is forced to follow the existing channel. This scenario is unlikely because:

- the existing cross-section upstream of the Highway 99 bridge provides insufficient conveyance to transport a debris flow without avulsion; and
- the Highway 99 bridge and road fill north of the bridge have created a very sharp channel bend which would tend to direct debris towards the south, and constrict the flow underneath the Highway bridge.

Alternatively, if the peak discharge of the 3 million m^3 debris flow is much lower than estimated, the debris flow would be more likely to remain confined to the existing channel. This scenario was not modelled as it provides a non-conservative alternative.

3.3 HAZARD ASSESSMENT WITH PROPOSED BERMS – SCENARIO 4

This scenario is based on Scenario 1 with the proposed deflection berms in place. The results are illustrated in Figure 3-4. This scenario assumes that the berms are high enough to intercept the debris flow material and only muddy water will flow into the Brackendale area at the Government Road crossing or at the BC Railway crossing.

The proposed berm would direct the debris flow lobes west towards the Squamish River. The berm would laterally confine the approaching debris, resulting in some super-elevation of debris along the berm. A flow depth ranging from 8 m for the uppermost berm to 4 m for the lowermost berm can be expected as shown on Figure 3-4.

The debris flow would then discharge into the Squamish River north of Waiwakum I.R. No. 14. As the debris flows steeply down to Squamish River, rapid retrogressive gullying could erode the BC Railway.

Section 4

Feasibility of Proposed Deflection Berm Scheme

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4. FEASIBILITY OF PROPOSED DEFLECTION BERM SCHEME

4.1 TRANSFER OF RISK

It is important that any mitigative scheme avoid risk transfer from one area to another, especially where this would affect a constructed facility. At the Cheekye Fan, risk transfer considerations potentially apply to the following local developments:

- development behind (south) the proposed berms;
- Cheekye Substation;
- Squamish Airport;
- Waikakum I.R. No. 14;
- other Reserve Lands; and
- scattered developments on the northern part of the fan.

Risk transfer may also apply to the following linear developments:

- Highway 99;
- BC Hydro transmission lines and towers;
- Government Road and other local roads; and
- BC Railway.

This section provides a brief discussion of risk transfer as it pertains to each of these facilities in view of the proposed deflection berm scheme and the debris flow modelling results of Section 3.

DEVELOPMENT BEHIND PROPOSED BERMS

Development behind the proposed berms will achieve a reduction in risk. Special consideration will need to be given at the design stage to the road and railway berm crossings to ensure that no localized increase in risk occurs in these locations.

There may be a need for floodproofing measures (elevation of buildings above ground level) for any future development behind the proposed berms.

CHEEKYE SUBSTATION

The substation is relatively well protected by the bedrock ridge to the east and the existing perimeter berm. The modelling does not indicate any increase to the substation, therefore no upgrading of the substation berm appears necessary as a result of the deflection berms being in place. Regular berm maintenance is recommended.

SQUAMISH AIRPORT

The scenario 1 model results show little debris deposition at the airport, and the risk to the existing facilities is relatively low. Only minimal risk transfer is indicated by the modelling, although a low berm would appear to be required with or without the proposed main deflection berm.

WAIWAKUM I.R. NO. 14

Waiwakum I.R. No. 14 is under the jurisdiction of the Squamish Nation, and is potentially of concern with respect to transfer of risk because it is located at the west end of the main berm. The modelling does not show any increase in risk at I.R. No. 14, provided that the deflection berm extends across the BC Railway to the Squamish River.

An increased measure of protection may be achieved for this area if the existing gravel pit in this area is used as a material source for berm construction. Enlarging the pit will effectively result in a debris basin, storing some of the debris flow material before discharging into the Squamish River.

OTHER RESERVE LANDS

Other Squamish Nation reserve lands in the vicinity of the Cheekye Fan include Cheakamus I.R. No. 11, Poquiosin and Skamain I.R. No. 13 and Seaicim I.R. No. 16.

Cheakamus I.R. No. 11 is located across the Cheakamus River from the mouth of the Cheekye River, and would not be subject to any risk transfer from the proposed deflection berms.

Poquiosin and Skamain I.R. No. 13 is an undeveloped reserve at the mouth of the Cheakamus River. The modelling does not show this reserve as being subject to an increase in risk as a result of the proposed deflection berms. In fact, any berms constructed to protect Squamish Airport may also protect I.R. No. 13.

Seaicim I.R. No. 16 is located at the south end of Brackendale, immediately inside the Squamish River dyke. This reserve is in a low hazard area with respect to the Cheekye River, but would be provided with an increased level of protection as a result of the proposed deflection berms.

DEVELOPMENT ON NORTHERN PART OF THE FAN

Scattered development on the north part of the fan will not be subject to transfer of risk, nor, however, will it be protected by the proposed deflection berm scheme.

Highway 99

The proposed deflection berms will protect the length of highway to the south of the main berm. The length of highway north of the berm will remain unprotected, but will not be subject to any transfer of risk as a result of the deflection berm scheme.

BC Hydro Transmission Lines

Several transmission lines cross the Cheekye Fan and are potentially subject to debris flow damage. The proposed deflection berms will protect those portions of the transmission lines south of the berm, but the outside transmission lines will remain unprotected. There is potential, because of increase in flow depth and flow velocity, for an increase in risk to transmission towers immediately to the north of the proposed berm. This may necessitate some protective measures at specific towers (i.e. such as rock berms or concrete walls around the tower bases).

Government Road and Other Local Roads

Roads south of the proposed main berm will be protected, and those north of the berm will remain at risk. While there may be an increase in risk for a short section of Government Road immediately north of the main berm, overall there will be a significant reduction in risk to the local road network.

BC Railway

The proposed deflection berms will protect the part of the BC Railway located south of the berm. There will be a localized increase in risks immediately to the north of the berm crossing. Overall, however, the risk to the railway will not be changed significantly by the deflection berms.

Municipal Infrastructure

The following District infrastructure will remain outside of the proposed deflection berms:

- Alice Lake reservoir and associated watermains; and
- sanitary landfill on Squamish Valley Road.

Although these facilities will not be protected, they will not be subject to any significant transfer of risk. No other major infrastructure is affected by risk transfer.

Squamish River

The proposed main berm will result in an increase in debris discharge to the Squamish River. Direct discharge to the river could be decreased somewhat by locating the Waiwakum berm section as far north as possible, thereby discharging overflow to gravel bars of the lower Cheakamus River rather than the active channel of the Squamish River.

Significant discharge to the Squamish River could cause a partial river blockage, increasing flow around the west side of Baynes Island. This could also result in a surge flood down the Squamish River. Significant aggradiation and sedimentation of the lower Squamish River would occur.

4.2 FEASIBILITY ASSESSMENT

For the design debris flow, the deflection berm concept is considered feasible to protect the residential area of Brackendale as an area wide hazard mitigation with no significant transfer of risk to other facilities.

Increased risk to short sections of linear developments such as the BC Railway and the BC Hydro transmission lines is neutralized by risk reduction to other sections of the corresponding corridors.

The berms will need to be large to prevent overtopping during the design event. For example, the height of the main deflection berm would need to be about 7 m. Therefore, while the deflection berm concept is considered feasible from a transfer of risk perspective, the extensive work required will result in a high construction cost. This is discussed further in Section 6. In addition it will be necessary either to regrade Highway 99 to allow it to cross the berm on an embankment, or alternatively, allow for culverts through the berm. Either way, considerable extra costs are involved. Dryden Creek will also require a crossing through the deflection berm.

Section 5

Design Criteria

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5. DESIGN CRITERIA

5.1 CREST ELEVATION

The crest elevation for the deflection berms can be based on the flow depth of the design debris flow, plus an allowance for superelevation and run-up. No additional freeboard would be required in this situation.

5.2 DESIGN CROSS-SECTION

The proposed typical cross-section design criteria for the Cheekye Fan deflection berms are summarized in Table 5-1.

Table 5-1
Typical Deflection Berm Design Criteria

Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Crest Width:	5 m
Crest Surface:	3.0 m wide / road mulch
Upstream Face Surface:	Riprap
Downstream Face Surface:	Landscaped

The riprap size will differ for the various berm sections on the basis of the debris flow velocity at that location. The riprap will require a toe trench for protection against scour by flowing water and debris. If the design debris flow force exceeds the ability of the riprap to withstand erosion at any location, site-specific grouting of the lower riprap slope may be necessary.

5.3 GEOTECHNICAL CONSIDERATIONS

The geotechnical investigation completed for this preliminary design report is included in Appendix A and provides a basis for establishing the geotechnical design criteria for the deflection berms.

The foundation conditions for the main berm are excellent. Little excavation of topsoil will be necessary. The thin topsoil layer should be stripped, followed by proof rolling of the foundation sands and gravels using a vibratory compactor.

Loose, saturated, silty sand is absent so liquefaction failure of the berm will not occur. The berm should be constructed of well-graded, sand and gravel compacted in lifts to achieve a dense structural fill. The proposed berm side slopes are as shown in Table 5-1, and the uphill face will incorporate a 1 m thick zone of riprap keyed in at the toe. With these conditions, sliding wedge stability analyses were carried out assuming friction angles of 35° and 45° for the foundation soils and berm fill respectively, and zero cohesion.

Factors of safety for the steeper uphill slope of the berm were calculated to be 3.6 for deep-seated failure surfaces through the foundation soils and 2.4 for shallow failures through the compacted berm fill. On the flatter downhill side of the berm the factor of safety against surficial slips, the most critical condition, is not less than 2.0.

Should a debris flow occur and temporary ponding of floodwater take place on the uphill side of the berm, the margin of stability during drawdown conditions will still be adequate.

Appendix A notes that debris flow deposits (Hdf) and flood deposits (Hf) occur at different locations along the berm alignment. The flood deposits are associated with the Squamish River and consist of clean sand and gravel that is suitable for berm construction. The debris flow deposits are associated with the Cheekye River and consist of more silty sand and gravel. While the latter could be used for berm construction, the materials would be more sensitive to placement moisture conditions and would be more difficult to compact in wet weather. As a result, some restrictions on placement and compaction in wet weather could apply to construction. Such restrictions would have to be weighed against increased haul distance for imported material as it relates to cost efficiency. It would be appropriate to involve a contractor in these discussions.

5.4 LINEAR CORRIDOR CROSSINGS

The preferred approach to design of linear corridor crossing is based on partial elevation of the Highway 99 and Government Road crossings over or through the main berm. This will minimize debris and/or floodwater inflow to the developed area. It is understood that future development behind the berm will involve elevating buildings 0.6 m above the surrounding grade, which would make minor inflow tolerable.

As the design is finalized, opportunities may arise to reconsider the highway and road crossings, provided that the resulting risk to the developed area is judged to be acceptable.

The main berm passes under the transmission line, and modifications to the transmission line will be necessary in order to maintain adequate clearance between the berm crest and the conductor cables.

5.5 DRAINAGE

Provision should be made for appropriate routing of drainage from storm runoff.

Drainage in the vicinity of the upper main berm should be routed to Dryden Creek where the grade is favourable.

Drainage along the main berm should be routed west along the main berm toward Squamish River. This may involve culverts at Government Road and the BC Railway. This drainage concept is consistent with the District's Brackendale Master Drainage Plan. The alternative would be to place culverts through the main berm and allow drainage flow into Brackendale. However, this would necessitate pumping of such flows, which may be problematic since the existing drainage pumps have limited capacity.

5.6 HIGHWAY AND ROAD DESIGN CRITERIA

The design criteria for regrading of Highway 99 and local roads is based on current Ministry of Transportation highway design criteria, as summarized below:

Table 5-2
Design Criteria

Road	Design Speed km/hr[2]	Minimum Length Sag Curve	Minimum Length Crest Curve
Highway 99[1]	110	55	150
Government Road at Main Berm	60	17	18
Government Road at Airport Berm	60	17	18

Notes:
1. Minimum 600 m radius of curvature.
2. Posted speed – 10 km/hr. less than design speed.

The proposed cross-section of Highway 99 will reflect the existing cross-section providing for two 3.7 m wide north bound lanes and one 3.7 m wide south bound lane each with a paved shoulder.

Section 6

Preliminary Design

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6. PRELIMINARY DESIGN

Figure 6-1 illustrates the updated deflection berm design concept. This incorporates minor changes to the berm alignments compared to the original concept proposed by the District and MWLAP. The preliminary design drawings are presented in Appendix E and are summarized as follows:

KWL preliminary design drawings No. 463-104:

Sheet	Drawing	Drawing Title/Description
1	G1	Location Map, Area Plan and Index to Drawings
2	R1	Highway 99 Realignment and Regrade – Sheet 1
3	R2	Highway 99 Realignment and Regrade – Sheet 2
4	SW1	Main and Upper Main Deflection Berms – Sheet 1
5	SW2	Waiwakum, Lower Main and Main Berms – Sheet 2
6	SW3	Airport Berms and Government Road Regrades
7	SW4	Typical Berm Sections

The base plan source information upon which the preliminary design is created is summarized as follows:

- legal property lines created by KWL from information provided by District of Squamish (the legal lines are approximately only and do not fully correlate with the aerial mapping);
- topographic mapping provided by McElhanney Consulting Ltd.;
- photographic image provided by MWLAP;
- field survey by KWL for the main berm between Ross Road and the highway; and
- legal ties for the KWL survey for the main berm based on legal plans and found legal evidence at Ross Road.

This section describes the preliminary design for each berm section.

6.1 UPPER MAIN BERM

The upper main berm starts at high ground about 700 m south of the Squamish Valley Road intersection with Highway 99. The berm crosses Dryden Creek and Highway 99, then runs south for about 400 m where it joins the main berm. The orientation of the upper main berm serves to deflect debris to the west and minimizes debris flow passage down the highway. The berm would be 12 m high above existing ground east of the highway, reducing to 8 m above existing highway elevation as it runs south along the highway.

The physical characteristics of the upper main berm are summarized as follows:

Length	300 m (approx.)
Height	8 m to 12 m
Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Base Width:	35 m to 49 m
Crest Width (off highway):	5 m
Upstream Face Surface:	heavy riprap
Downstream Face Surface:	landscaped

Key design considerations for the upper main berm are identified as follows:

- the proposed upstream tie-in location is within a disturbed area (former quarry site), resulting in less tree removal;
- the upper berm crosses Dryden Creek, necessitating a crossing to allow the creek to pass through the berm, but prevent significant debris flow material from passing through the berm;
- the proposed Dryden Creek crossing is a corrugated steel arch culvert sized for 20 m^3/s flow capacity and includes a gravel base (the design flow is approximately twice the Dryden Creek Q_{200}, 200-year return period flood flow), and
- environmental issues associated with Dryden Creek dictate avoiding construction between Highway 99 and Dryden Creek (refer to Section 7.4).

Issues associated with the highway crossing are identified in Section 6.2.

6.2 HIGHWAY CROSSING

The original concept involved a highway relocation, incorporating a mild S-bend. In view of the high cost and implementation issues associated with the highway relocation, berm alternatives that do not necessitate a highway relocation have been reviewed. It has been concluded that it is feasible to retain the existing highway alignment, but considerable regrading of the highway will be required.

The proposed regrading provides for raising the highway up and over the main berm; the grade change at the berm crossing location would be about 8 m above the existing highway elevation.

Ministry of Transportation staff were consulted during the preliminary design phase and commented as follows:

- there is no objection to the highway regrading as long as the applicable highway design criteria are followed;
- the design should accommodate ultimate widening of the highway to three or four lanes in this area; and
- there is no commitment on behalf of the Ministry to pay for the highway work.

The concept for the regraded highway crossing is summarized as follows:

- the existing highway grade between Squamish Valley Road and Depot Road varies between about 2% and 6%;
- the design should provide for a design speed of up to 110 km/hr.;
- the vertical realignment of the highway over the berm is based on providing the preliminary design speed crest curve K factor of 150 and sag curve K factor of 55;
- to meet this design criteria, road regrading may extend about 700 m north of the main berm crossing and about 1,000 m south of the crossing;
- the maximum approach grade to the main berm from the south will be +6% to +8%, and the transition grade north of the berm will be +2% to +5%;
- the design provides for maintaining the existing east highway shoulder and constructing the new highway to the west; and
- the highway regrading is not expected to impact existing utilities.

This provides the basis for preliminary design for regrading the highway over the berm. Notwithstanding this, there are some other possible alternatives for the highway crossing that are identified in Section 7.

6.3 MAIN BERM

The main berm extends from Highway 99 to the BC Railway. The section between Government Road and the BC Railway is referred to as the lower main berm. The main berm would be approximately 7.5 m high over its entire length. The lower main berm would be about 6 m high.

A typical design cross-section for the main berm is shown in Figure 6-2.

The physical characteristics of the main berm are summarized as follows:

Length:	1,440 m (approx.)
Height:	7.5 m
Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Base Width:	34 m (approx.)
Crest Width:	5 m
Upstream Face Surface:	Riprap
Downstream Face Surface:	Landscaped

The physical characteristics of the Lower Main Berm are summarized as follows:

Length:	280 m (approx.)
Height:	6 m
Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Base Width:	28 m
Crest Width:	5 m
Upstream Face Surface:	Riprap
Downstream Face Surface:	Landscaped

Key design considerations for the berm are identified as follows:

- the alignment provides for clearing a right-of-way about 50 m wide in second growth forest, an area of about 9.2 ha;
- there are some environmental issues associated with the tree removal (these are addressed in Section 7.4);
- the berm crosses under four BC Hydro high voltage transmission lines, three near Highway 99 and one adjacent to the BC Railway, for which clearance will be a design constraint;

- at Government Road, the berm is interrupted, with the road regraded over about 350 m in this location to create an elevation increase of about 3.5 m at the berm opening;
- at the BC Railway, the berm swings to the north to deflect debris away from Waiwakum I.R. No. 14, and away from the active Squamish River channel; and
- special construction techniques may be required where the berm crosses a watermain near the east BC Hydro right-of-way.

This provides the basis for preliminary design of the main berm and lower main berm.

6.4 WAIWAKUM BERM

The Waiwakum berm is an extension of the lower main berm west of the BC Railway to deflect debris away from Waiwakum I.R. No. 14. The berm parallels the BC Railway for about 400 m, providing an overlap with the downstream end of the lower main berm. Between the two berm sections will be a small gap through which only very minor quantities of mud and floodwater could escape. Special consideration will need to be given to any impact of berm construction on the railway.

Associated with construction of this berm is the proposed extension of the existing Squamish River dyke to tie with the Waiwakum berm, as well as some bank protection works at the point where debris would enter the Squamish River.

The physical characteristics of the proposed Waiwakum berm are summarized as follows:

Length:	500 m (approx.)
Height:	4.5 m
Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Base Width:	23 m (approx.)
Crest Width:	5 m
Upstream Face Surface:	Riprap
Downstream Face Surface:	Landscaped

6.5 AIRPORT BERM

A berm up to about 3.0 m high is needed at the airport. The original concept involved a berm on the airport (west) side of Government Road. This would necessitate relocation of the airport access road.

Following discussion with the District, for preliminary design purposes, a two-part berm is proposed, with one section located on the east side of Government Road and the other located west of Government Road and wrapping 90 degrees around the corner of the airport property.

Construction of the berm is not expected to have any significant impact on existing utilities.

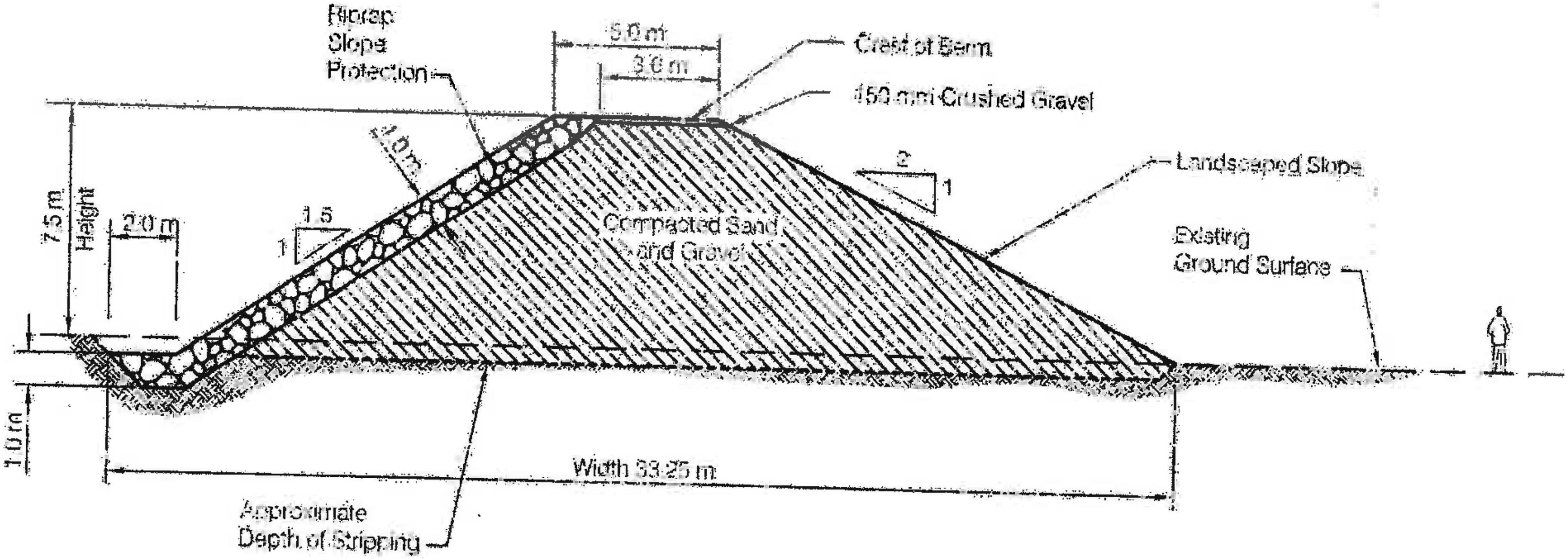
A typical design cross-section for the airport berm is shown in Figure 6-3.

The physical characteristics of the proposed airport berm are summarized as follows:

Length:	750 m (approx.)
Height:	3 m
Slope of Upstream Face:	1.5:1 H:V
Slope of Downstream Face:	2:1 H:V
Base Width:	17.5 m
Crest Width:	5 m
Upstream Face Surface:	Riprap
Downstream Face Surface:	Landscaped

6.6 SUBSTATION BERM

The existing perimeter berm at the Cheekye Substation appears to be high enough for flood and debris flow protection. There is no transfer of risk to the substation berm as a result of the proposed deflection berms. Therefore, no modifications to the existing berm are proposed. Regular maintenance of the substation berm is recommended.



KERR WOOD LEIDAL
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District of Squamish
Preliminary Design Report for Cheekye Fan Deflection Berms

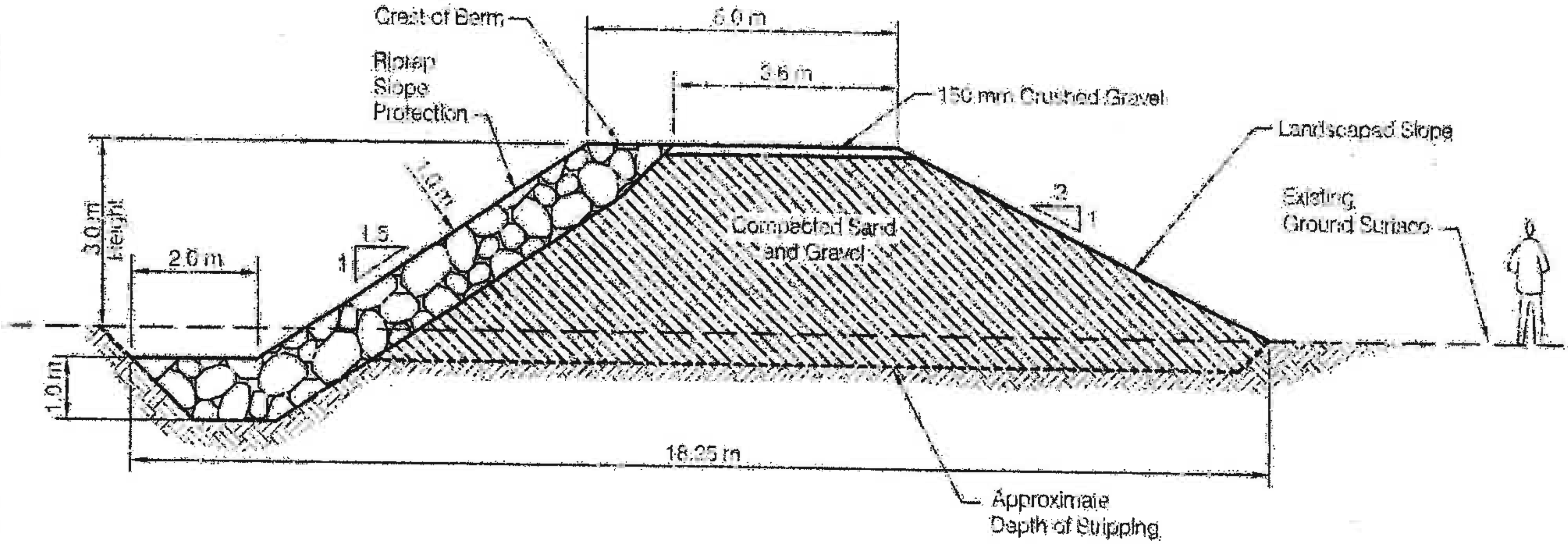
Project No.	Date
463-104	June 2003

5 0 5
Scale in Metres

Typical Main Berm Section

Figure 6-2

463-10\0\Drawings\463104Fig6-3.dwg Jun 17/03



KERR WOOD LEIDAL associates limited CONSULTING ENGINEERS		District of Squamish Preliminary Design Report for Cheekye Fan Deflection Berms
Project No. 463-104	Date June 2003	**Typical Airport Berm Section**
2.5 0 2.5 Scale in Metres		**Figure 6-3**

Section 7

Implementation Considerations

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7. IMPLEMENTATION CONSIDERATIONS

7.1 CONSTRUCTION COST ESTIMATES

Preliminary construction cost estimates for the various berm sections are presented in Appendix B, and are summarized as follows:

Berm Section	Construction Cost Estimate	
	Low Scenario	High Scenario
Upper Main Berm	$7,837,000	$13,393,000
Main Berm	$3,438,000	$5,877,000
Lower Berm	$563,000	$936,000
Waiwakum Berm	$953,000	$1,408,000
Airport Berm	$808,000	$1,099,000
Total	**$13,599,000**	**$22,713,000**

Two cost scenarios are presented. The high cost is based on the current market price of pit run gravel berm core material at $15.00 per cubic metre. The lower cost scenario is based on a more economical supply of berm core material from local excavations or river sources at $5.00 per cubic metre.

The capital cost estimates include the following:

- the upper main berm cost includes the highway regrading cost and an allowance for environmental compensation;
- the main berm cost includes an allowance to raise the BC Hydro overhead power lines and the cost to regrade Government Road at Ross Road;
- the lower main berm cost includes an allowance to regrade the single overhead power line;
- the Waiwakum berm cost includes construction costs of the dyke and river bank protection works;
- the airport berm cost includes the cost to regrade Government Road at the airport; and
- the costs include 10% engineering, 15% contingency, and 7% GST.

BC Hydro have reviewed the costs to design and construct tower and cable modifications to accommodate clearance requirements to the proposed Main Berm. Their letter of March 4, 2003 that addresses this cost is presented in Appendix C.

7.2 STAKEHOLDER CONSULTATION

The primary stakeholders for this project are the Ministry of Transportation, Land and Water BC, the Squamish Nation and BC Hydro. Some discussions have occurred with these parties during the preliminary design work. Further discussions will be necessary prior to detailed design. Additional stakeholders should also be identified and consulted.

7.3 PHASING OPPORTUNITIES

Construction of the main berm could be staged, but to avoid an interim transfer of risk, it would be necessary to commence work at the downstream end. This would involve construction of the Waiwakum berm first, followed by the main berm and upper berm.

7.4 ENVIRONMENTAL ISSUES

Preliminary design has involved an initial environmental review. The environmental report is included in Appendix D.

The most significant environmental issue is the main berm crossing of Dryden Creek. The associated environmental issues are removal of riparian vegetation and instream construction which will necessitate some compensatory work.

Clearing for the various berm sections could result in some wildlife impacts, such as removal of raptor nesting trees. The environmental report includes some recommendations in this regard.

7.5 MATERIAL SUPPLY SOURCES

The project will require large quantities of berm fill and rock riprap.

Some of the berm construction material could come from excavation and levelling for a proposed golf course in this vicinity. Any excavation on the uphill side of the berm enhances the potential for deposition and storage of debris flow material, provided that the site grading is performed in an appropriate manner.

The existing gravel pit area on the north side of the lower main berm would be an ideal fill source for the berms. Excavation of fill from this area would have the added benefit of providing a debris storage area.

The existing garbage dump area represents a much less desirable fill source due to the high silt content of the soil in this area.

Economical fill sources may also arise from the ongoing Highway 99 upgrading.

7.6 OTHER DESIGN CONCEPTS

In the course of this study, some alternative concepts for debris flow management and berm construction have been identified. These alternatives will not affect the alignment of the main berm and are presented as follows.

HIGHWAY UNDERPASS CULVERT

As an alternative to raising the grade of Highway 99 to pass over the berm, consideration has been given to keeping the highway near the current grade level and passing through the main berm in large culverts. This concept is shown on Figure 7-1. It is not possible to pass three lanes through the berm in a single culvert because of size limitation with metal plate culverts. The maximum span is limited to 15.2 m, whereas three lanes of 3.7 m each and 3 m shoulders requires 16.7 m width of roadway. Alternatives such as semi-circular Tech-Span concrete culverts would be too high. Figure 7-1 therefore shows two culverts allowing for two lanes each way. These culverts would be 13.4 m span each, and the height would be close to the berm height of 8 m.

Final designs would require debris flow modelling to assess the quantity of debris that might pass through the culverts. Depending on the results of such an analysis, a low downstream berm might be needed on the west flank of the highway in order to prevent debris flowing into development south of the main berm. There is a tendency for culverts to plug during debris flow, mainly because they either jam with large woody debris or structural collapse takes place. It might be appropriate to deliberately design the culverts to favour structural collapse by extending the uphill mouth of the metal plate arch to protrude beyond the earth fill of the main berm.

As a variation of the highway culvert concept, enhanced debris containment may be achieved by constructing two parallel concrete retaining headwalls and a *portcullis* type of gate on the north end of the underpass. This would involve an automatic closure that would be triggered by an event and would reduce the amount of debris that could pass through the highway opening.

CUT-OFF BERMS AND CONTAINMENT BASIN

To minimize the extent of highway regrading and maintain the existing highway alignment, the main berm could be supplemented with secondary cut-off berms south of the main berm as shown on Figure 7-2. This would result in a gap being left in the main berm crossing at Highway 99, and any flow through the gap being intercepted in a constructed basin downstream. Some degree of highway regrading would also be necessary, but this would be less than for the original concept. Construction of the catchment basin would be very favourable in view of existing topographic features. A berm / barrier crossing of lower Dryden Creek would also be necessary.

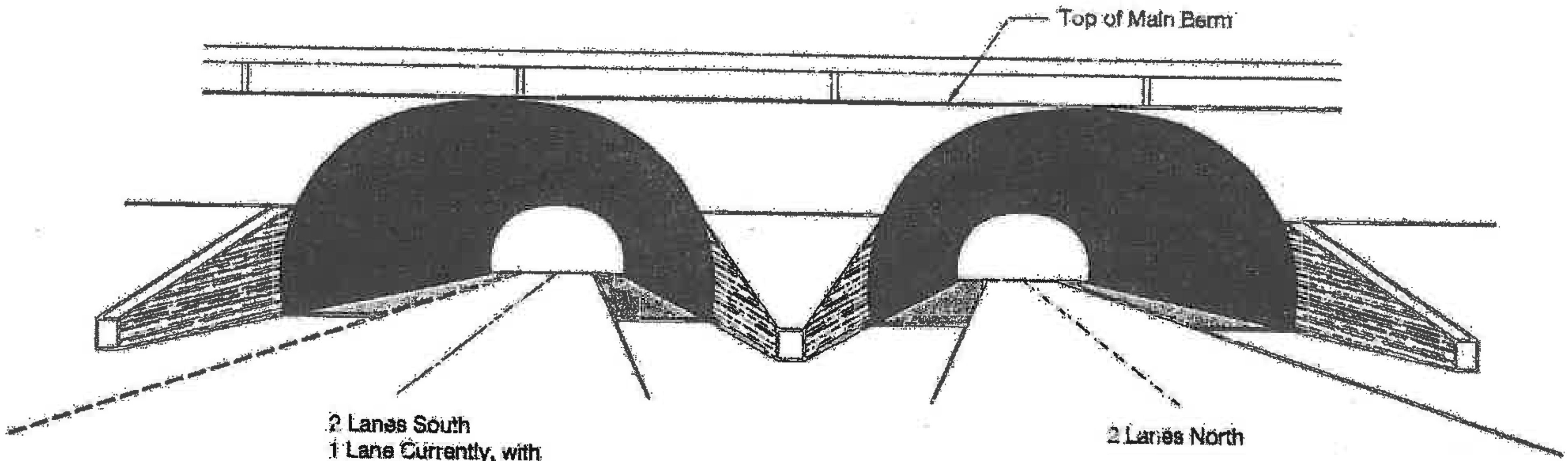
ROLLER COMPACTED CONCRETE BERM ALTERNATIVE

As an alternative to compacted sand and gravel for the berm construction, roller compacted concrete (RCC) could be used. This would involve a much smaller cross-section of about 60 m^2 using a 3.6 m wide crest and 0.7:1 H:V side downhill slope and 0.3:1 H:V uphill slope. RCC is used extensively in dam construction. It is also used extensively in B.C. for log sorts. It utilizes "dirty" sand and gravel with a low cement content and the material is placed as a dry mix, spread by dozer in layers and compacted with vibratory rollers. The requirements for impermeability and strength for berm construction would be less stringent than for water retention dam construction. The French variation, known as hardfill, uses a cement content of about 50 kg/m^3. Use of such RCC, or hardfill would have the advantage of being erosion resistant so that the upstream riprap slope protection could be eliminated, resulting in an appreciable cost saving. The steep uphill face of the berm would also minimize debris flow run-up.

The cost of a RCC berm could be as low as $1 million per kilometre run of a 7 m high berm.

Further consideration could be given to these alternatives prior to a final choice being made.

463-104\Drawings\463104Fig7-1.dwg Jun 17/03



NOTE:

1. Highway 99 to remain near existing grade.
2. Highway assumed rebuilt to 4 lanes.
3. Corrugated steel plate culverts 13.37 m span by 6.88 m rise (area of opening 55 sq. m).

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Concept for Culvert Openings for Main Berm Crossing of Highway 99

Figure 7-1

Section 8

Summary

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8. SUMMARY

The key findings of this report are summarized as follows:

HAZARD MAGNITUDE

1. The specified design event volume of 7 million m³ appears to be overly conservative on the basis of recent research. A value of about 5.4 million m³ may be a more appropriate volume of the largest debris flow to occur in the last 10,000 years.

2. The largest debris flow to occur in the last 10,000 years may have a return period that exceeds 10,000 years.

3. The previous estimate of design debris flow discharge of 1,700 m³/s is considered far too low. A value of 15,000 m³/s is more appropriate for a debris flow of 5.4 million m³ volume.

4. For the purpose of this study, the design debris flow magnitude has been specified as a volume of 7 million m³, along with a peak discharge of 15,000 m³/s by MWLAP.

DEFLECTION BERM CONCEPT

5. For the purpose of this study, a deflection berm concept was proposed by MWLAP and the District (Figure 1-3).

6. The deflection berm concept has been refined on the basis of the investigations undertaken for this project (Figure 6-1).

DEBRIS FLOW MODELLING

7. Debris flow modelling with FLO-2D provides a basis for assessing the effectiveness of the proposed deflection berm scheme, identifying transfer of risk issues, and providing preliminary berm heights for the 7 million m³ design debris flow.

8. Based on the modelling results, the proposed deflection berm scheme is considered feasible for protecting the Brackendale area with no significant transfer of risk, provided that appropriate design considerations are applied.

PRELIMINARY DESIGN FOR DEFLECTION BERM CONCEPT

9. The upper main berm would be about 12 m high east of the highway, reducing to about 8 m along the highway. A key design consideration is the need for a large culvert where Dryden Creek crosses the berm. It will also be necessary to maintain an appropriate riparian corridor along Dryden Creek.

10. Raising Highway 99 over the main berm would involve a significant highway regrading extending nearly from Squamish Valley Road to Depot Road.

11. The main berm would be about 7.5 m high and the lower main berm about 6.0 m high. A key design consideration is the need to provide sufficient clearance between the berm crest and overhead BC Hydro high voltage transmission lines. This will necessitate modifications to the transmission line system.

12. Special design considerations will be required at each of the linear development crossings of the main berm (Highway 99, watermain, powerlines, Government Road, BC Railway).

13. The Waiwakum berm should be kept as far north as reasonably possible in order to avoid land use conflicts on I.R. No. 14, and to avoid directing debris directly into the Squamish River. This berm should connect with the existing Squamish River dyke at the downstream end in order to provide continuous protection. Protection of an unstable river bank at the point of discharge will also likely be necessary.

14. A relatively low berm that is about 3.0 m high will be sufficient to protect the Squamish Airport.

15. The existing berms at the Cheekye Substation do not appear to warrant upgrading as a result of the proposed deflection berms.

CONSTRUCTION COST ESTIMATES

16. Preliminary cost estimates for the various berm sections are summarized as follows:

Berm Section	Construction Cost Estimate	
	Low Scenario	High Scenario
Upper Main Berm	$7,837,000	$13,393,000
Main Berm	$3,438,000	$5,877,000
Lower Berm	$563,000	$936,000
Waiwakum Berm	$953,000	$1,408,000
Airport Berm	$808,000	$1,099,000
Total	**$13,599,000**	**$22,713,000**

These costs reflect high and low cost scenarios based on possible price variations for berm core gravel. The high cost is based on $15.00 per cubic metre gravel if purchased from a commercial pit and the low scenario based on $5.00 per cubic metre if the material is supplied as a disposal item for excavations in the general area.

17. The high cost of the project is reflected in three key issues:

- the very large size of the various berm sections resulting from such an extreme design event;
- the significant amount of highway regrading required; and
- the need to regrade the overhead hydro transmission lines.

18. The construction cost could tend toward the low scenario if an economical fill supply source can be identified.

19. The construction cost could also be reduced if the debris flow design criteria is reduced below the 10,000-year return period (as a result of smaller berms).

IMPLEMENTATION CONSIDERATIONS

20. Further consultation with the key stakeholders will be necessary prior to detailed design of mitigative measures.

21. Construction of the main berm could be staged, but work would need to start from the downstream (Waiwakum) end.

22. Environmental issues associated with the deflection berm concept have been identified. The main berm crossing of Dryden Creek is the primary issue. Wildlife (raptor) use associated with tree removal is another issue.

REPORT SUBMISSION

Prepared by:

KERR WOOD LEIDAL ASSOCIATES LTD.

Matthias Jakob, Ph.D., P.Geo.
Senior Geoscientist

Ken Ferraby, P.Eng.
Senior Design Engineer

Reviewed by:

Mike V. Currie, M.Eng., P.Eng.
Project Manager

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Appendix A

Geotechnical Investigation

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1. SITE INVESTIGATION

In order to investigate foundation conditions for the proposed main berm, test pits were excavated, soil strata logged and samples taken for sieve analyses. Exposures of sand and gravel formations were also inspected in the garbage dump cuts and in the large borrow pit alongside the BC Railway west of Government Road south of the airport.

KWL carried out test pitting along the alignment of the main berm between Highway 99 and Government Road on January 22 and 23, 2003. A total of 8 test pits TP-1 to TP-8 were excavated to depths varying between 1.9 m and 3.3 m below the existing ground surface. The location of the test pits are shown on the preliminary design drawings (Appendix D).

The test pits were excavated using a small hydraulic excavator (Cat 304.5) was hired from MacDonald Trucking Ltd., in West Vancouver.

On the first day of test pitting, approximately 20 cm of snow had fallen during the morning and prior to the work, and it rained in the afternoon. There was intermittent rain during the second day of test pitting, and very little snow remained from the previous day. The wet weather during the test pitting program was preceded by a relatively dry period.

Logging of test pits was conducted by David Matsubara, P.Eng. under the direction of Nigel Skermer, P.Eng., Geotechnical Engineer.

The test pit logs are as follows:

TP-1
Near the intersection of Ross Road and Government Road within the proposed main berm footprint

Depth (m)	Description
0.0 to 0.15	Black ORGANIC soil with roots
0.15 to 0.55	Poorly graded, brown, loose, fine to coarse SAND with some cobbles and boulders in the matrix. Slightly moist.
0.55 to 1.20	Loose, brown, fine to coarse SILTY SAND with some gravel and cobbles. Moist. Sample taken at 0.55 m
1.20 to 1.80	Poorly graded, compact GRAVELLY SAND with some cobbles and boulders. Boulders and cobbles angular to rounded.
1.80 to 2.45	Buried root layer observed at 1.8 m. Poorly graded, grey, compact SILTY SAND with some gravel, cobbles and boulders. No water encountered in the test pit. Sample taken at 2.45 m – end of test pit.

TP-2
Opposite to school on Ross Road within the proposed main berm footprint

Depth (m)	Description
0.0 to 0.20	Black ORGANIC soil with roots
0.20 to 1.0	Brown, loose to compact, SILTY SAND. Distinct root layer seen at 0.6 m depth.
1.0 to 1.60	Poorly graded, light brown SILTY SAND with some gravel and cobbles.
1.60 to 2.0	Poorly graded, grey, compact GRAVELLY SAND with some cobbles and boulders – generally rounded to subrounded (diameter up to 200 mm). Sample taken at 1.5 m.
2.0 to 2.30	Poorly graded, grey, compact SILTY SAND and boulders and cobbles (diameter up to 300 mm). No water encountered in the test pit. End of test pit at 2.3 m.

TP-3
East of school on Ross Road within the proposed main berm footprint

Depth (m)	Description
0.0 to 0.20	Black ORGANIC soil with roots
0.20 to 0.9	Brown, loose to compact SILTY SAND with some gravel, slightly cohesive.
0.9 to 1.1	Thin seam of brown, slightly cohesive, compact SILTY SAND.
0.9 to 2.1	Grey, loose to compact SAND with cobbles and boulders – angular to rounded. Sample taken at 1.8 m.
2.1 to 2.3	Compact, slightly cohesive, SILTY SAND with cobbles and boulders. Sample taken at 2.1 m. No water encountered in the test pit. End of test pit at 2.3 m.

TP-4
East of bend in Ross Road within proposed main berm footprint

Depth (m)	Description
0.0 to 0.30	Black ORGANIC soil with roots
0.30 to 1.1	Brown, loose, coarse SAND with some silt and/or fine sand. Sample taken at 1.1 m.
1.1 to 2.1	Poorly graded, brown, moderately compact, coarse, SAND with some silt and/or fine sand and gravel with generally rounded to subrounded cobbles and boulders (> 600 mm dia.). Sample taken at 1.65 m.
2.1 to 2.8	Poorly graded, compact, coarse, GRAVELLY SAND with cobbles and boulders (> 600 mm dia.). More resistant to digging than upper strata. No water encountered in the test pit. End of test pit at 2.8 m.

TP-5
Between Ross Road and the BC Hydro Right-of-Way along main berm centreline

Depth (m)	Description
0.0 to 0.10	Black ORGANIC soil with roots.
0.10 to 1.0	Loose, brown, coarse SAND with some silt with rounded cobbles and boulders.
1.0 to 1.2	Compact to dense, grey, well graded SANDY GRAVEL with cobbles and boulders. Sample taken at 1.2 m.
1.2 to 1.9	Compact to dense, grey, well graded SANDY GRAVEL and cobbles and boulders. Difficult to advance the hole with available machine. No water encountered in the test pit. Sample taken at 1.8 m. End of test pit at 1.9 m.

TP-6
East of BC Hydro right-of-way along berm centreline

Depth (m)	Description
0.0 to 0.10	Black ORGANIC soil with roots. Boulders visible on ground surface
0.10 to 0.6	Very loose, brown, poorly graded, very well drained, coarse SILTY SAND with rounded cobbles and boulders and some gravel.
0.6 to 1.3	Compact, brown SANDY GRAVEL with cobbles and boulders – angular to rounded. Sample taken at 0.7 m. Steady seepage first noted at 1.1 m.
1.3 to 2.7	Compact grey SANDY GRAVEL with cobbles and boulders and a trace of silt. Steady seepage noted at various points in the test pit at 1.9 m. No water encountered in the test pit. Sample taken at 1.3 m. End of test pit at 2.7 m.

TP-7
Between BC Hydro Right-of-Way and Highway 99 along berm centreline

Depth (m)	Description
0.0 to 0.10	Very thin black ORGANIC soil with roots.
0.10 to 0.15	Very thin seams, white, CLAYEY SILT (possibly wood or volcanic ash).
0.15 to 1.1	Loose, brown, poorly graded, coarse SILTY SAND with cobbles and small boulders (up to 300 mm diameter) and some gravel. Sample taken at 0.5 m.
1.1 to 1.6	Compact, grey SANDY GRAVEL with a trace of cobbles. Sample taken at 1.75 m. High seepage first noted at 1.1 m.
1.6 to 2.6	Thin root layer at 1.6 m. Brown, compact SANDY GRAVEL with occasional boulders and some cobbles – rounded to sub-rounded. Seepage at 1.5 to 1.6 m. Sample taken at 2.4 m
2.6 to 3.3	Loose to moderately compact, fine SILTY SAND (60 – 70%) with cobbles and boulders (30 to 40%). High water content. Sample taken at 3.3 m. No water encountered in the test pit. End of test pit at 3.3 m.

TP-8
West of Highway 99 along berm centreline

Depth (m)	Description
0.0 to 0.20	Black ORGANIC soil with roots.
0.20 to 0.60	Dark brown, loose, fine to coarse SAND. Sample taken at 0.3 m.
0.6 to 0.9	Light brown, loose to compact GRAVELLY SAND with some cohesive silt. Approximately 10 % boulders (200 to 900 mm dia.) - sub-rounded to sub-angular. Sample taken at 0.75 m.
0.9 to 1.1	Clean dense uniform fine sand. Root layer at 1.1 m (Sample taken of roots)
1.1 to 2.8	Grey, compact SANDY GRAVEL, with large boulders near the 1.1 m and near 2.5 m. Some cobbles and boulders in matrix. No water encountered in the test pit. Sample taken at 2.4 m. End of test pit at 2.8 m.

In general, the soil conditions are found to be quite uniform. A thin 0.15 – 0.30 m thick layer of organic topsoil is underlain by silty sand or silty sand and gravel with cobbles and small boulders in places. The gradation of the subsurface soils varies in places from gravelly sands to sandy gravels, but overall conditions are quite uniform. The uppermost 0.5 m to 1.0 m of silty sand is loose, below which the soils become compact and in local zones even dense. Occasional larger boulders were encountered (eg., TP-8). No standing water was encountered in any of the test pits.

2. LABORATORY TESTING

A total of 11 samples of soil from different test pits was sent to Metro Testing Laboratories in Burnaby for grain size analysis. Sieve tests were carried out on washed samples generally below 50 mm (2 in.) maximum particle size. The results of tests are shown as the attached grain size curves.

The results indicate generally well-graded soils with the following ranges of particle size:

- Gravel 30 – 80%
- Sand 20 – 65%
- Silt 1 – 25%

3. PREVIOUS TEST PITS BY OTHERS

The previous test pits from the 1991 Thurber-Golder study were also reviewed. The relevant Thurber-Golder test pits are shown on their Figure 3-4, and listed as follows:

- 91-53
- 91-6
- 91-23

- 91-16
- 91-61

These tests were excavated to depths ranging between 0.8 m and 3.0 m. The descriptions are written in terms of geomorphic processes (i.e. fluvial, colluvial, or glacial), but nevertheless confirm the presence of silty sand and gravel in all test pits. Figure 3-4 in the Thurber-Golder report also differentiates between debris flow deposits (Hdf) and flood deposits (Hf). Relevant to this study debris flow deposits were mapped east of Government Road close to the junction with Ross Road, while flood deposits are mapped west of Government Road.

METRO TESTING LABORATORIES LTD.
6991 Curragh Avenue, Burnaby B.C., V5J 4V6
Tel: (604) 436-9111 Fax: (604) 436-9050

SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

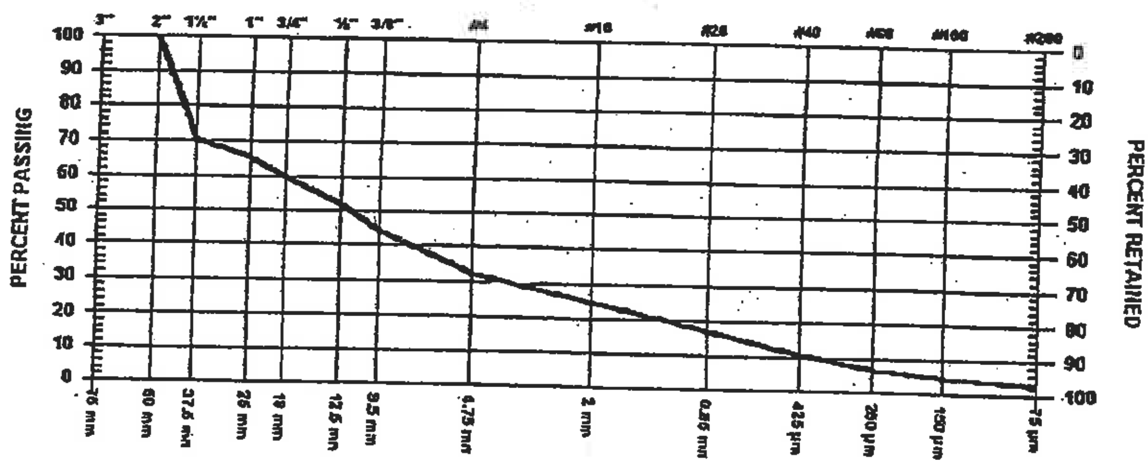
TO
KERR WOOD LEIDAL ASSOCIATES LIMITED
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 2 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.22

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
"	75 mm		
"	50 mm	100.0	
1/2"	37.5 mm	70.7	
"	25 mm	65.4	
/4"	19 mm	59.7	
/2"	12.5 mm	52.3	
/8"	9.5 mm	44.4	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	32.3	
No. 10	2.00 mm	25.0	
No. 20	850 µm	16.9	
No. 40	425 µm	10.6	
No. 60	250 µm	6.9	
No. 100	150 µm	4.7	
No. 200	75 µm	3.0	

COMMENTS
1 DEPTH 2.45M

 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER.

METRO TESTING LABORATORIES LTD.
6991 Curragh Avenue, Burnaby B.C., V5J 4V6
Tel: (604) 436-9111 Fax: (604) 436-9050

SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

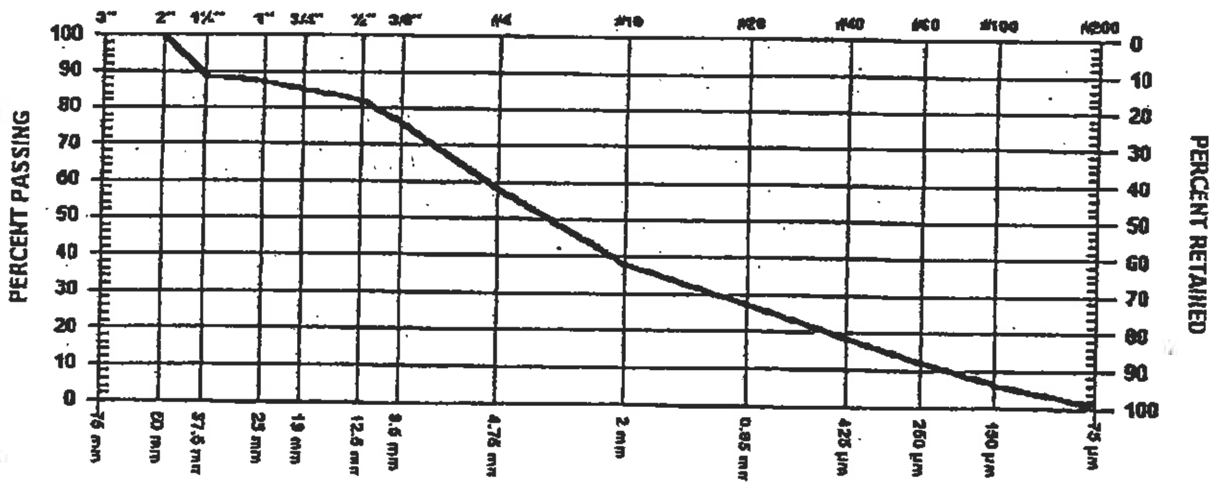
TO
KERR WOOD LEIDAL ASSOCIATES LIMITED
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
ONTRACTOR KERR WOOD

SIEVE TEST NO. 1 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.:

_JPPLIER
SOURCE SITE
PECIFICATION
ATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
3"	75	mm		
2"	50	mm	100.0	
1/2"	37.5	mm	88.9	
."	25	mm	87.3	
3/4"	19	mm	85.1	
/2"	12.5	mm	82.3	
/8"	9.5	mm	76.0	

SAND SIZES AND FINES			PERCENT PASSING	GRADATION LIMITS
No. 4	4.75	mm	58.3	
No. 10	2.00	mm	37.9	
No. 20	850	µm	27.5	
No. 40	425	µm	18.4	
No. 60	250	µm	12.0	
No. 100	150	µm	6.5	
No. 200	75	µm	0.8	

)MMENTS
?-2 DEPTH IS 1.5M

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
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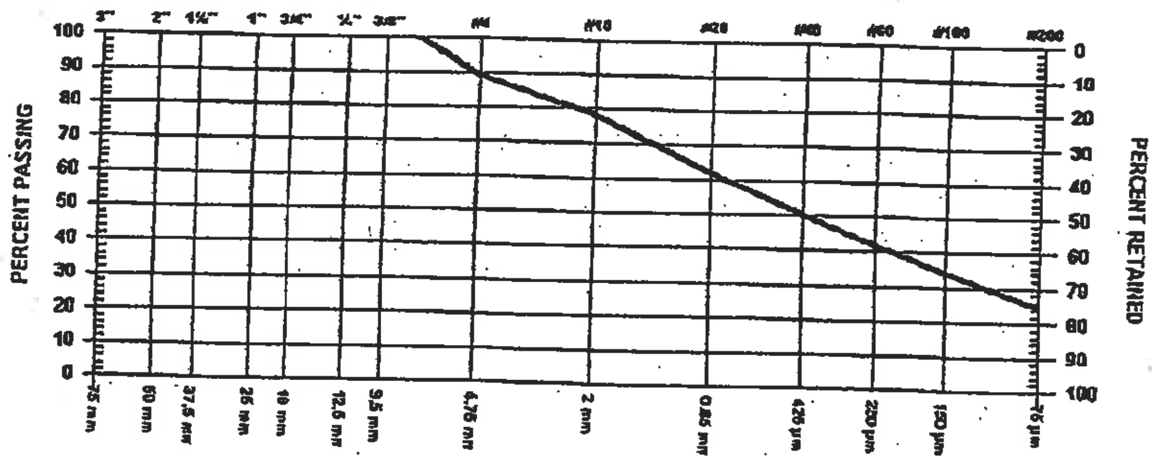
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. SIEVES - CHEEKEYE BERM
CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 9 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
"	75 mm		
"	50 mm		
1/2"	37.5 mm		
"	25 mm		
/4"	19 mm	100.0	
/2"	12.5 mm	116.8	
/8"	9.5 mm	106.2	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	89.3	
No. 10	2.00 mm	78.2	
No. 20	850 µm	62.2	
No. 40	425 µm	50.5	
No. 60	250 µm	42.0	
No. 100	150 µm	34.1	
No. 200	75 µm	24.9	

COMMENTS
-3 DEPTH 1.8M

 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____

TP-8
West of Highway 99 along berm centreline

Depth (m)	Description
0.0 to 0.20	Black ORGANIC soil with roots.
0.20 to 0.60	Dark brown, loose, fine to coarse SAND. Sample taken at 0.3 m.
0.6 to 0.9	Light brown, loose to compact GRAVELLY SAND with some cohesive silt. Approximately 10 % boulders (200 to 900 mm dia.) - sub-rounded to sub-angular. Sample taken at 0.75 m.
0.9 to 1.1	Clean dense uniform fine sand. Root layer at 1.1 m (Sample taken of roots)
1.1 to 2.8	Grey, compact SANDY GRAVEL, with large boulders near the 1.1 m and near 2.5 m. Some cobbles and boulders in matrix. No water encountered in the test pit. Sample taken at 2.4 m. End of test pit at 2.8 m.

In general, the soil conditions are found to be quite uniform. A thin 0.15 – 0.30 m thick layer of organic topsoil is underlain by silty sand or silty sand and gravel with cobbles and small boulders in places. The gradation of the subsurface soils varies in places from gravelly sands to sandy gravels, but overall conditions are quite uniform. The uppermost 0.5 m to 1.0 m of silty sand is loose, below which the soils become compact and in local zones even dense. Occasional larger boulders were encountered (eg., TP-8). No standing water was encountered in any of the test pits.

2. LABORATORY TESTING

A total of 11 samples of soil from different test pits was sent to Metro Testing Laboratories in Burnaby for grain size analysis. Sieve tests were carried out on washed samples generally below 50 mm (2 in.) maximum particle size. The results of tests are shown as the attached grain size curves.

The results indicate generally well-graded soils with the following ranges of particle size:

- Gravel 30 – 80%
- Sand 20 – 65%
- Silt 1 – 25%

3. PREVIOUS TEST PITS BY OTHERS

The previous test pits from the 1991 Thurber-Golder study were also reviewed. The relevant Thurber-Golder test pits are shown on their Figure 3-4, and listed as follows:

- 91-53
- 91-6
- 91-23

- 91-16
- 91-61

These tests were excavated to depths ranging between 0.8 m and 3.0 m. The descriptions are written in terms of geomorphic processes (i.e. fluvial, colluvial, or glacial), but nevertheless confirm the presence of silty sand and gravel in all test pits. Figure 3-4 in the Thurber-Golder report also differentiates between debris flow deposits (Hdf) and flood deposits (Hf). Relevant to this study debris flow deposits were mapped east of Government Road close to the junction with Ross Road, while flood deposits are mapped west of Government Road.

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

TO
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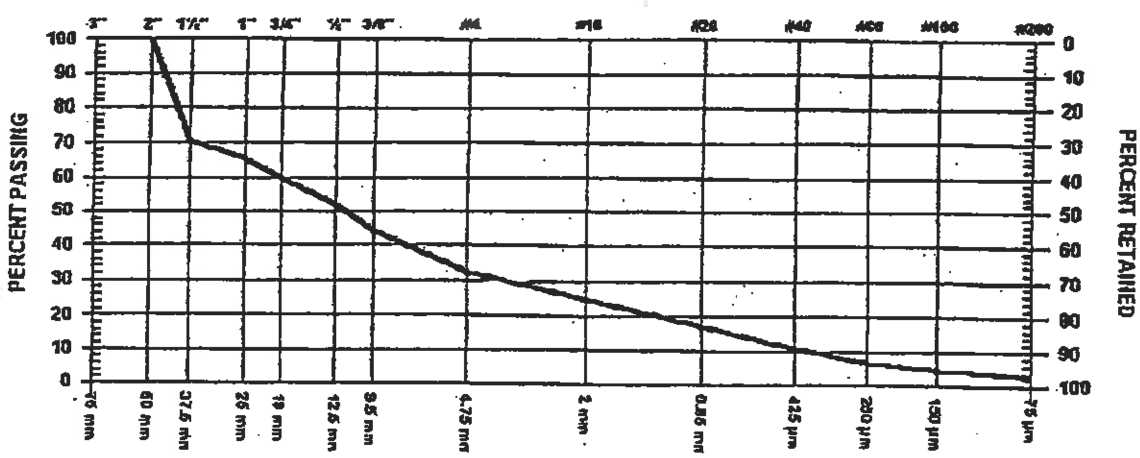
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 2 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.22

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
3"	75	mm		
2"	50	mm	100.0	
1 1/2"	37.5	mm	70.7	
1"	25	mm	65.4	
3/4"	19	mm	59.7	
1/2"	12.5	mm	52.3	
3/8"	9.5	mm	44.4	

SAND SIZES AND FINES			PERCENT PASSING	GRADATION LIMITS
No. 4	4.75	mm	32.3	
No. 10	2.00	mm	25.0	
No. 20	850	µm	16.9	
No. 40	425	µm	10.6	
No. 60	250	µm	6.9	
No. 100	150	µm	4.7	
No. 200	75	µm	3.0	

COMMENTS
TP-1 DEPTH 2.45M

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

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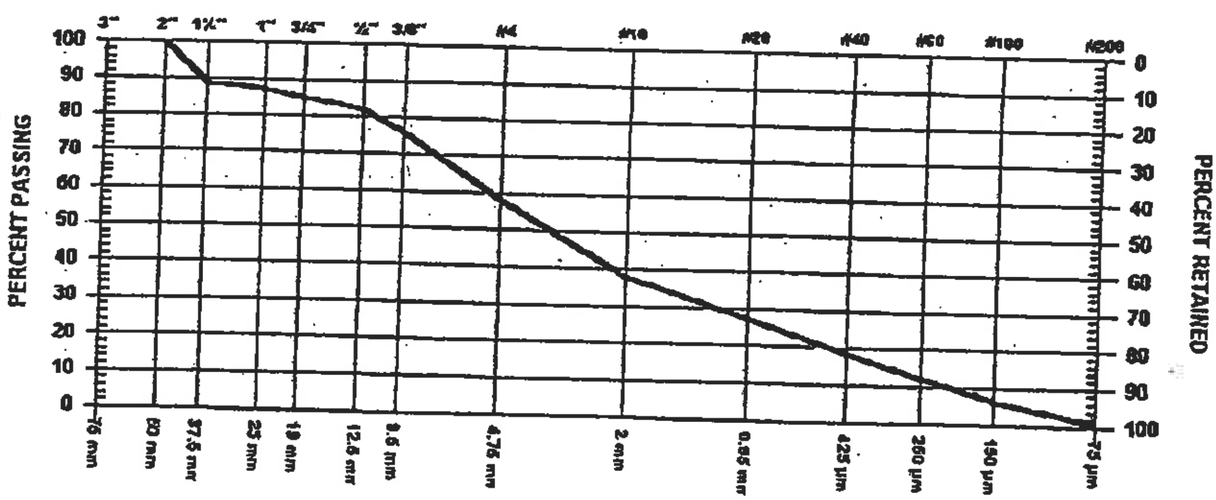
IECT KERR WOOD LEIDAL ASSOCIATES LTD.
SIEVES - CHEEKEYE BERM
CHEEKEYE BERM
IRACTOR KERR WOOD

TEST NO. 1 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.

LIER
CE SITE
IFICATION
RIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
	75	mm		
	50	mm	100.0	
2"	37.5	mm	88.9	
	25	mm	87.3	
	19	mm	85.1	
	12.5	mm	82.3	
	9.5	mm	76.0	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	58.3	
No. 10	2.00 mm	37.9	
No. 20	850 µm	27.5	
No. 40	425 µm	18.4	
No. 60	250 µm	12.0	
No. 100	150 µm	6.5	
No. 200	75 µm	0.8	

ITS
DEPTH IS 1.5M

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SIEVE ANALYSIS REPORT
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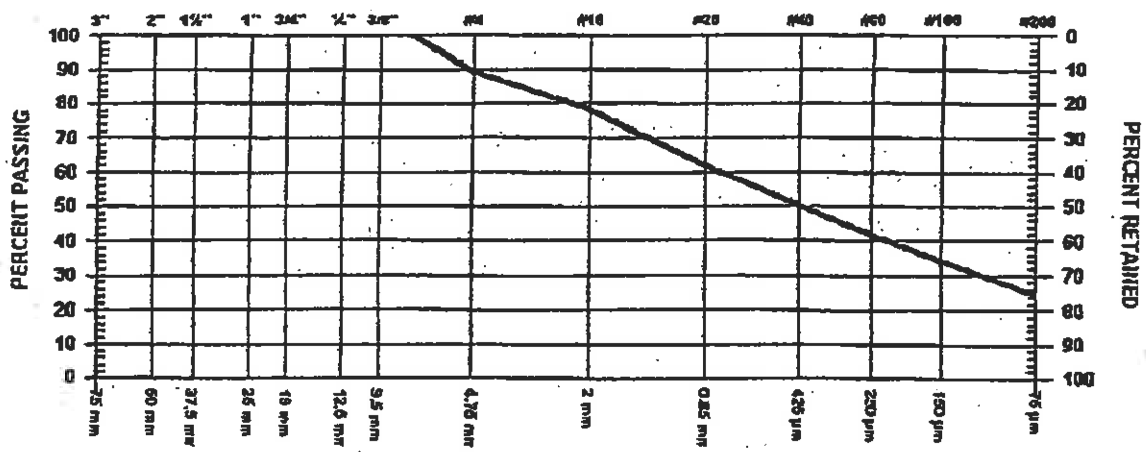
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 9 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm		
1"	25 mm		
3/4"	19 mm	100.0	
1/2"	12.5 mm	116.8	
3/8"	9.5 mm	106.2	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	89.3	
No. 10	2.00 mm	78.2	
No. 20	850 µm	62.2	
No. 40	425 µm	50.5	
No. 60	250 µm	42.0	
No. 100	150 µm	34.1	
No. 200	75 µm	24.9	

COMMENTS
TP-3 DEPTH 1.8M

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
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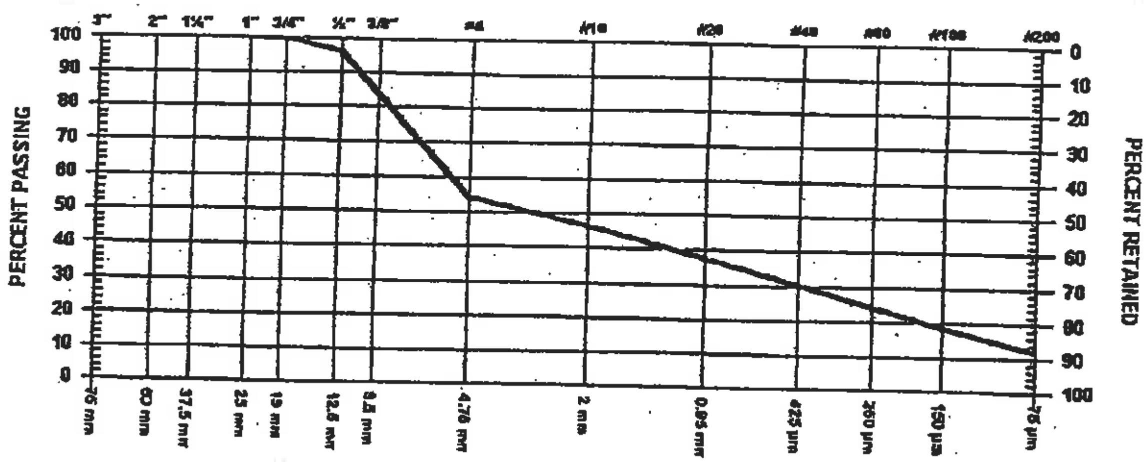
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

ROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
ONTRACTOR KERR WOOD

EVE TEST NO. 3 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

IPPLIER
OURCE SITE
ECIFICATION
ATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
"	75 mm		
"	50 mm		
1/2"	37.5 mm		
"	25 mm		
4"	19 mm	100.0	
2"	12.5 mm	96.1	
8"	9.5 mm	84.0	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	54.2	
No. 10	2.00 mm	46.4	
No. 20	850 µm	37.5	
No. 40	425 µm	30.2	
No. 60	250 µm	24.5	
No. 100	150 µm	18.9	
No. 200	75 µm	12.0	

MENTS.
DEPTH 2.1M

e 1 of 1 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____________

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10 20 40 60 SERIES

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CLIENT KERR WOOD LEIDAL ASSOCIATES
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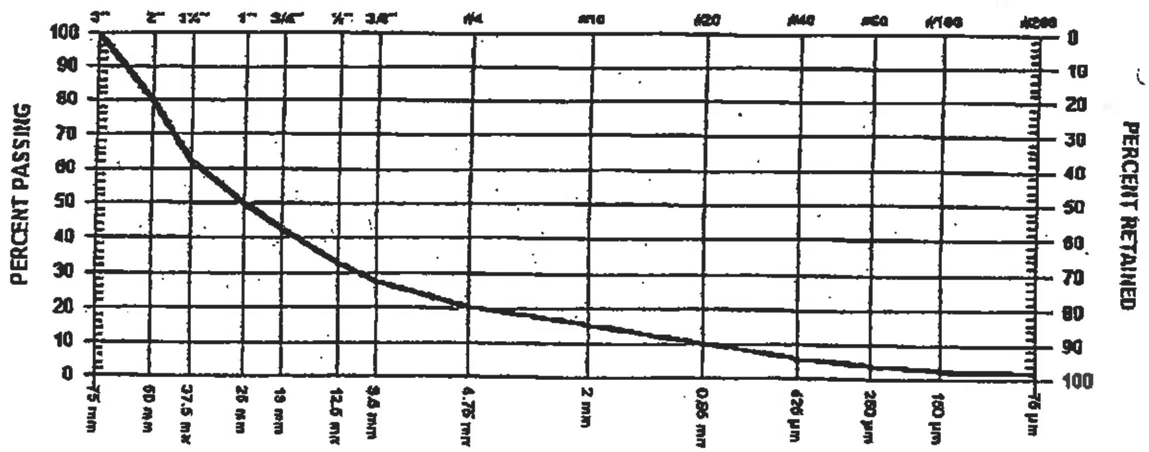
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 11 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
3"	75	mm	100.0	
2"	50	mm	80.1	
1 1/2"	37.5	mm	62.5	
1"	25	mm	50.1	
3/4"	19	mm	42.9	
1/2"	12.5	mm	32.9	
3/8"	9.5	mm	27.8	

SAND SIZES AND FINES			PERCENT PASSING	GRADATION LIMITS
No. 4	4.75	mm	20.4	
No. 10	2.00	mm	15.2	
No. 20	850	µm	10.3	
No. 40	425	µm	6.1	
No. 60	250	µm	3.9	
No. 100	150	µm	2.6	
No. 200	75	µm	1.7	

COMMENTS
TB4 DEPTH 1.65M

 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____________

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SIEVE ANALYSIS REPORT
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TO
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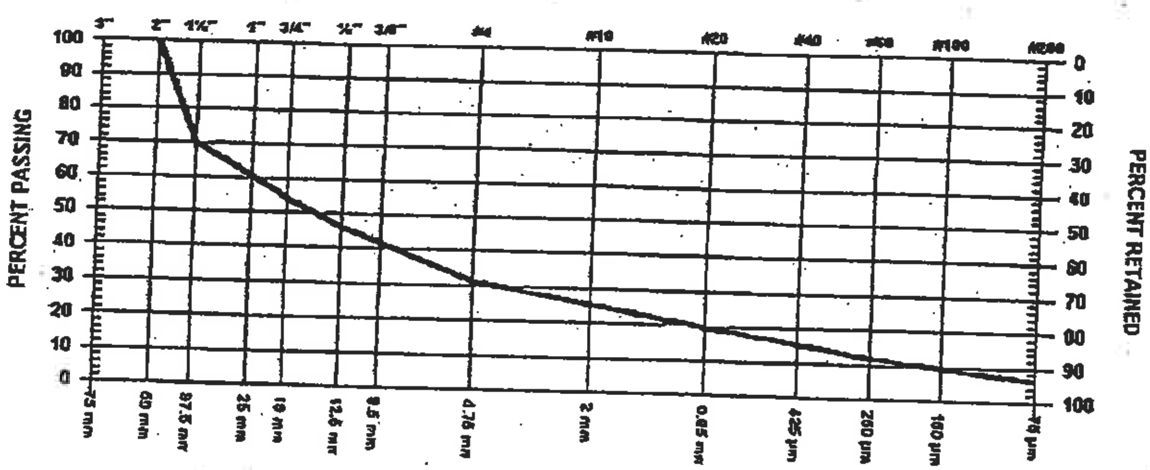
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD.
SIEVES - CHEEKEYE BERM
CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 10 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
"	75 mm		
"	50 mm	100.0	
1/2"	37.5 mm	70.2	
"	25 mm	60.9	
4"	19 mm	54.1	
2"	12.5 mm	46.1	
8"	9.5 mm	42.1	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	31.4	
No. 10	2.00 mm	25.7	
No. 20	850 µm	19.8	
No. 40	425 µm	15.2	
No. 60	250 µm	12.0	
No. 100	150 µm	9.2	
No. 200	75 µm	6.4	

MENTS
DEPTH 1.0 M

e 1 of 1 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER.

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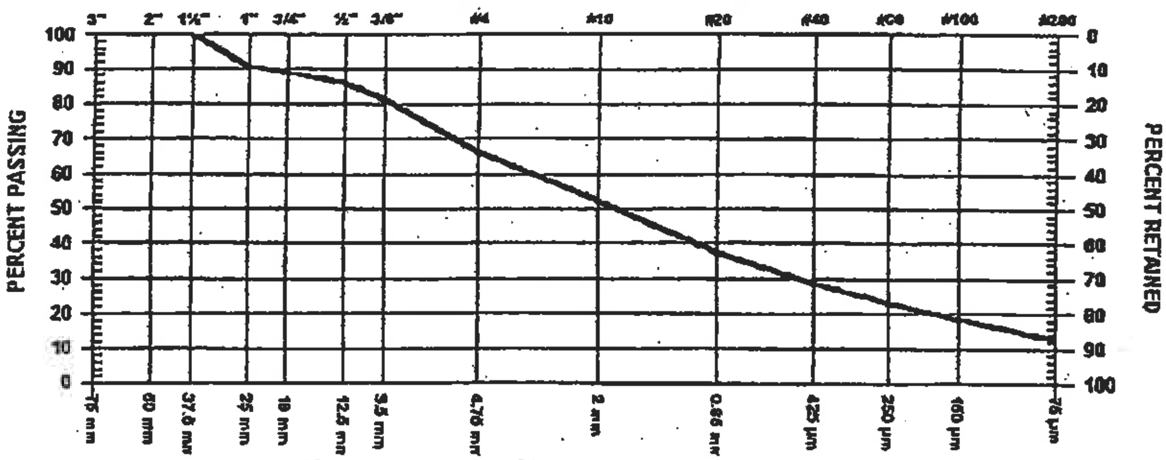
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. SIEVES - CHEEKEYE BERM   CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 7   DATE RECEIVED 2003.Feb.07   DATE TESTED 2003.Feb.10   DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm		
1 1/2"	37.5 mm	100.0	
1"	25 mm	90.8	
3/4"	19 mm	88.9	
1/2"	12.5 mm	85.8	
3/8"	9.5 mm	81.3	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	66.1	
No. 10	2.00 mm	52.8	
No. 20	850 µm	37.5	
No. 40	425 µm	28.7	
No. 60	250 µm	23.2	
No. 100	150 µm	18.4	
No. 200	75 µm	13.0	

COMMENTS
TP6 DEPTH 0.6M

    2003.Feb.11   METRO TESTING LABORATORIES LTD. PER. ____________

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

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CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

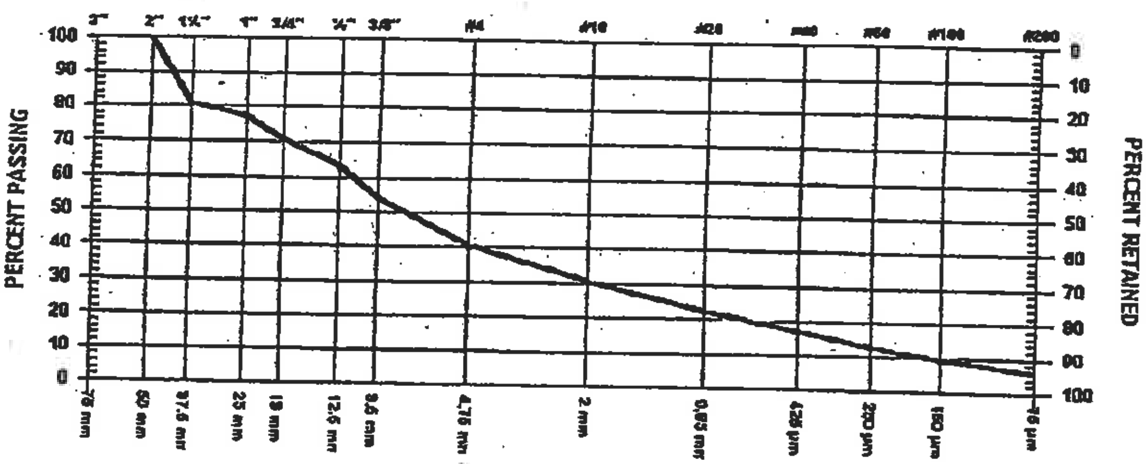
TO
KERR WOOD LEIDAL ASSOCIATES LIMITED
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 8 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Feb.06

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm	100.0	
1 1/2"	37.5 mm	80.8	
1"	25 mm	77.3	
3/4"	19 mm	70.8	
1/2"	12.5 mm	63.3	
3/8"	9.5 mm	54.1	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	40.6	
No. 10	2.00 mm	30.8	
No. 20	850 µm	22.5	
No. 40	425 µm	17.0	
No. 60	250 µm	13.0	
No. 100	150 µm	9.5	
No. 200	75 µm	5.9	

COMMENTS
?7 DEPTH 3.2M

 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____________

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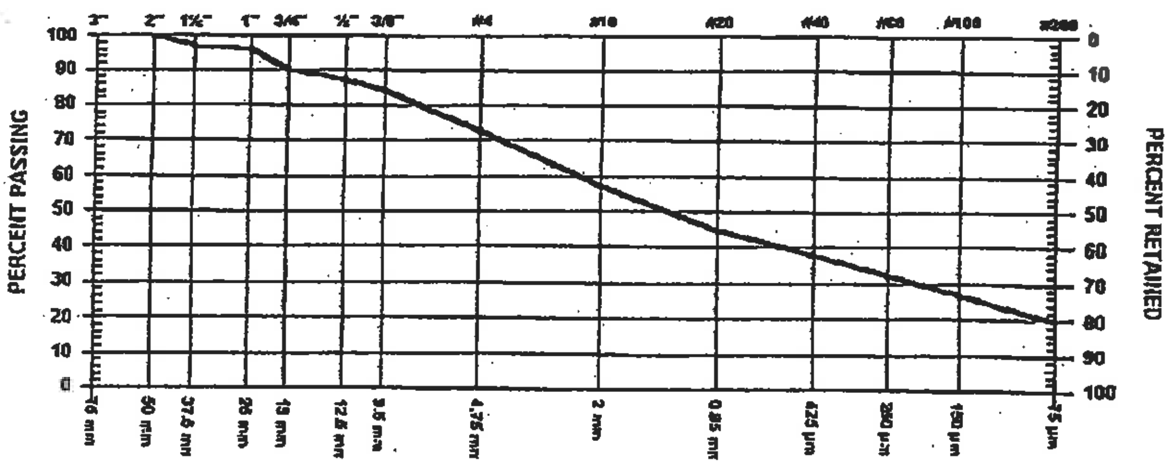
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 4 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm		
2"	50 mm	100.0	
1 1/2"	37.5 mm	97.3	
1"	25 mm	96.3	
3/4"	19 mm	90.4	
1/2"	12.5 mm	87.1	
3/8"	9.5 mm	84.3	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	72.9	
No. 10	2.00 mm	57.3	
No. 20	850 µm	45.1	
No. 40	425 µm	38.1	
No. 60	250 µm	32.4	
No. 100	150 µm	27.0	
No. 200	75 µm	19.8	

COMMENTS
TP8 DEPTH 0.3

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SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

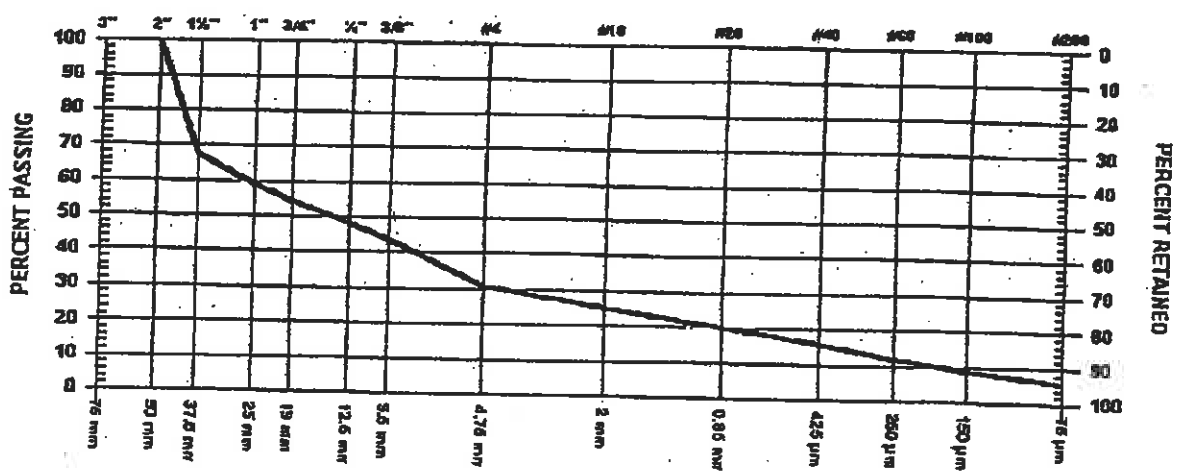
O
KERR WOOD LEIDAL ASSOCIATES LIMITED
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

ROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
NTRACTOR KERR WOOD

EVE TEST NO. 5 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

PPLIER
URCE SITE
ECIFICATION
TERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES			PERCENT PASSING	GRADATION LIMITS
	75	mm		
	50	mm	100.0	
1/2"	37.5	mm	67.4	
	25	mm	59.1	
4"	19	mm	54.1	
2"	12.5	mm	48.5	
8"	9.5	mm	43.7	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	30.9	
No. 10	2.00 mm	25.4	
No. 20	850 µm	20.2	
No. 40	425 µm	15.9	
No. 60	250 µm	12.1	
No. 100	150 µm	8.8	
No. 200	75 µm	5.5	

IENTS
DEPTH 0.8M

e 1 of 1 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____________

METRO TESTING LABORATORIES LTD.

6391 Curragh Avenue, Burnaby B.C., V5J 4V6
Tel: (604) 436-9111 Fax: (604) 436-9050

SIEVE ANALYSIS REPORT
10 20 40 60 SERIES

PROJECT NO. 6383
CLIENT KERR WOOD LEIDAL ASSOCIATES
C.C.

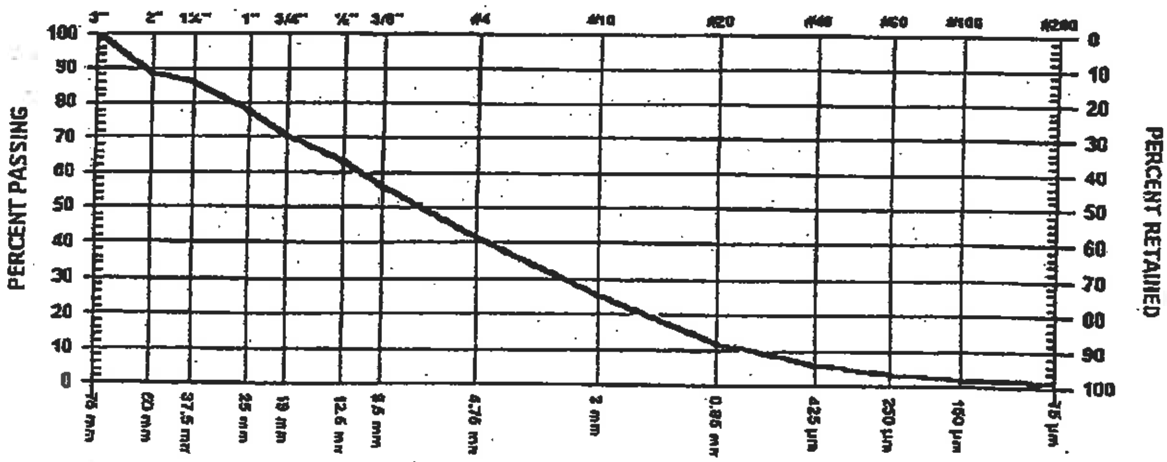
TO
KERR WOOD LEIDAL ASSOCIATES LIMITED
139 WEST 16TH STREET
NORTH VANCOUVER, BRITISH COLUMBI
V7M 1T3

PROJECT KERR WOOD LEIDAL ASSOCIATES LTD. CHEEKEYE BERM
SIEVES - CHEEKEYE BERM
CONTRACTOR KERR WOOD

SIEVE TEST NO. 6 DATE RECEIVED 2003.Feb.07 DATE TESTED 2003.Feb.10 DATE SAMPLED 2003.Jan.23

SUPPLIER
SOURCE SITE
SPECIFICATION
MATERIAL TYPE NATIVE

SAMPLED BY CLIENT
TESTED BY NM
TEST METHOD WASHED



GRAVEL SIZES		PERCENT PASSING	GRADATION LIMITS
3"	75 mm	100.0	
2"	50 mm	88.4	
1 1/2"	37.5 mm	85.9	
1"	25 mm	77.9	
3/4"	19 mm	70.7	
1/2"	12.5 mm	63.1	
3/8"	9.5 mm	55.9	

SAND SIZES AND FINES		PERCENT PASSING	GRADATION LIMITS
No. 4	4.75 mm	41.3	
No. 10	2.00 mm	25.7	
No. 20	850 µm	12.1	
No. 40	425 µm	6.0	
No. 60	250 µm	3.6	
No. 100	150 µm	2.1	
No. 200	75 µm	1.1	

COMMENTS
TP8 DEPTH 2.2M

 2003.Feb.11 METRO TESTING LABORATORIES LTD. PER. ____________

Appendix B

Construction Cost Estimates

- Appendix B-1 High Cost
- Appendix B-2 Low Cost

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

Appendix B-1

High Cost

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Upper Main Berm 12m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	8,000.00	8,000
	Sub-total				20,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.1	20,000.00	42,000
2.2	Stripping	cu.m	7400	6.00	44,400
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	99,420	15.00	1,491,300
2.5	Riprap	sq.m	6600	40.00	264,000
2.6	Berm Gravel Surfacing	sq.m	1000	5.00	5,000
2.7	Native Topsoil Dressing	sq.m	7500	2.30	17,250
2.8	Hydroseeding	sq.m	7500	1.20	9,000
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				1,878,350
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	0	-	0
3.2	Dryden Creek Arch Culvert	L.S.	1	575,000.00	575,000
3.3	Environmental Compensation	L.S.	1	300,000.00	300,000
3.4	Drainage Culverts	ea	0	2,700.00	0
3.5	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				878,000
	SUBTOTAL				**2,776,350**
	Engineering 10%				277,635
	Contingencies 15%				416,453
	SUBTOTAL				3,470,438
	Plus 7% GST				242,931
	Total Estimated Cost				**3,713,368**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Highway 99 Regrading

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE($)	TOTAL($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	20,000.00	20,000
1.2	Mobilization/Demobilization	L.S.	1	10,000.00	10,000
1.3	Construction Survey Layout	L.S.	1	40,000.00	40,000
	Sub-total				70,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.1	20,000.00	42,000
2.2	Stripping	cu.m	7400	6.00	44,400
2.3	Mill Existing Pavement	sq.m	32000	2.50	80,000
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	316000	15.00	4,740,000
2.6	Subbase Construction - 300 mm	sq.m	33920	12.00	407,040
2.7	Base Construction - 150 mm	sq.m	33920	6.00	203,520
2.8	Pavement Construction - 100 mm	sq.m	32000	20.00	640,000
2.9	Shoulder Gravel Construction - 100 mm	sq.m	1920	8.00	15,360
2.10	Ditching	l.m	2000	80.00	160,000
2.11	Line Painting	L.S.	1	5,000.00	5,000
2.12	No Post Barriers	l.m.	3000	80.00	240,000
2.13	Slope Top Dressing	sq.m	22800	2.30	52,440
2.14	Hydroseeding	sq.m	22800	1.20	27,360
	Sub-total				6,657,120
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		500,000
3.5	Environmental Controls	L.S.	1	10,000.00	10,000
	Sub-total				510,000
	SUBTOTAL				**7,237,120**
	Engineering 10%				723,712
	Contingencies 15%				1,085,568
	SUBTOTAL				9,046,400
	Plus 7% GST				633,248
	Total Estimated Cost				**9,679,648**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Main Berm 7.5m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE	TOTAL($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	20,000.00	20,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	20,000.00	20,000
	Sub-total				46,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	7.8	20,000.00	156,000
2.2	Stripping	cu.m	24480	6.00	146,880
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	176910	15.00	2,653,650
2.5	Riprap	sq.m	19950	40.00	798,000
2.6	Berm Gravel Surfacing	sq.m	5500	5.00	27,500
2.7	Native Topsoil Dressing	sq.m	27360	2.30	62,928
2.8	Hydroseeding	sq.m	27360	1.20	32,832
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				3,883,190
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	1	200,000.00	200,000
3.2	Drainage Culverts	L.S.	5	2,700.00	13,500
3.3	Environmental Controls	L.S.	1	10,000.00	10,000
	Sub-total				223,500
	SUBTOTAL				**4,152,690**
	Engineering 10%				415,269
	Contingencies 15%				622,904
	SUBTOTAL				5,190,863
	Plus 7% GST				363,360
	Total Estimated Cost				**5,554,223**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Government Road Regrading at Main Berm

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	1,500.00	1,500
1.2	Mobilization/Demobilization	L.S.	1	1,000.00	1,000
1.3	Construction Survey Layout	L.S.	1	1,500.00	1,500
	Sub-total				4,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	0.1	20,000.00	2,000
2.2	Stripping	cu.m	200	6.00	1,200
2.3	Mill Existing Pavement	sq.m	2600	2.50	6,500
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	5450	15.00	81,750
2.6	Subbase Construction - 300 mm	sq.m	3640	12.00	43,680
2.7	Base Construction - 150 mm	sq.m	3640	6.00	21,840
2.8	Pavement Construction - 100 mm	sq.m	2590	20.00	51,800
2.9	Shoulder Gravel Construction - 100 mm	sq.m	1050	8.00	8,400
2.10	Ditching	l.m	350	30.00	10,500
2.11	Line Painting	L.S.	1	500.00	500
2.12	No Post Barriers	l.m.		80.00	0
2.13	Slope Top Dressing	sq.m	1400	2.30	3,220
2.14	Hydroseeding	sq.m	1400	1.20	1,680
	Sub-total				233,070
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		3,000
3.5	Environmental Controls	L.S.	1	10,000.00	1,000
	Sub-total				4,000
	SUBTOTAL				**241,070**
	Engineering 10%				24,107
	Contingencies 15%				36,161
	SUBTOTAL				301,338
	Plus 7% GST				21,094
	Total Estimated Cost				**322,431**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Lower Main Berm 6m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	8,000.00	8,000
	Sub-total				20,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	1.4	20,000.00	28,000
2.2	Stripping	cu.m	3920	6.00	23,520
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	27920	15.00	418,800
2.5	Riprap	sq.m	3220	40.00	128,800
2.6	Berm Gravel Surfacing	sq.m	1040	5.00	5,200
2.7	Native Topsoil Dressing	sq.m	4200	2.30	9,660
2.8	Hydroseeding	sq.m	4200	1.20	5,040
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				624,420
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	1	-	50,000
3.2	Drainage Culverts	ea	1	2,700.00	2,700
3.3	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				55,700
	SUBTOTAL				**700,120**
	Engineering 10%				70,012
	Contingencies 15%				105,018
	SUBTOTAL				875,150
	Plus 7% GST				61,261
	Total Estimated Cost				**936,411**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Waiwakum Berm 4.5m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	4,000.00	4,000
1.3	Construction Survey Layout	L.S.	1	7,000.00	7,000
	Sub-total				17,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.2	20,000.00	44,000
2.2	Stripping	cu.m	5870	6.00	35,220
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	26520	15.00	397,800
2.5	Riprap	sq.m	4820	40.00	192,800
2.6	Berm Gravel Surfacing	sq.m	1920	5.00	9,600
2.7	Native Topsoil Dressing	sq.m	6120	2.30	14,076
2.8	Hydroseeding	sq.m	6120	1.20	7,344
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				706,240
3.	**Miscellaneous Allowances**				
3.1	Drainage Culverts	ea	1	2,700.00	2,700
3.2	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				5,700
	SUBTOTAL				**728,940**
	Engineering 10%				72,894
	Contingencies 15%				109,341
	SUBTOTAL				911,175
	Plus 7% GST				63,782
	Total Estimated Cost				**974,957**

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Notes:

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Walwakum Dyke and Bank Protection

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance				
1.2	Mobilization/Demobilization	L.S.	1	2,000.00	2,000
1.3	Construction Survey Layout	L.S.	1	1,000.00	1,000
	Sub-total	L.S.	1	1,500.00	1,500
					4,500
2.	**Site Work**				
2.1	Clearing and Grubbing				
2.2	Stripping	ha.	0.6	20,000.00	12,000
2.3	Common Excavation	cu.m	2000	6.00	12,000
2.4	Berm Core Construction	cu.m	0	7.00	0
2.5	Riprap	cu.m	7510	15.00	112,650
2.6	Berm Gravel Surfacing	sq.m	1480	40.00	59,200
2.7	Native Topsoil Dressing	sq.m	720	5.00	3,600
2.8	Hydroseeding	sq.m	1740	2.30	4,002
2.9	Supply and Install Access Gate	sq.m	1740	1.20	2,088
2.10	Imported Topsoil	L.S.	1	2,700.00	2,700
	Sub-total	cu.m	0	25.00	0
					208,240
3.	**Miscellaneous Allowances**				
3.1	River Riprap Bank Protection/Environmental Enhancement				
3.2	Environmental Controls	sq.m	900	120.00	108,000
		L.S.	1	3,000.00	3,000
	Sub-total				
					111,000
	SUBTOTAL				
	Engineering 10%				323,740
	Contingencies 15%				32,374
	SUBTOTAL				48,561
	Plus 7% GST				404,675
	Total Estimated Cost				28,327
					433,002

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Airport Berms 3m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	3,800.00	3,800
1.2	Mobilization/Demobilization	L.S.	1	3,700.00	3,700
1.3	Construction Survey Layout	L.S.	1	6,600.00	6,600
	Sub-total				14,100
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.4	20,000.00	48,000
2.2	Stripping	cu.m	4500	6.00	27,000
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	19670	15.00	295,050
2.5	Riprap	sq.m	5400	40.00	216,000
2.6	Berm Gravel Surfacing	sq.m	2800	5.00	14,000
2.7	Native Topsoil Dressing	sq.m	6530	2.30	15,019
2.8	Hydroseeding	sq.m	6530	1.20	7,836
2.9	Supply and Install Access Gate	L.S.	4	2,700.00	10,800
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				633,705
3.	**Miscellaneous Allowances**				
3.1	Drainage Culverts	ea	1	2,700.00	2,700
3.2	Environmental Controls	L.S.	1	2,000.00	2,000
	Sub-total				4700
	SUBTOTAL				652,505
	Engineering 10%				65,251
	Contingencies 15%				97,876
	SUBTOTAL				815,631
	Plus 7% GST				57,094
	Total Estimated Cost				**872,725**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Government Road Regrading at Airport Berm

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE ($)	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	1,500.00	1,500
1.2	Mobilization/Demobilization	L.S.	1	1,000.00	1,000
1.3	Construction Survey Layout	L.S.	1	1,500.00	1,500
	Sub-total				4,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	0.1	20,000.00	2,000
2.2	Stripping	cu.m	200	6.00	1,200
2.3	Mill Existing Pavement	sq.m	2220	2.50	5,550
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	2045	15.00	30,675
2.6	Subbase Construction - 300 mm	sq.m	3120	12.00	37,440
2.7	Base Construction - 150 mm	sq.m	3120	6.00	18,720
2.8	Pavement Construction - 100 mm	sq.m	2220	20.00	44,400
2.9	Shoulder Gravel Construction - 100 mm	sq.m	900	8.00	7,200
2.10	Ditching	l.m	300	30.00	9,000
2.11	Line Painting	L.S.	1	500.00	500
2.12	No Post Barriers	l.m		80.00	0
2.13	Slope Top Dressing	sq.m	1200	2.30	2,760
2.14	Hydroseeding	sq.m	1200	1.20	1,440
	Sub-total				160,885
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		3,000
3.5	Environmental Controls	L.S.	1	10,000.00	1,000
	Sub-total				4,000
	SUBTOTAL				**168,885**
	Engineering 10%				16,889
	Contingencies 15%				25,333
	SUBTOTAL				211,106
	Plus 7% GST				14,777
	Total Estimated Cost				**225,884**

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Notes:

Appendix B-2

Low Cost

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

Minimum Cost

District of Squamish
Construction of Hazard Mitigation Berms
Upper Main Berm 12m High

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	8,000.00	8,000
	Sub-total				20,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.1	20,000.00	42,000
2.2	Stripping	cu.m	7400	6.00	44,400
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	99,420	5.00	497,100
2.5	Riprap	sq.m	6600	40.00	264,000
2.6	Berm Gravel Surfacing	sq.m	1000	5.00	5,000
2.7	Native Topsoil Dressing	sq.m	7500	2.30	17,250
2.8	Hydroseeding	sq.m	7500	1.20	9,000
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				884,150
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	0	-	0
3.2	Dryden Creek Arch Culvert	L.S.	1	575,000.00	575,000
3.3	Environmental Compensation	L.S.	1	300,000.00	300,000
3.4	Drainage Culverts	ea	0	2,700.00	0
3.5	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				878,000
	SUBTOTAL				1,782,150
	Engineering 10%				178,215
	Contingencies 15%				267,323
	SUBTOTAL				2,227,688
	Plus 7% GST				155,938
	Total Estimated Cost				2,383,626

O:\0400-0499\463-104\Capital Cost Estimates\[March 7-03BermLOWCostEstimate.xls]Main Berm

Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Highway 99 Regrading

Minimum Cost

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	20,000.00	20,000
1:2	Mobilization/Demobilization	L.S.	1	10,000.00	10,000
1.3	Construction Survey Layout	L.S.	1	40,000.00	40,000
	Subtotal				70,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.1	20,000.00	42,000
2.2	Stripping	cu.m	7400	6.00	44,400
2.3	Mill Existing Pavement	sq.m	32000	2.50	80,000
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	316000	5.00	1,580,000
2.6	Subase Construction - 300 mm	sq.m	33920	12.00	407,040
2.7	Base Construction - 150 mm	sq.m	33920	6.00	203,520
2.8	Pavement Construction - 100 mm	sq.m	32000	20.00	640,000
2.9	Shoulder Gravel Construction - 100 mm	sq.m	1920	8.00	15,360
2.10	Ditching	l.m	2000	80.00	160,000
2.11	Line Painting	L.S.	1	5,000.00	5,000
2.12	No Post Barriers	l.m.	3000	80.00	240,000
2.13	Slope Top Dressing	sq.m	22800	2.30	52,440
2.14	Hydroseeding	sq.m	22800	1.20	27,360
	Sub-total				3,497,120
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		500,000
3.5	Environmental Controls	L.S.	1	10,000.00	10,000
	Sub-total				510,000
	SUBTOTAL				4,077,120
	Engineering 10%				407,712
	Contingencies 15%				611,568
	SUBTOTAL				5,096,400
	Plus 7% GST				356,748
	Total Estimated Cost				5,453,148

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

Minimum Cost

District of Squamish
Construction of Hazard Mitigation Berms
Main Berm 7.5m High

ITEM	DESCRIPTION	UNITS	QUANTITY	UNIT PRICE ($)	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	20,000.00	20,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	20,000.00	20,000
	Sub-total				46,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	7.8	20,000.00	156,000
2.2	Stripping	cu.m	24480	6.00	146,880
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	176910	5.00	884,550
2.5	Riprap	sq.m	19950	40.00	798,000
2.6	Berm Gravel Surfacing	sq.m	5500	5.00	27,500
2.7	Native Topsoil Dressing	sq.m	27360	2.30	62,928
2.8	Hydroseeding	sq.m	27360	1.20	32,832
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				2,114,090
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	1	200,000.00	200,000
3.2	Drainage Culverts	L.S.	5	2,700.00	13,500
3.3	Environmental Controls	L.S.	1	10,000.00	10,000
	Sub-total				223,500
	SUBTOTAL				**2,383,590**
	Engineering 10%				238,359
	Contingencies 15%				357,539
	SUBTOTAL				2,979,488
	Plus 7% GST				208,564
	Total Estimated Cost				**3,188,052**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Lower Main Berm 6m High

Minimum Cost

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	6,000.00	6,000
1.3	Construction Survey Layout	L.S.	1	8,000.00	8,000
	Sub-total				20,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	1.4	20,000.00	28,000
2.2	Stripping	cu.m	3920	6.00	23,520
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	27920	5.00	139,600
2.5	Riprap	sq.m	3220	40.00	128,800
2.6	Berm Gravel Surfacing	sq.m	1040	5.00	5,200
2.7	Native Topsoil Dressing	sq.m	4200	2.30	9,660
2.8	Hydroseeding	sq.m	4200	1.20	5,040
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				345,220
3.	**Miscellaneous Allowances**				
3.1	BC Hydro Transmission Line Regrade	L.S.	1	-	50,000
3.2	Drainage Culverts	ea	1	2,700.00	2,700
3.3	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				55,700
	SUBTOTAL				**420,920**
	Engineering 10%				42,092
	Contingencies 15%				63,138
	SUBTOTAL				526,150
	Plus 7% GST				36,831
	Total Estimated Cost				**562,981**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

Minimum Cost

District of Squamish
Construction of Hazard Mitigation Berms
Government Road Regrading at Main Berm

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE ($)	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	1,500.00	1,500
1.2	Mobilization/Demobilization	L.S.	1	1,000.00	1,000
1.3	Construction Survey Layout	L.S.	1	1,500.00	1,500
	Subtotal				4,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	0.1	20,000.00	2,000
2.2	Stripping	cu.m	200	6.00	1,200
2.3	Mill Existing Pavement	sq.m	2600	2.50	6,500
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	5450	5.00	27,250
2.6	Subbase Construction - 300 mm	sq.m	3640	12.00	43,680
2.7	Base Construction - 150 mm	sq.m	3640	6.00	21,840
2.8	Pavement Construction - 100 mm	sq.m	2590	20.00	51,800
2.9	Shoulder Gravel Construction - 100 mm	sq.m	1050	8.00	8,400
2.10	Ditching	l.m	350	30.00	10,500
2.11	Line Painting	L.S.	1	500.00	500
2.12	No Post Barriers	l.m.	--	80.00	0
2.13	Slope Top Dressing	sq.m	1400	2.30	3,220
2.14	Hydroseeding	sq.m	1400	1.20	1,680
	Subtotal				178,570
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		3,000
3.5	Environmental Controls	L.S.	1	10,000.00	1,000
	Subtotal				4,000
	SUBTOTAL				**186,570**
	Engineering 10%				18,657
	Contingencies 15%				27,986
	SUBTOTAL				233,213
	Plus 7% GST				16,325
	Total Estimated Cost				**249,537**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Walwakum Berm 4.5m High

Minimum Cost

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	6,000.00	6,000
1.2	Mobilization/Demobilization	L.S.	1	4,000.00	4,000
1.3	Construction Survey Layout	L.S.	1	7,000.00	7,000
	Subtotal				17,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.2	20,000.00	44,000
2.2	Stripping	cu.m	5870	6.00	35,220
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	26520	5.00	132,600
2.5	Riprap	sq.m	4820	40.00	192,800
2.6	Berm Gravel Surfacing	sq.m	1920	5.00	9,600
2.7	Native Topsoil Dressing	sq.m	6120	2.30	14,076
2.8	Hydroseeding	sq.m	6120	1.20	7,344
2.9	Supply and Install Access Gate	L.S.	2	2,700.00	5,400
2.10	Imported Topsoil	cu.m	0	25.00	0
	Subtotal				441,040
3.	**Miscellaneous Allowances**				
3.1	Drainage Culverts	ea	1	2,700.00	2,700
3.2	Environmental Controls	L.S.	1	3,000.00	3,000
	Subtotal				5,700
	SUBTOTAL				**463,740**
	Engineering 10%				46,374
	Contingencies 15%				69,561
	SUBTOTAL				579,675
	Plus 7% GST				40,577
	Total Estimated Cost				**620,252**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

Minimum Cost

District of Squamish
Construction of Hazard Mitigation Berms
Walwakum Dyke and Bank Protection

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	2,000.00	2,000
1.2	Mobilization/Demobilization	L.S.	1	1,000.00	1,000
1.3	Construction Survey Layout	L.S.	1	1,500.00	1,500
	Sub-total				4,500
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	0.6	20,000.00	12,000
2.2	Stripping	cu.m	2000	6.00	12,000
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	7510	5.00	37,550
2.5	Riprap	sq.m	1480	40.00	59,200
2.6	Berm Gravel Surfacing	sq.m	720	5.00	3,600
2.7	Native Topsoil Dressing	sq.m	1740	2.30	4,002
2.8	Hydroseeding	sq.m	1740	1.20	2,088
2.9	Supply and Install Access Gate	L.S.	1	2,700.00	2,700
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				133,140
3.	**Miscellaneous Allowances**				
3.1	River Riprap Bank Protection/Environmental Enhancement	sq.m	900	120.00	108,000
3.2	Environmental Controls	L.S.	1	3,000.00	3,000
	Sub-total				111,000
	SUBTOTAL				248,640
	Engineering 10%				24,864
	Contingencies 15%				37,296
	SUBTOTAL				310,800
	Plus 7% GST				21,756
	Total Estimated Cost				332,556

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

District of Squamish
Construction of Hazard Mitigation Berms
Airport Berms 3m High

Minimum Cost

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE $	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	3,800.00	3,800
1.2	Mobilization/Demobilization	L.S.	1	3,700.00	3,700
1.3	Construction Survey Layout	L.S.	1	6,600.00	6,600
	Sub-total				14,100
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	2.4	20,000.00	48,000
2.2	Stripping	cu.m	4500	6.00	27,000
2.3	Common Excavation	cu.m	0	7.00	0
2.4	Berm Core Construction	cu.m	19670	5.00	98,350
2.5	Riprap	sq.m	5400	40.00	216,000
2.6	Berm Gravel Surfacing	sq.m	2800	5.00	14,000
2.7	Native Topsoil Dressing	sq.m	6530	2.30	15,019
2.8	Hydroseeding	sq.m	6530	1.20	7,836
2.9	Supply and Install Access Gate	L.S.	4	2,700.00	10,800
2.10	Imported Topsoil	cu.m	0	25.00	0
	Sub-total				437,005
3.	**Miscellaneous Allowances**				
3.1	Drainage Culverts	ea	1	2,700.00	2,700
3.2	Environmental Controls	L.S.	1	2,000.00	2,000
	Subtotal				4,700
	SUBTOTAL				**455,805**
	Engineering 10%				45,581
	Contingencies 15%				68,371
	SUBTOTAL				569,756
	Plus 7% GST				39,883
	Total Estimated Cost				**609,639**

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Notes:

KERR WOOD LEIDAL ASSOCIATES LTD.
Consulting Engineers

File No. 463.104
March 7,2003

Minimum Cost

District of Squamish
Construction of Hazard Mitigation Berms
Government Road Regrading at Airport Berm

ITEM	DESCRIPTION	UNIT	QUANTITY	UNIT PRICE ($)	TOTAL ($)
1.	**General**				
1.1	Bonding and Insurance	L.S.	1	1,500.00	1,500
1.2	Mobilization/Demobilization	L.S.	1	1,000.00	1,000
1.3	Construction Survey Layout	L.S.	1	1,500.00	1,500
	Sub-total				4,000
2.	**Site Work**				
2.1	Clearing and Grubbing	ha.	0.1	20,000.00	2,000
2.2	Stripping	cu.m	200	6.00	1,200
2.3	Mill Existing Pavement	sq.m	2220	2.50	5,550
2.4	Common Excavation	cu.m	0	7.00	0
2.5	Subgrade Fill Construction	cu.m	2045	5.00	10,225
2.6	Subbase Construction - 300 mm	sq.m	3120	12.00	37,440
2.7	Base Construction - 150 mm	sq.m	3120	6.00	18,720
2.8	Pavement Construction - 100 mm	sq.m	2220	20.00	44,400
2.9	Shoulder Gravel Construction - 100 mm	sq.m	900	8.00	7,200
2.10	Ditching	l.m	300	30.00	9,000
2.11	Line Painting	L.S.	1	500.00	500
2.12	No Post Barriers	l.m.		80.00	0
2.13	Slope Top Dressing	sq.m	1200	2.30	2,760
2.14	Hydroseeding	sq.m	1200	1.20	1,440
	Sub-total				140,435
3.	**Miscellaneous Allowances**				
3.1	Traffic Control and Construction Traffic Re-routing	L.S.	1		3,000
3.5	Environmental Controls	L.S.	1	10,000.00	1,000
	Sub-total				4,000
	SUBTOTAL				148,435
	Engineering 10%				14,844
	Contingencies 15%				22,265
	SUBTOTAL				185,544
	Plus 7% GST				12,988
	Total Estimated Cost				198,532

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Notes:

Appendix C

BC Hydro Letter on Transmission Line Cost

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

BC hydro THE POWER IS YOURS

Property Rights Management
Ingledow Substation
Phone: (604) 590-7664
FAX: (604) 590-7681

RECEIVED MAR 06 2003

FAXED Mar 4/03

4 March 2003

Assignment: 7802
File: 8351 BCH Pt. 1
158 BR
Circuits: 60L68, 2L09/13
Your File: 463.104

VIA FAX: (604) 985-3705

Mr. Ken Ferraby, P.Eng.
Kerr Wood Leidal
139 West 16th Street
North Vancouver, B.C.
V7M 1T3

Dear Mr. Ferraby:

Debris Flow Hazard Mitigation – Deflection Berm – within B.C. Hydro Rights of Way GD117203 and 423746M affecting That part of the NW ¼ of Sec. 23 in Ref. Plan 2623, Twp. 50, Grp. 1, N.W.D and the Northerly 12 ½ Chains of the NW ¼, Sec. 23, Twp. 50, N.W.D.
– South of Cheekye Substation @ Hwy. 99/Alice Lake Road

Thank you for your letter of February 14, 2003.

B.C. Hydro has reviewed your drawings and we have no objection in principle to your proposal. This deflection berm is part of a larger project called the " Cheekye Fan Debris Flow Hazard Mitigation". The berm crosses at right angles to Circuit 2L09 (Str. 460), Circuit 2L13 (Str. 1/3) and Circuit 60L68 and varies in depth from 7 to 9 metres.

To accommodate this, Circuits 2L09 and 2L13 would need additional or replacement structures installed in the area of the proposed berm. Circuit 60L68 runs along the west side of 2L09 and would also need to be raised. The approximate cost for design and construction is $200,000.00.

A separate right of way agreement for the berm across that portion of B.C. Hydro fee owned land (Ref. Plan 2623) will also be required. Please submit a draft right of way agreement for our review.

You may wish to contact Vince Masek, B.C. Hydro Project Management at (604) 528-2874 or Rudy Rugge at (604) 528-2866 to see if your schedule could be coordinated with some uprating work we have planned on these same circuits. This uprating work is schedule to start in early May 2003 and completing June 30, 2003.

Please advise on your course of action. If you have any questions please contact myself or Mike Prettejohn at (604) 590-7693.

Yours truly,

Allison Baguley
Property Management Coordinator

C: V. Masek, E-B03

Appendix D

Environmental Report

KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS

CASCADE ENVIRONMENTAL RESOURCE GROUP LTD.

MEMORANDUM

DATE:	March 6, 2003
TO:	Mike Currie, KWL
CC:	n/a
FROM:	Mike Nelson, R.P.Bio.
RE:	Cheekye Debris Flow Berm – Environmental Issues
FILE #:	036-10-01

INTRODUCTION

Kerr Wood Leidel Ltd. (KWL) is presently conducting a design review of a debris flow protection berm on the Cheekye Fan within the District of Squamish. KWL have retained Cascade Environmental Resource Group Ltd. (CERG) to elucidate the environmental issues associated with this project.

Mike Nelson, R.P.Bio, conducted a cursory investigation on March 4, 2003, consisting of a walking transect along the proposed berm alignment. Vegetation along the route was described, and biophysical information on watercourses encountered was collected. Wildlife and wildlife sign observed during the site visit were noted. Additional information on the area was gathered through existing sources, including forest cover mapping and the fisheries information summary system (FISS).

BASELINE INFORMATION

The length of the proposed berm lies within the dry marine coastal western hemlock biogeoclimatic subzone (CWHdm) This subzone typically occurs in lower elevations (sea level to 650m) on the mainland and adjacent islands in southwestern British Columbia. Climate within the CWHdm subzone consists of warm, relatively dry summers, and moist mild winters with little snowfall.

For the purposes of this evaluation, then project is divided into three segments: the portion of the proposed berm east of Highway 99, the portion of the proposed berm between Highway 99 and Government Road, and the portion of the proposed berm between Government road and the confluence of the Cheakamus and Squamish Rivers.

Proposed Berm East of Highway 99

East of Highway 99, the proposed berm would be located in a young mixed forest, and would parallel and then cross Dryden Creek. This area was previously logged, as is evident by springboard notches in remnant stumps, and was also used for quarrying activities in the past.

WHISTLER OFFICE
Unit 3 – 1005 Alpha Lake Road
Whistler, BC V0N 1B1
Phone (604) 938-1949 Fax (604) 938-1247

SQUAMISH OFFICE
P.O. Box 1043, 2135 Ridgeway Crescent
Garibaldi Highlands, BC V0N 1T0
Phone (604) 898-9859 Fax (604) 898-4326

Dominant tree species within this area include western redcedar, western hemlock, Douglas-fir, and red alder, with bigleaf maple and the occasional Sitka spruce. Forest cover mapping indicates that the trees are between 81 and 100 years of age, and 36.5 to 46.4m in height, with a canopy closure of 66 to 75%. Diameters at breast height (dbh) for typical conifers ranged from 30 to 40 cm, with the occasional veteran western redcedar observed to 80cm dbh. The shrub layer included vine maple, salmonberry, red huckleberry and juvenile western redcedar and western hemlock. Ground cover species included sword fern and Oregon grape, and various mosses.

Mixed forests are productive and attractive to many wildlife species because of the diversity of trees, the presence of snags, and varied under-story. Common mammals likely to be found in the young mixed forests of the subject area include Douglas squirrel, yellow-pine chipmunks, shrews, southern red-backed vole, the bushy-tailed woodrat, white-footed mouse, Pacific jumping mouse, and bats. Larger mammals would include American black bear, black-tailed deer, coyote, raccoon, and cougar.

Passerine bird species are likely to be abundant in the young mixed forest east of Highway 99. The most common species would include song sparrow, spotted towhee, dark-eyed junco, American robin, Swainson's thrush, white-crowned sparrow, and various warblers. Raptors, such as the bald eagle, are expected to use the veteran trees for roosts.

Amphibians and reptiles, typical of the CWBdm subzone would also utilize this area. Typical species could include Pacific tree frog, red-legged frog and common garter snake.

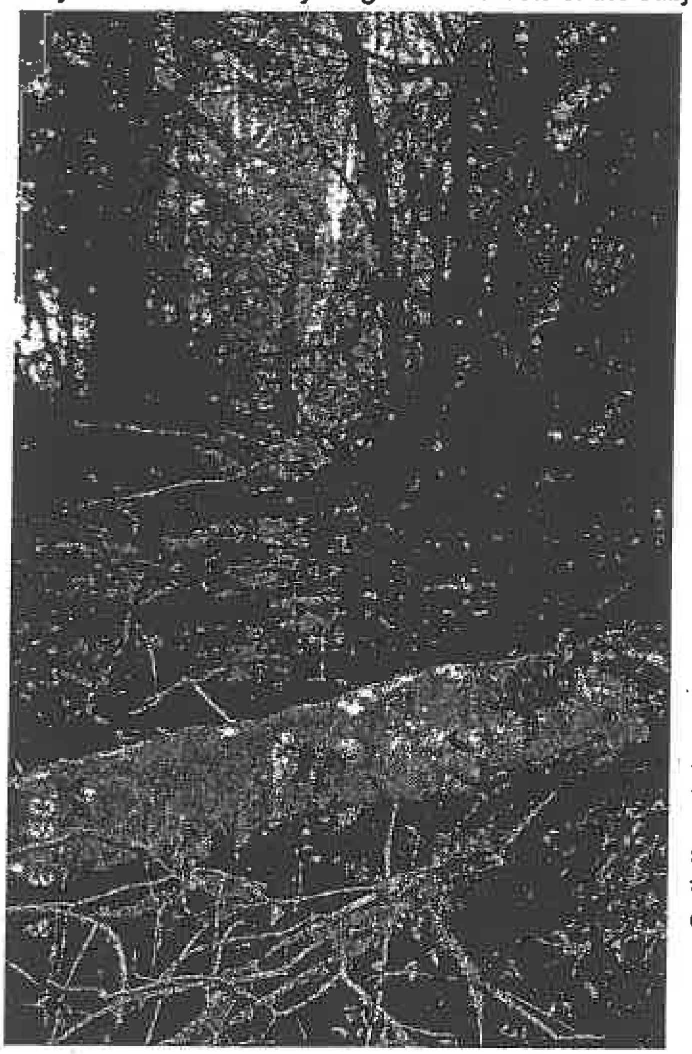

Photo 1 – Dryden Creek at berm crossings site

WHISTLER OFFICE
Unit 3 – 1005 Alpha Lake Road
Whistler, BC V0N 1B1
Phone (604) 938-1949 Fax (604) 938-1247

SQUAMISH OFFICE
P.O. Box 1043, 2135 Ridgeway Crescent
Garibaldi Highlands, BC V0N 1T0
Phone (604) 898-9859 Fax (604) 898-4326

The proposed berm would also parallel and cross Dryden Creek. This small creek is known to support anadromous chum and coho salmon, as well as adfluvial cutthroat and rainbow trout, and lamprey. Steelhead are also noted in the FISS records.

On March 4, 2003, the wetted width of Dryden Creek at the proposed berm crossing site was 2.5m, with a channel width of 4m. The gradient was approximately 3%, and flow was considered low (~ 0.05 m^3/s). The flows were characterized a 70% riffle, 20% glide and 10% pool, over a gravel and cobble dominated substrate. Stream cover was provided by over-stream vegetation, both small and large woody debris, and the occasional deeper pool. At the time of the site visit, the water was clear with the temperature recorded at 4.9 °C.

Proposed Berm Between Highway 99 and Government Road

West of Highway 99 and east of Government Road, the proposed berm is located in a young coniferous forest, which was logged during the same time period as the forest east of Highway 99. A high voltage BC Hydro transmission line also transects, the site where the tree cover is removed. There are no watercourses or wetlands in this area.

Photo 2 – Young Coniferous Forest adjacent to Ross Road

Dominant tree species within this area include western hemlock, western redcedar and Douglas-fir. The ages of the trees range between 81 and 100 years, with heights varying from 28.5 to 37.4m in drier sections and varying from 37.5 to 46.4m in height in richer sites. The canopy closure is 66 to 75%. Representative tree diameters for the former sites were 21cm dbh for a western redcedar, and 13 & 25 cm dbh for two western hemlock, and 24 & 24 cm dbh for two Douglas-fir.

On the richer sites, typical diameters were 57cm dbh for a western redcedar, 46cm dbh for a western hemlock, and 54cm dbh for a Douglas-fir. Occasional veteran Douglas fir trees with dbh's of over 1m were also observed. The shrub layer was generally sparse, and comprised of species are similar to those described for the lands east of Highway 99. Ground cover consisted of an almost continuous moss layer comprised of step moss, pipe cleaner moss, among others. Under the powerlines, vegetation is maintained to a restricted high, and therefore is confined to ground cover and shrubs, with juvenile trees. Compared to the portion of the berm east of Highway 99 and west of Government Road, there are few snags in this young forest.

Wildlife in this area would be similar to that previously described, although the bird community may shift to include species such as chestnut-backed chickadee, golden-crowned kinglet, Steller's jay and Pacificslope flycatcher. The presence of amphibians may also be reduced due to the lack of ponding water in this area. As with the lands east of Highway 99, veteran trees may also provide suitable roost sites for raptors, and potential denning sites for bats.

Proposed Berm West of Government Road

West of Government Road, the proposed berm would be located in areas of young coniferous forest, as well as in areas described as non-productive brush. The berm would abut the banks of the Squamish River at its confluence with the Cheakamus River, where there would be armouring requirements.

The young coniferous forest is similar to those previously described, however, closer to the river the forest varies to a pole-sapling mixed forest with a shrub component in the forest openings. There is evidence of historic springboard logging, and old skidders roads throughout. The pole-sapling forest is dominated by western hemlock, with examples of western redcedar, red alder, some paper birch and Douglas-fir. The shrub and ground cover layers vary from very sparse to dense, depending on the canopy closures, with species including salmonberry, red huckleberry, vine maple, salal, sword fern, bunchberry. Some small snags are present.

Wildlife occurring in the young coniferous forest would be similar to that described for the portion of the berm between Highway 99 and Government Road. Within the sapling pole forest and clearings, there would be similar species, with a more abundant passerine bird population.

The Squamish and Cheakamus Rivers form the western terminus of the proposed berm. A detailed examination of those systems is beyond the scope of this review; however, fisheries, aquatic and riparian habitat values associated with these systems are known to be high. The gravel bars on the rivers would also be utilized by bald eagles in the winter months in the quest food (i.e. salmon carcasses). Tall riparian vegetation would also be used as roosting sites.

CASCADE ENVIRONMENTAL RESOURCE GROUP LTD.

WHISTLER OFFICE
Unit 3 – 1005 Alpha Lake Road
Whistler, BC V0N 1B1
Phone (604) 938-1949 Fax (604) 938-1247

SQUAMISH OFFICE
P.O. Box 1043, 2135 Ridgeway Crescent
Garibaldi Highlands, BC V0N 1T0
Phone (604) 898-9859 Fax (604) 898-4326

ENVIRONMENTAL ISSUES

The location of the proposed berm will result in the loss of young coniferous and mixed forests along its alignment, which in turn will result in a displacement of wildlife along the route. In addition, the berm will parallel and the cross Dryden Creek which will result in a potential loss of both riparian and aquatic habitat. The bank armouring at the confluence of the Squamish and Cheakamus Rivers could also result in losses of riparian habitat. Specific areas of environmental concern are as follows:

- There will be a loss or young coniferous and young mixed forest along the berm alignment. These impacts can be adequately addressed through an appropriate berm revegetation plan that includes shrub and tree species.
- There will be a potential loss of small mammal and passerine bird habitat. This issue can again be addressed with adequate revegetation of the berm.
- There could be potential disruptions to large mammal movement through the area as a result of berm construction. Mitigation could include appropriate accessible slope angles on the berm, as well as provision of adequate vegetation cover.
- Removal of remnant veteran trees may affect potential roosting and possibly nesting sites for raptors, particularly bald eagle, as well as roosting sites for bats.
- The berm paralleling Dryden Creek will potentially reduce riparian habitat. Revegetation will mitigate these effects.
- Aquatic habitat within Dryden Creek will be affected by the berm crossing. The crossing type should be reviewed with regards to habitat requirements, flow limitations, and fish passage concerns.
- Armouring the bank at the confluence of the Squamish and Cheakamus River could impact riparian vegetation and aquatic habitat. At present, this bank is an un-vegetated gravel slope, set back from the rivers. However, with time the river could shift to this location, or the slopes may stabilize and become vegetated. Armouring at this location will require compensatory works. Timing of the armouring may also be an issue, particularly as it relates to fisheries windows and bald eagle movements in this area.
- Potential aesthetic and recreational impacts were not assessed as part of this review.

RECOMMENDATIONS AND CONCLUSIONS

This memorandum serves as a cursory environmental review of the Cheekye Fan debris flow deflection berm. The purpose of this review is to briefly assess environmental concerns and provide recommendations for development of appropriate compensation and mitigation, and to recommend further studies where there are information gaps.

Based on the information reviewed and the conditions observed, the following recommendations are made to minimize potential negative environmental impacts on the site arising from construction of the berm:

1. The berm should be sloped at a low angle to facilitate movement of wildlife through the area. A blanket of material should be placed on the surface of the berm, so that the berm can be re-vegetated.

2. Paralleling Dryden creek with the berm will result in removal of riparian habitat. It is recommended that the berm not parallel the creek if possible, but rather approach the creek crossing on a right angle. If this is not possible, extensive re-vegetation efforts will be necessary, along with possible compensation measures.

3. The berm crossing of Dryden Creek should be required upon completion of the final design. The design should consider timing of construction, minimization of habitat losses, and fish passage concerns. Any potential alteration or destruction of fish habitat will require authorization for Fisheries and Oceans Canada (as well as from the ministry of Water, Land and Air Protection), which will likely entail development and implementation of a mitigation/compensation plan.

4. Armouring of the bank of the Squamish and Cheakamus River will also require approval from the fish and wildlife protection agencies. While this bank is presently an un-vegetated gravel slope, the regulatory agencies will likely require compensation for lost potential habitat. The works will also have to cognizant of the fisheries window, a well as bald eagle movements in the area, particularly in the winter months.

5. Land clearing activity should be conducted with due diligence between April 1 and July 31, to comply with the Section 34 of the Wildlife Act, which forbids the destruction of nests occupied by a bird, its eggs, or its young.

6. Site preparation and construction works should be monitored by a qualified environmental monitor.

The following additional studies/plans are recommended:

1. A revegetation/landscape plan should be developed to address concerns and potential conflicts with development adjacent to riparian areas, and to re-establish native shrub and tree species to facilitate wildlife movements.

2. A raptor survey should be conducted prior to detailed design of the berm. Nests of raptors such as bald eagle, red-tailed hawk and northern goshawk must be adequately protected by forested buffer while the nest is occupied. Nests of bald eagle and great blue heron require protection whether they are active or not.

3. A drainage plan should also be developed to deal with concerns related to land clearing, grubbing, and construction. The drainage plans should adhere to the Land Development Guidelines for the protection of Aquatic Habitat.

4. Construction of the berm crossing of Dryden Creek, and armouring the bank of the Squamish and Cheakamus River confluence require review under Section 9 of the *Water Act*, and approval under section 35(2) of the *Fisheries Act*.

WHISTLER OFFICE
Unit 3 – 1005 Alpha Lake Road
Whistler, BC V0N 1B1
Phone (604) 938-1949 Fax (604) 938-1247

SQUAMISH OFFICE
P.O. Box 1043, 2135 Ridgeway Crescent
Garibaldi Highlands, BC V0N 1T0
Phone (604) 898-9859 Fax (604) 898-4326

Appendix E

KWL Drawings 463.104, Sheets, 1 to 7, Revision 0

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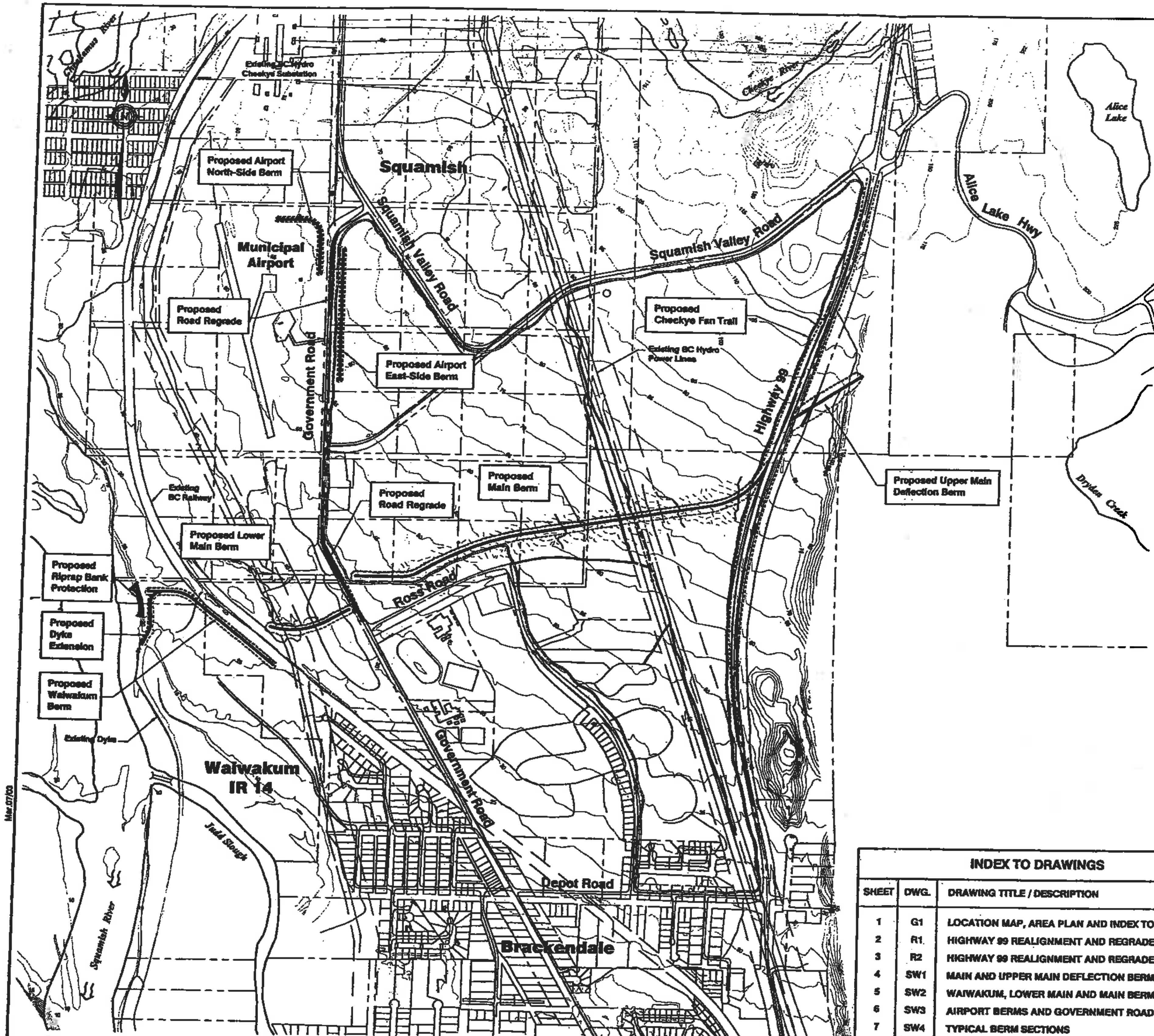

AREA PLAN

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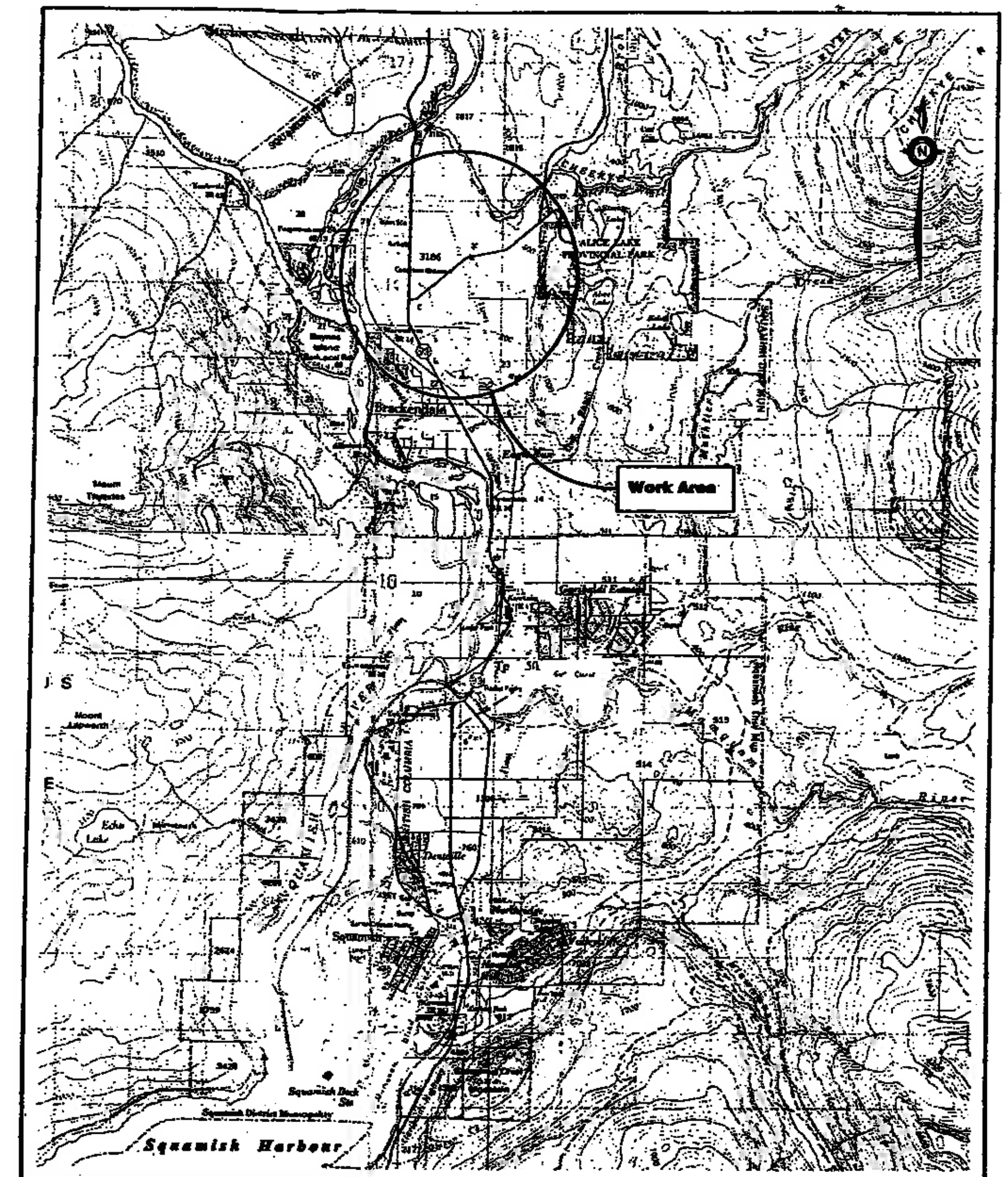

LOCATION MAP

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INDEX TO DRAWINGS		
SHEET	DWG.	DRAWING TITLE / DESCRIPTION
1	G1	LOCATION MAP, AREA PLAN AND INDEX TO DRAWINGS
2	R1	HIGHWAY 99 REALIGNMENT AND REGRADE - SHEET 1
3	R2	HIGHWAY 99 REALIGNMENT AND REGRADE - SHEET 2
4	SW1	MAIN AND UPPER MAIN DEFLECTION BERMS - SHEET 1
5	SW2	WAIWAKUM, LOWER MAIN AND MAIN BERMS - SHEET 2
6	SW3	AIRPORT BERMS AND GOVERNMENT ROAD REGRADES
7	SW4	TYPICAL BERM SECTIONS

DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS

ISSUED INFORMATION: Issued for	Issue	Date	Issued By
Reference			
Approvals	A0	Mar.07/03	KF
Tender			
Permits			
Construction			
Record Drawings			

REVISION INFORMATION: Rev. No.	Date	Designed	Drawn	Checked	Description of Revision	Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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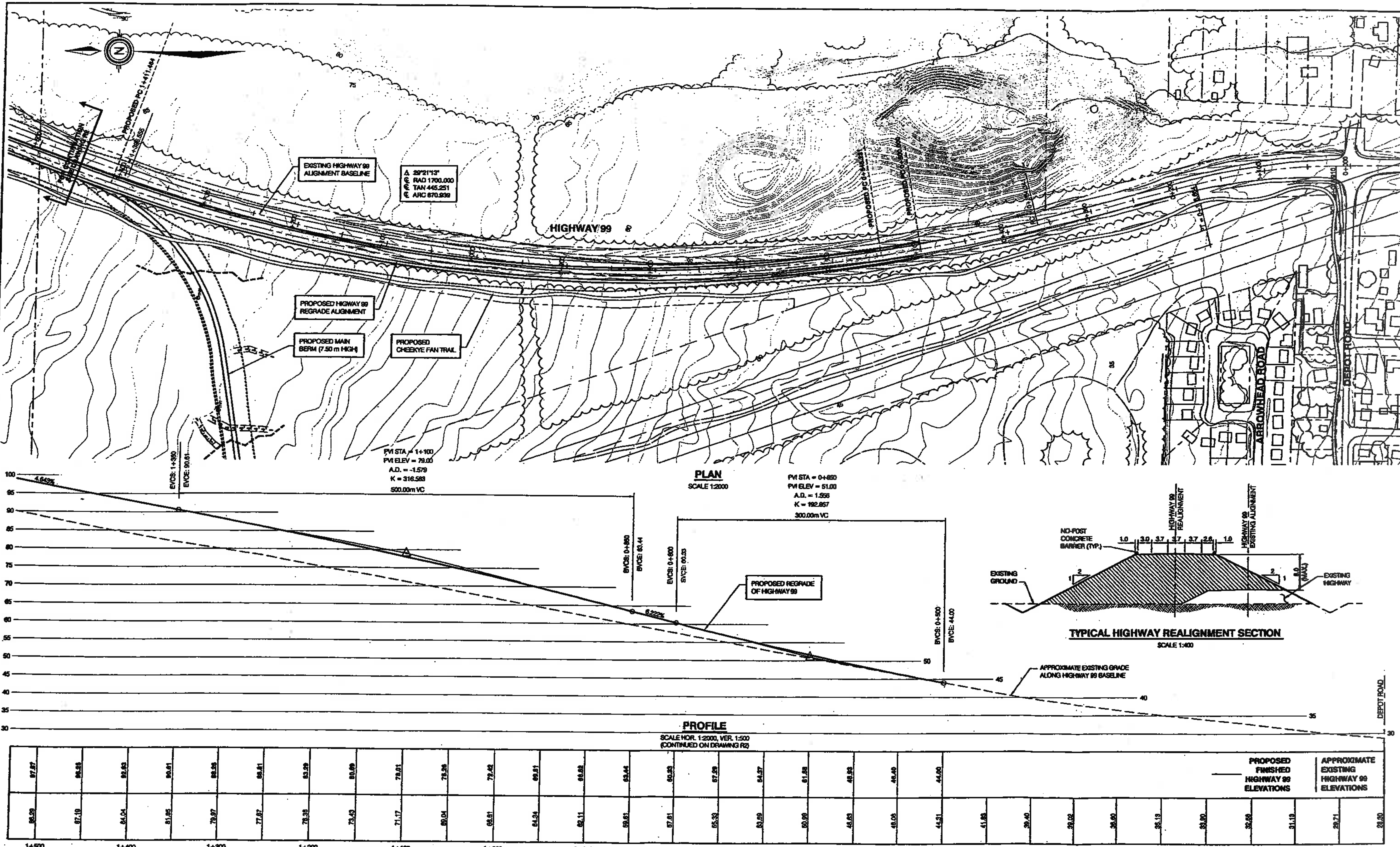
DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
LOCATION MAP, AREA PLAN & INDEX TO DRAWINGS

KWL Project No. 463.104 | Scale AS SHOWN | G1 Drawing Number
Sheet 1 of 7 | Rev. No. 0
Client: District of Squamish | This Drawing Reduced by 50 % (x)

463-104\Drawings\463104G1.dwg
Mar.07/03



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DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
HIGHWAY 99 REALIGNMENT & REGRADE - SHEET 1

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Sheet 2 of 7 Rev. No. 0
Drawing Number R1
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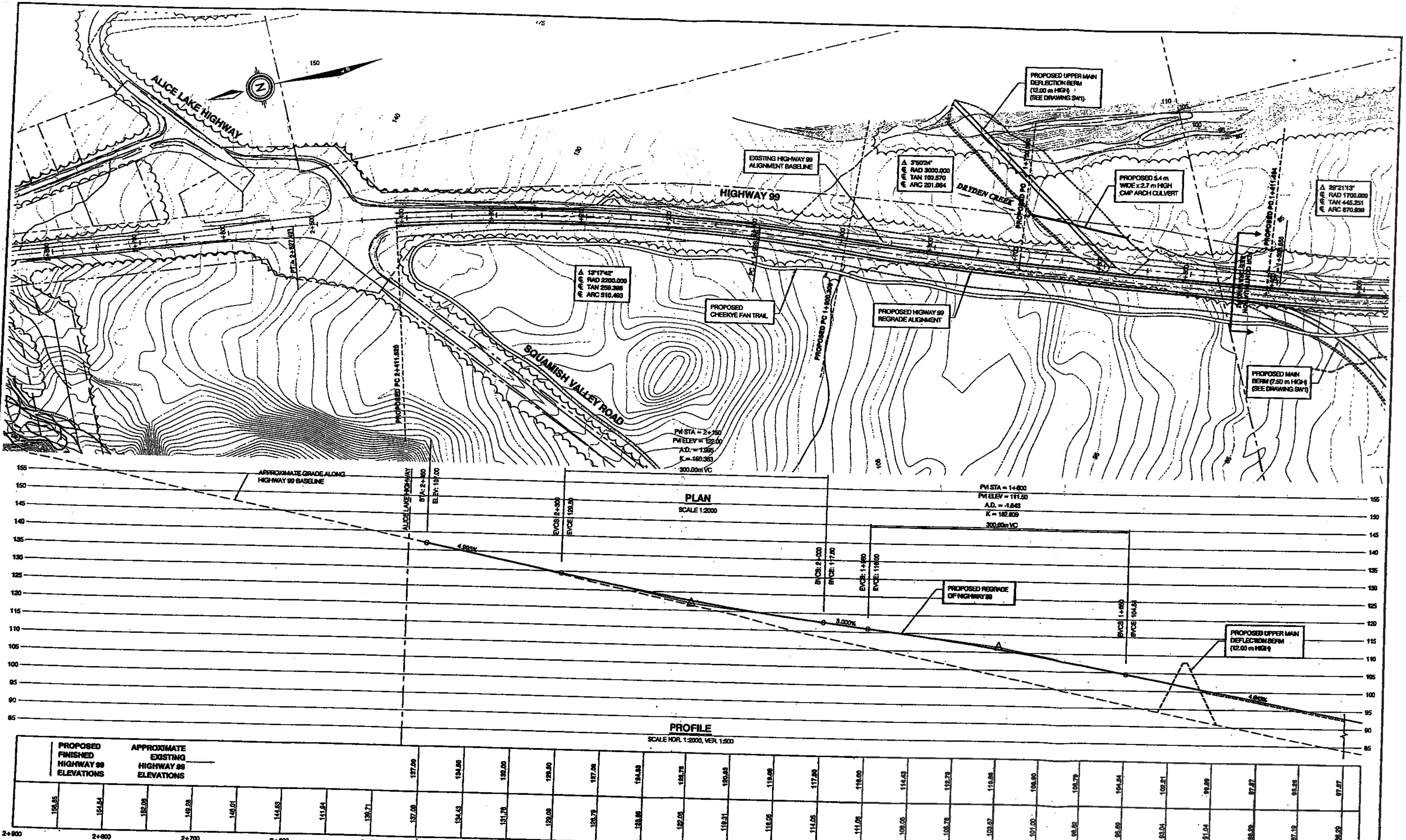

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DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
HIGHWAY 99 REALIGNMENT & REGRADE - SHEET 2

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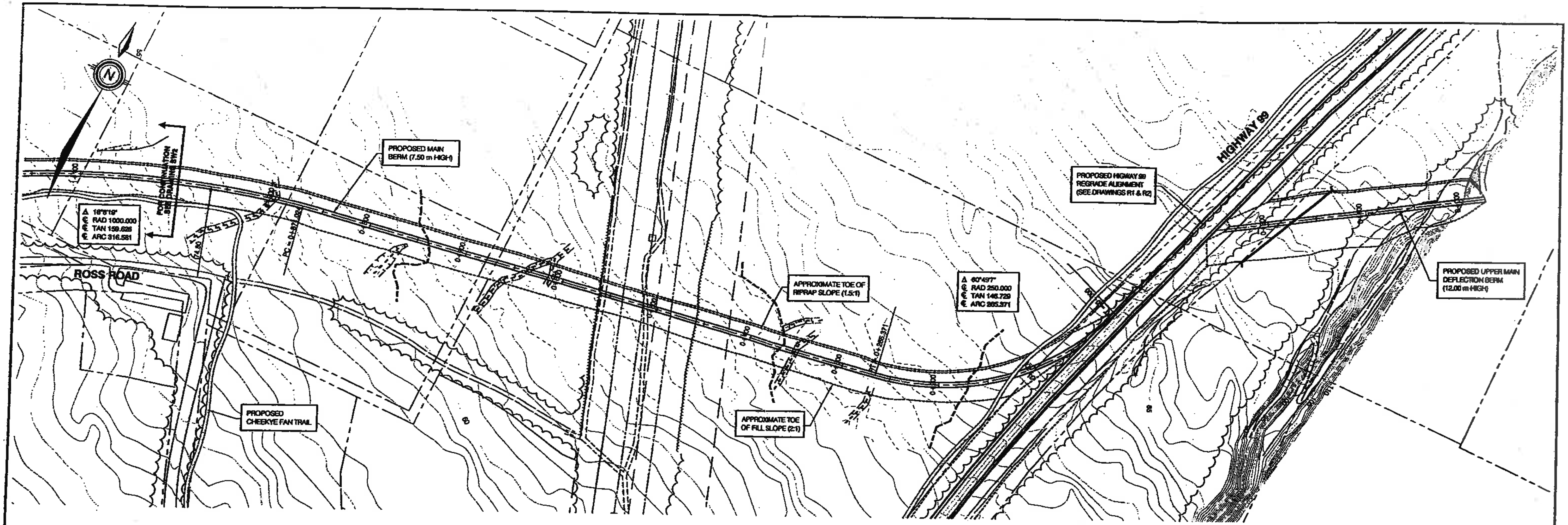

PLAN

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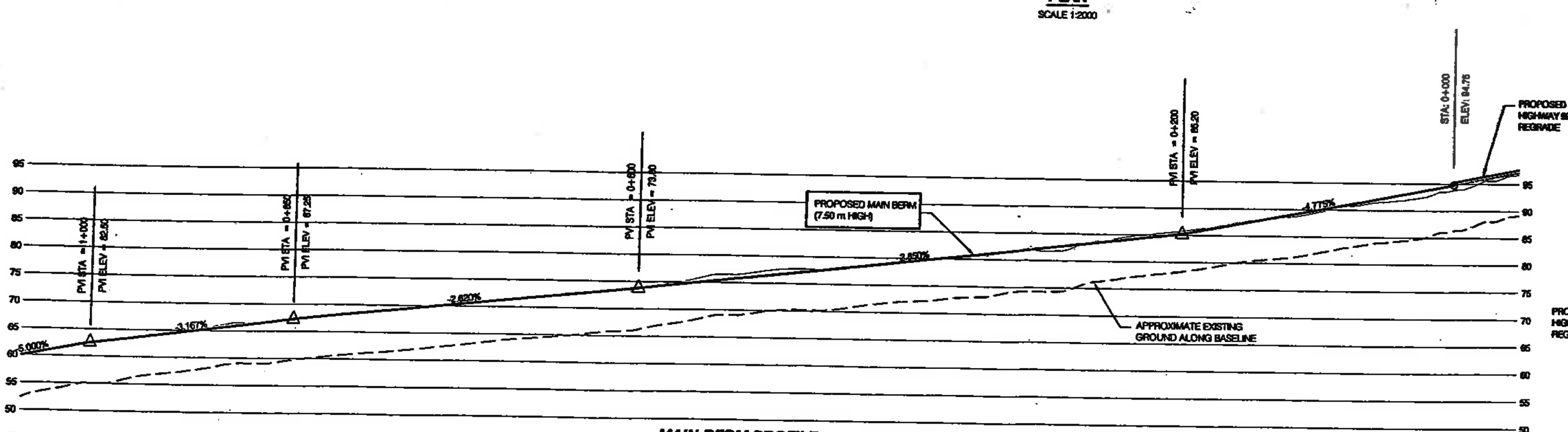
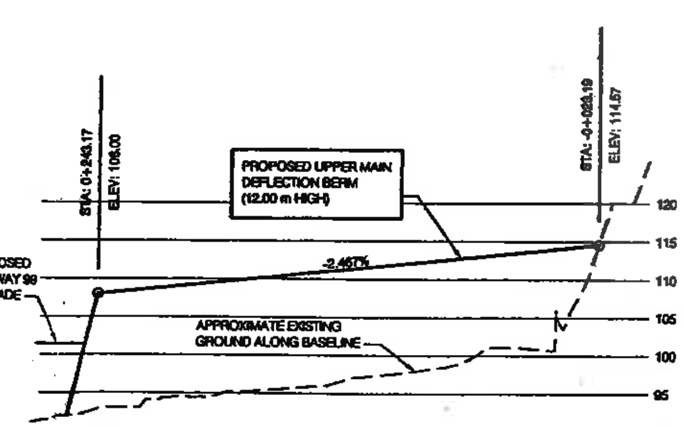


MAIN BERM PROFILE

SCALE HOR. 1:2000, VER. 1:500
(CONTINUED ON DRAWING SW2)

Station	BERM ELEV'S
1+000	62.50
	64.08
0+900	65.67
	67.25
0+800	68.58
	69.87
0+700	71.18
	72.49
0+600	73.80
	75.22
0+500	76.65
	78.07
0+400	79.50
	80.92
0+300	82.35
	83.77
0+200	85.20
	87.59
0+100	89.97
	92.36
0+000	94.76



UPPER MAIN DEFLECTION BERM PROFILE

SCALE HOR. 1:2000, VER. 1:500

Station	BERM ELEV'S
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	110.30
0+100	111.53
	112.77
0+000	114.00

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Issued for	Issue	Date	Issued By
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Approvals	A0	Mar.07/03	KF
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Permits			
Construction			
Record Drawings			

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Rev. No.	Date	Designed	Drawn	Checked	Description of Revision
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DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
MAIN & UPPER MAIN DEFLECTION BERMS - SHEET 1

KWL Project No. 463.164 | Scale AS SHOWN | SW1 Drawing Number
Sheet 4 of 7 | Rev. No. 0

Client: District of Squamish

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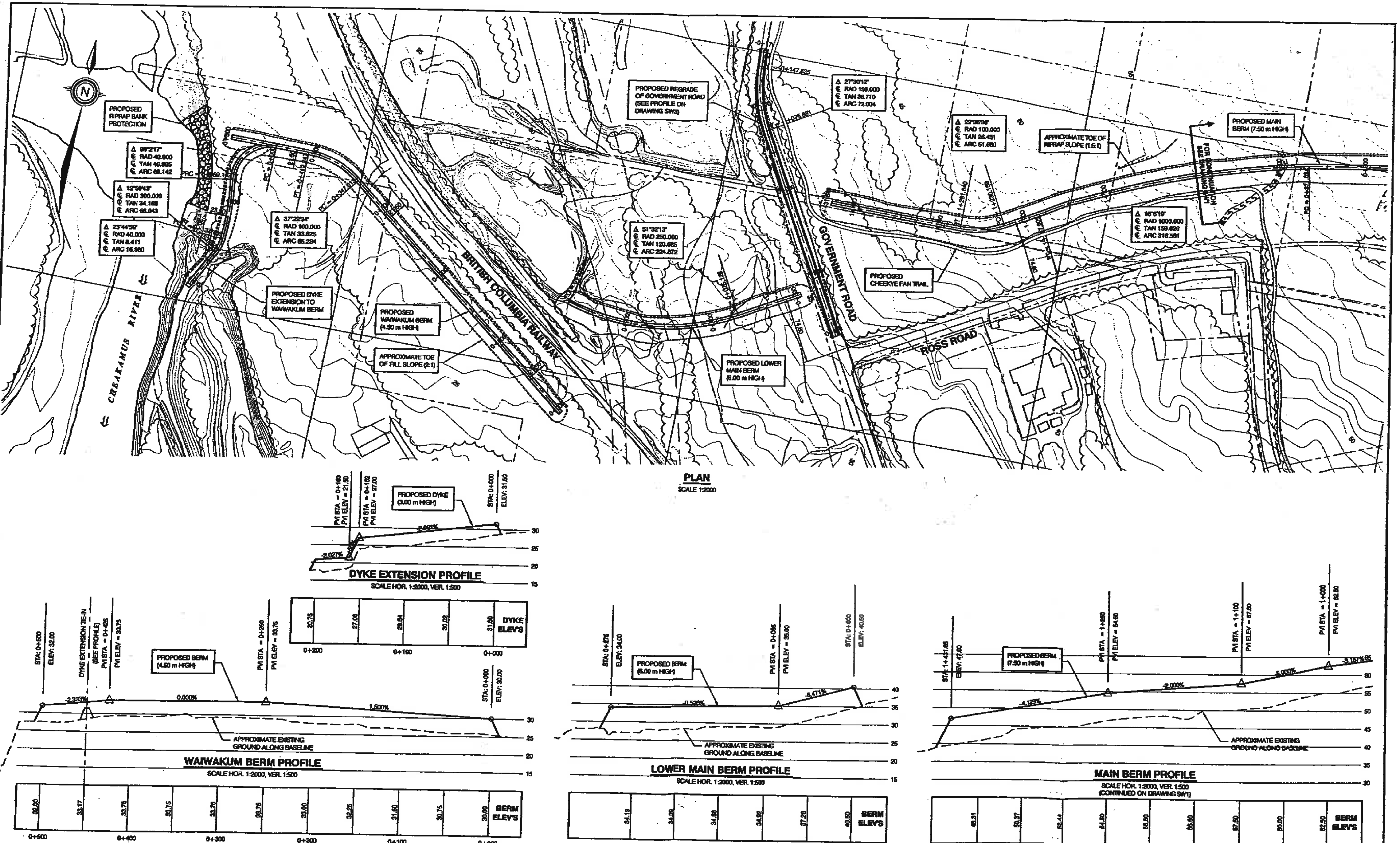

Issued for	Issue	Date	Issued By
Reference			
Approvals	A0	Mar.07/03	KF
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Permits			
Construction			
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DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
WAIWAKUM, LOWER MAIN & MAIN BERMS - SHEET 2

KWL Project No. 463.104 | Scale AS SHOWN
Sheet 5 of 7 | Rev. No. 0
Client: District of Squamish

SW2
Drawing Number

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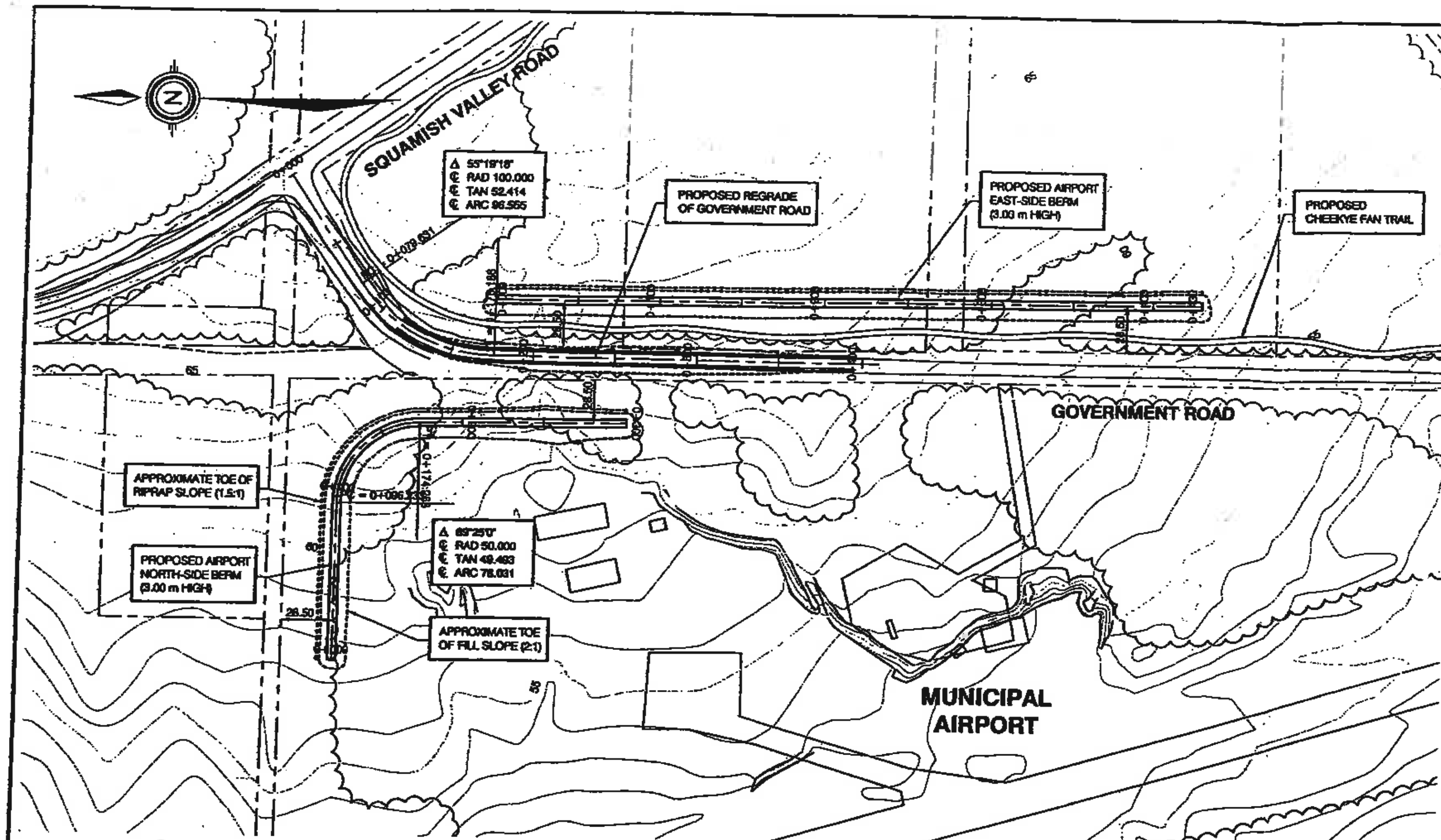

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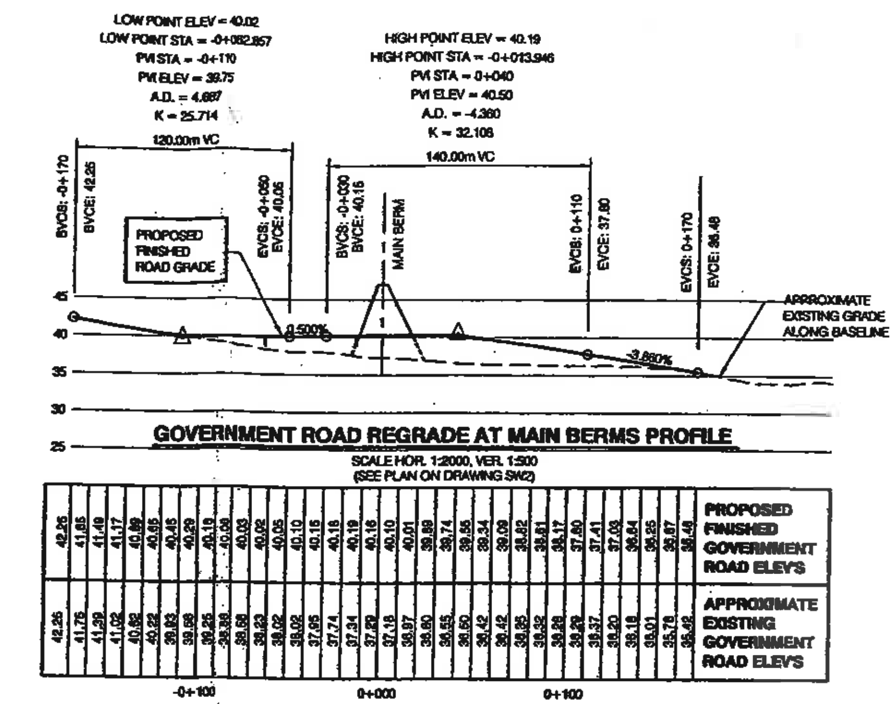

GOVERNMENT ROAD REGRADE AT MAIN BERMS PROFILE
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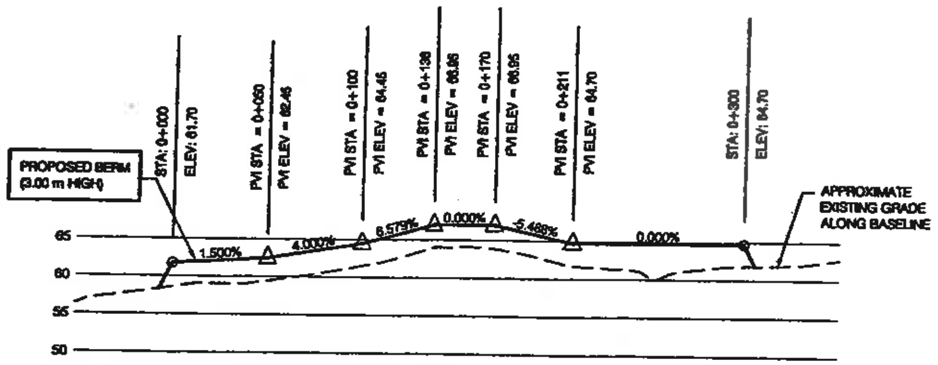
(SEE PLAN ON DRAWING SW2)



AIRPORT NORTH-SIDE BERM PROFILE
SCALE HOR. 1:2000, VER. 1:500

BERM ELEV'S						
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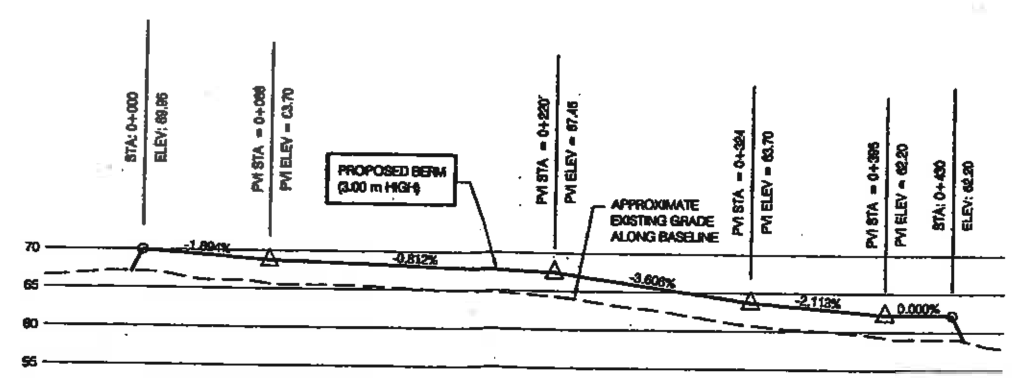
0+000 0+100 0+200 0+300



AIRPORT EAST-SIDE BERM PROFILE
SCALE HOR. 1:2000, VER. 1:500

BERM ELEV'S								
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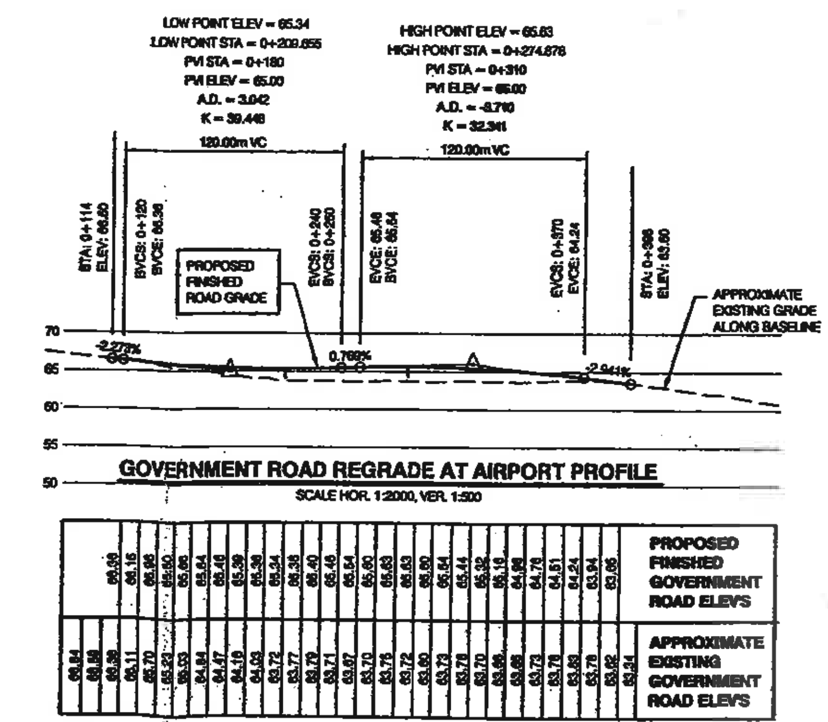
0+000 0+100 0+200 0+300 0+400



GOVERNMENT ROAD REGRADE AT AIRPORT PROFILE
SCALE HOR. 1:2000, VER. 1:500

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Approvals	A0	Mar.07/03	KF
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Permits			
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DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
AIRPORT BERMS & GOVERNMENT ROAD REGRADES

KWL Project No. 463.104 | Scale AS SHOWN
Sheet 6 of 7 | Rev. No. 0
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Drawing Number
Client: District of Squamish
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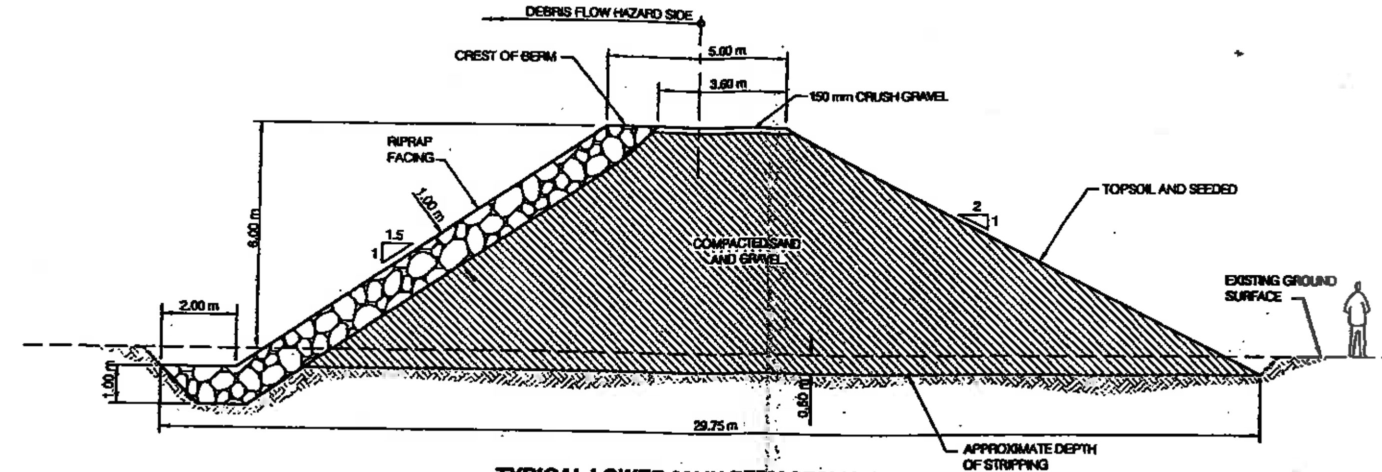

TYPICAL LOWER MAIN BERM SECTION

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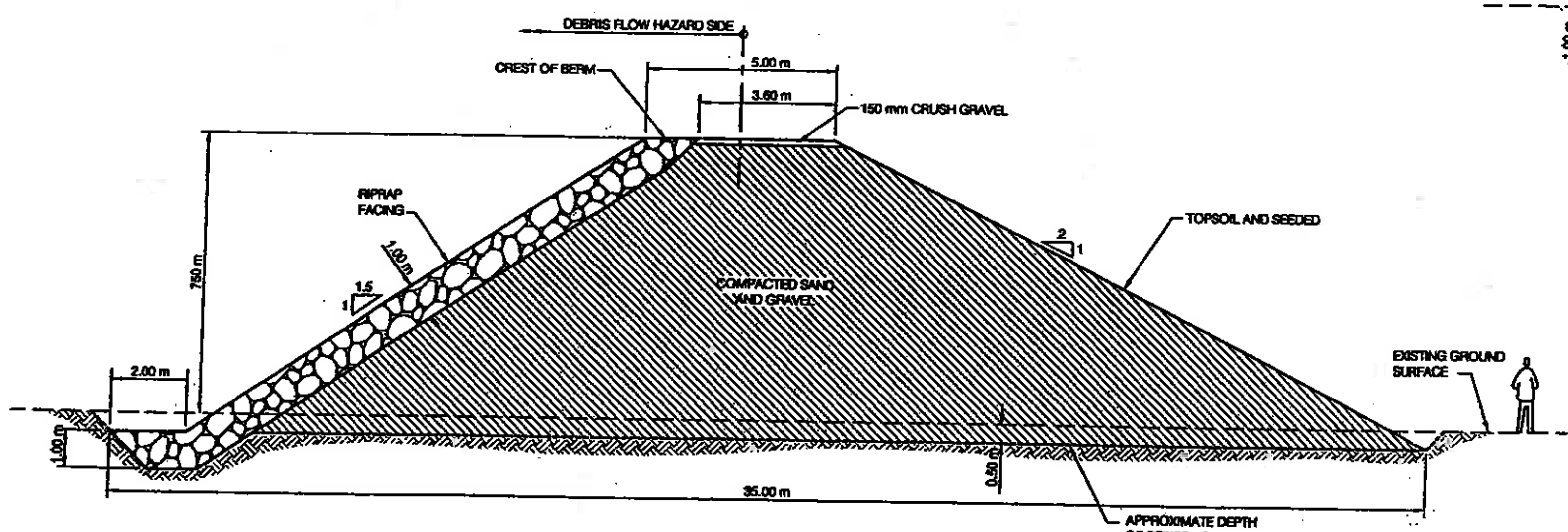

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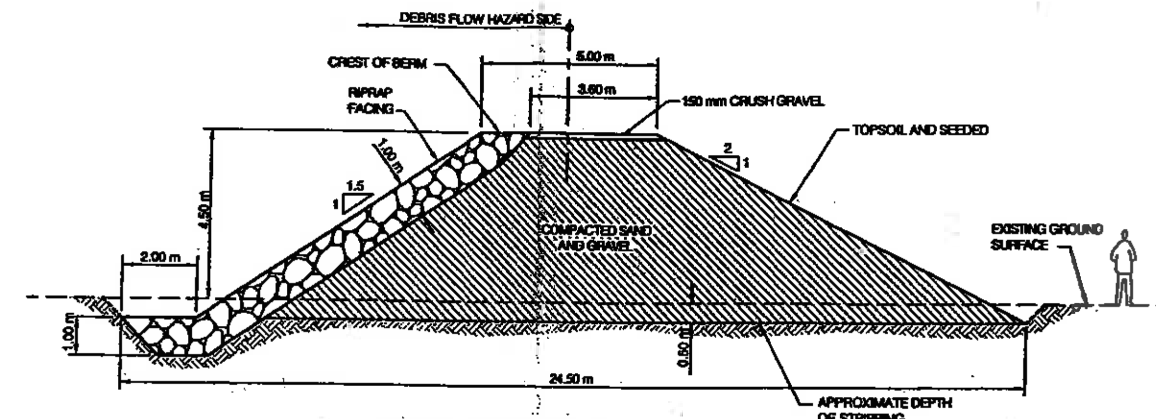

TYPICAL WAIWAKUM BERM SECTION

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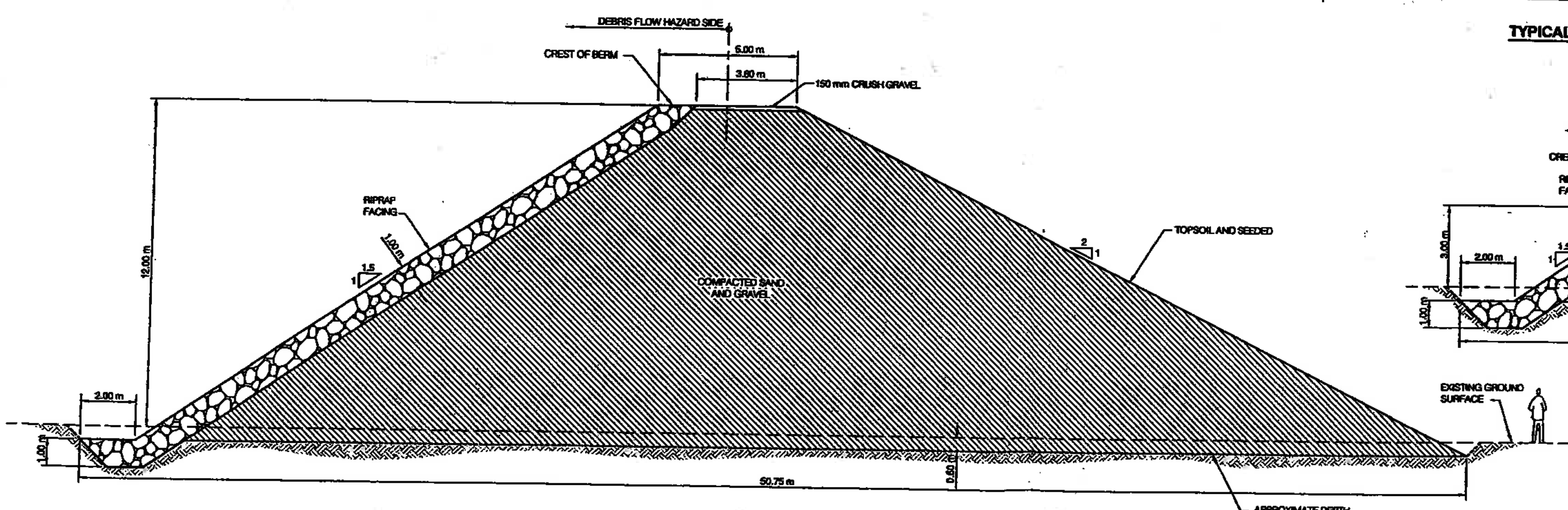

TYPICAL UPPER MAIN DEFLECTION BERM SECTION

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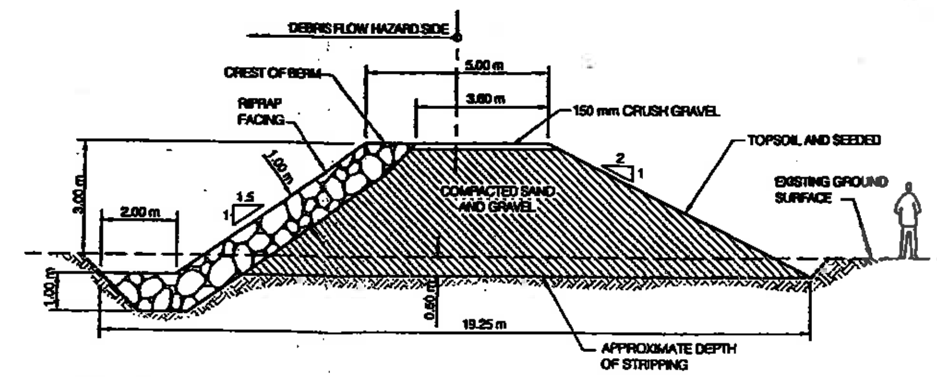

TYPICAL AIRPORT BERMS SECTION

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Mar.07/03

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ISSUED INFORMATION

Issued for	Issue	Date	Issued By
Reference			
Approvals	A0	Mar.07/03	KF
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REVISION INFORMATION

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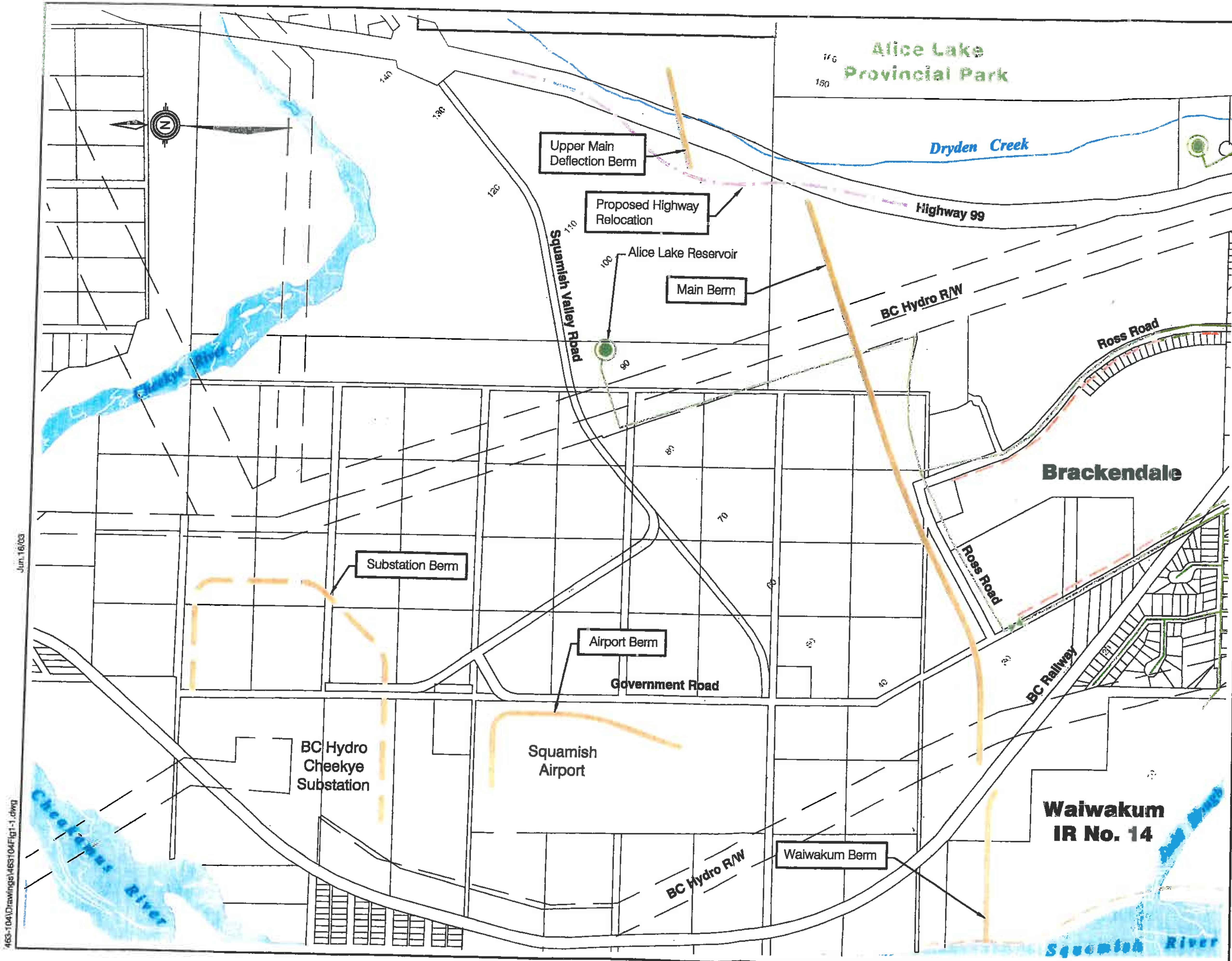
DISTRICT OF SQUAMISH
CHEEKYE FAN DEBRIS FLOW DEFLECTION BERMS
TYPICAL BERM SECTIONS

KWL Project No. 463.104		Scale AS SHOWN		SW4 Drawing Number
Sheet 7 of 7		Rev. No. 0		
Client: District of Squamish			This Drawing Reduced by 50 % (x) [illegible]	



District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms

Note:

This figure shows the original deflection berm scheme proposed by the District and MWLAP.

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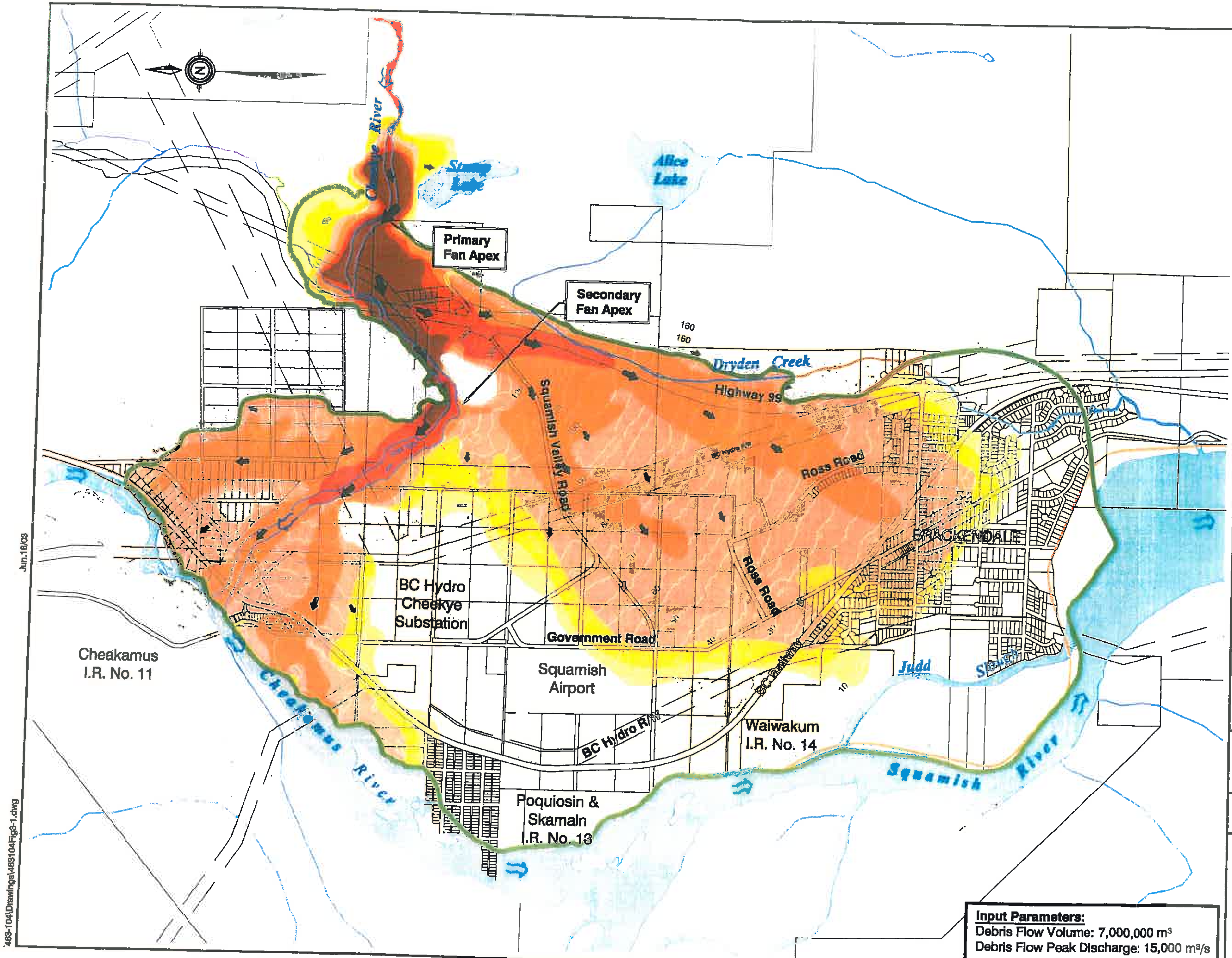
Project No.	Date
463-104	June 2003

Original Deflection Berm Concept

Figure 1-1

Jun.16/03

463-104\Drawings\463104Fig1-1.dwg



District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms

Legend

Flow Depth (m)	Flow Velocity (m/s)
0 - 0.3	
0.3 - 2	0-2
2 - 4	2-4
4 - 6	4-6
6 - 8	6-8
> 8	>8

Existing Dyke

Fan Boundary (Approximate)

Notes:

Debris deposition areas shown on this figure are generalizations of model results.

Local avulsions could change the distribution, depth and velocity of debris flows.

Debris flow reaching Cheakamus River will likely cause temporary blockage or diversion. Debris deposition is purposely ended on the east bank of Cheakamus River.

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500 0 500
Scale in Metres

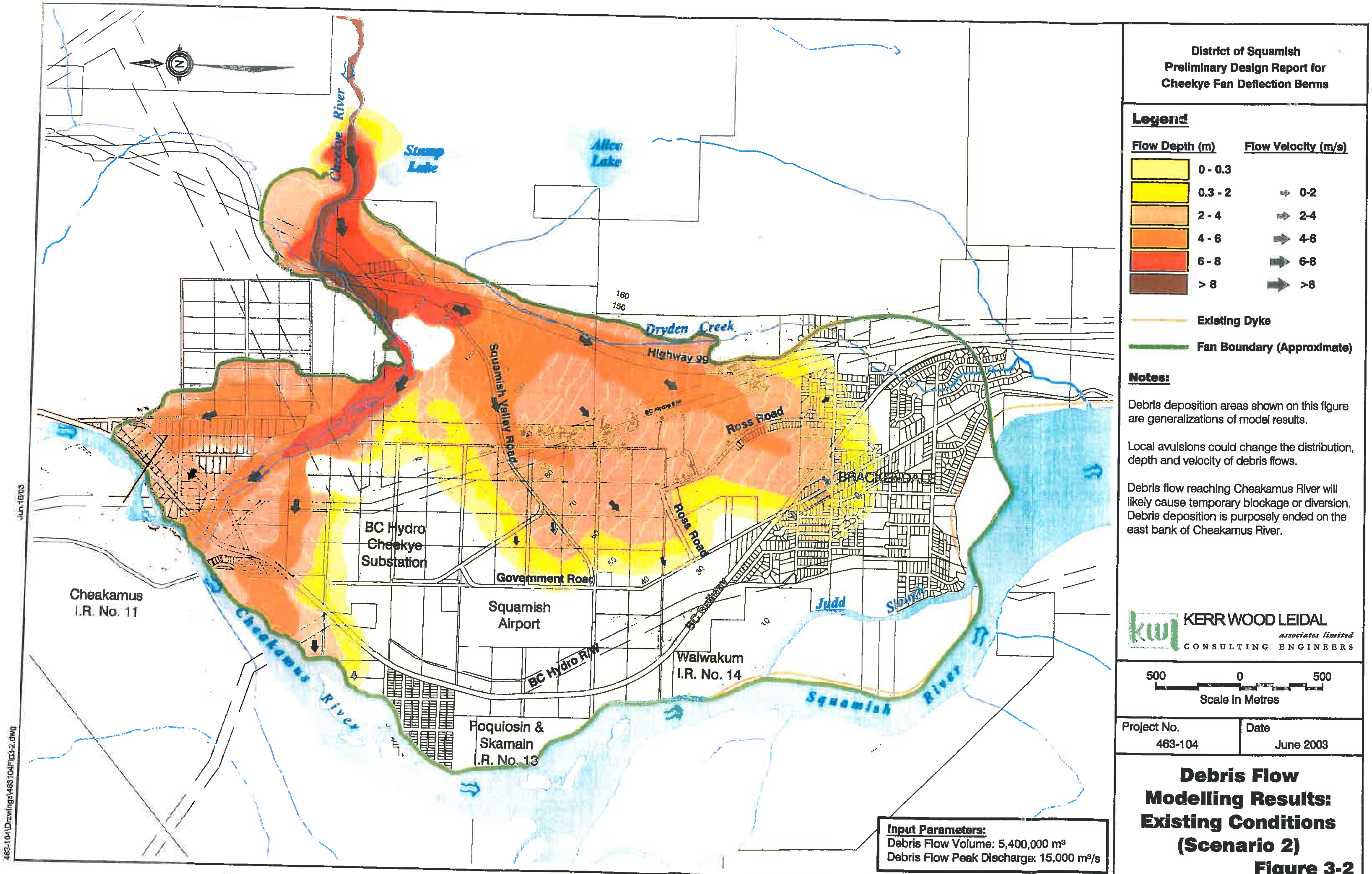
Project No.	Date
463-104	June 2003

Debris Flow Modelling Results: Existing Conditions (Scenario 1)

Figure 3-1

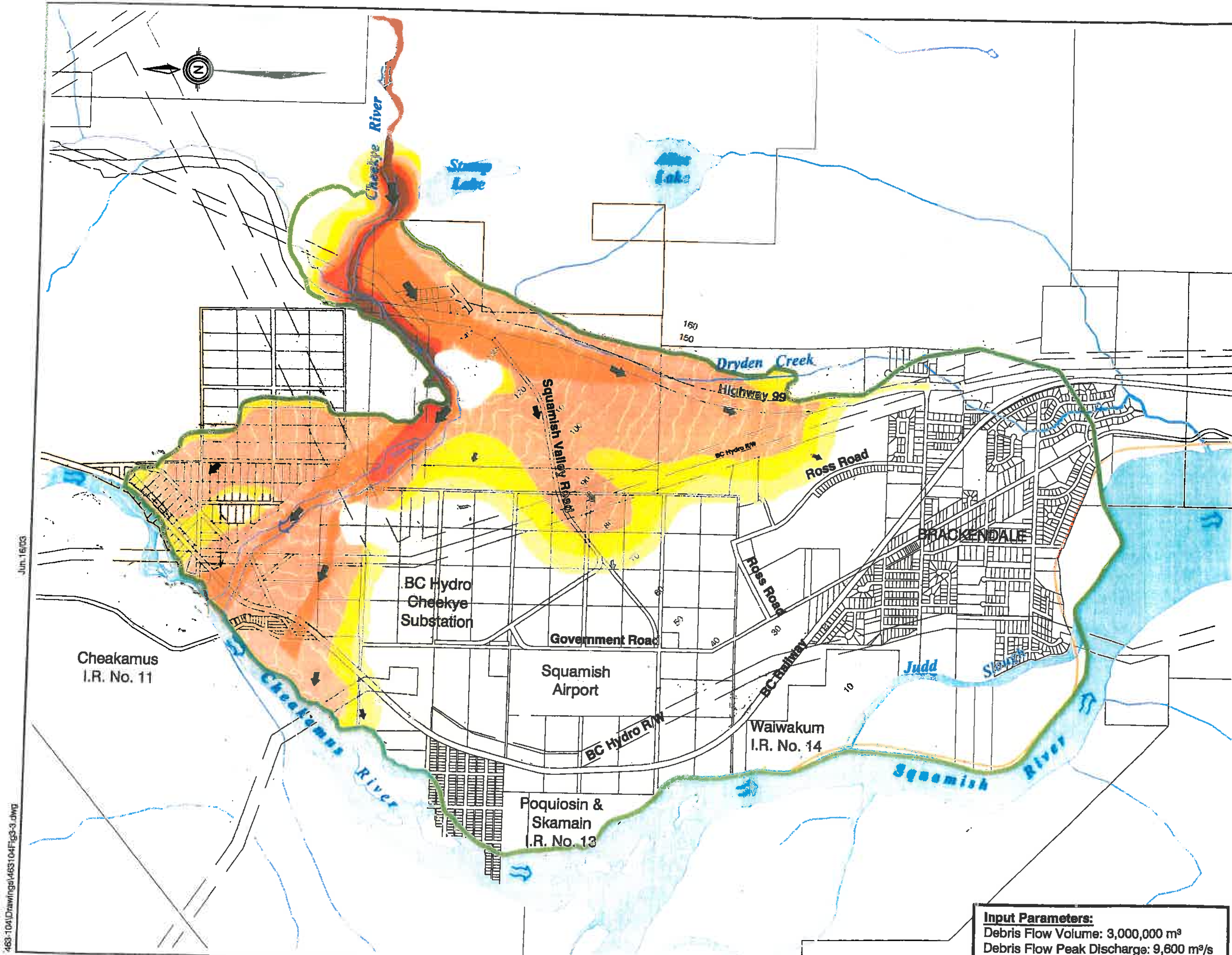
Jun.16/03

463-104\Drawings\463104Fig3-1.dwg



Debris Flow Modelling Results: Existing Conditions (Scenario 2)

Figure 3-2



District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms

Legend

Flow Depth (m)	Flow Velocity (m/s)
0 - 0.3	
0.3 - 2	0-2
2 - 4	2-4
4 - 6	4-6
6 - 8	6-8
> 8	>8

Existing Dyke

Fan Boundary (Approximate)

Notes:

Debris deposition areas shown on this figure are generalizations of model results.

Local avulsions could change the distribution, depth and velocity of debris flows.

Debris flow reaching Cheakamus River will likely cause temporary blockage or diversion. Debris deposition is purposely ended on the east bank of Cheakamus River.

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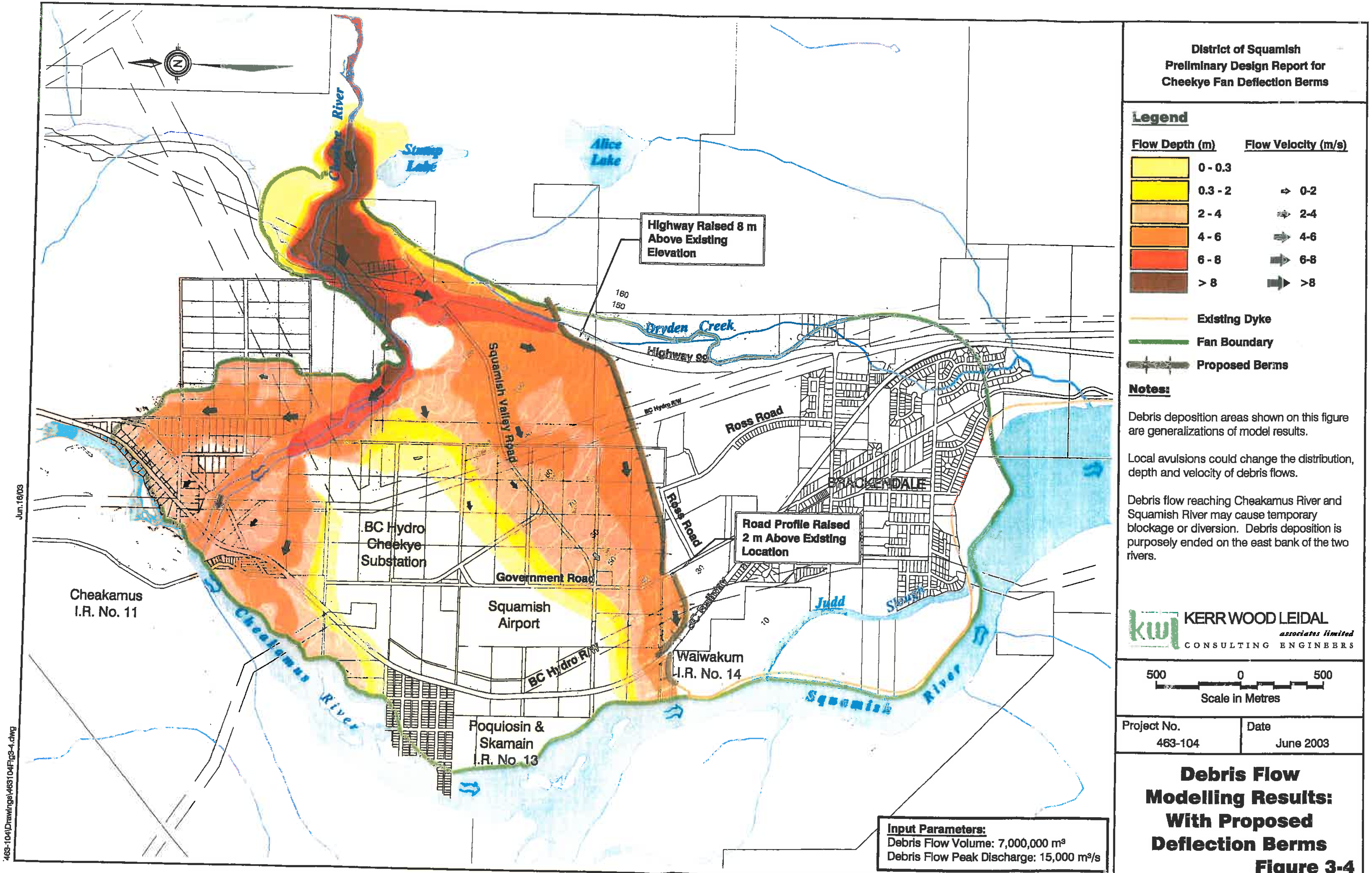
500 0 500
Scale in Metres

Project No.	Date
463-104	June 2003

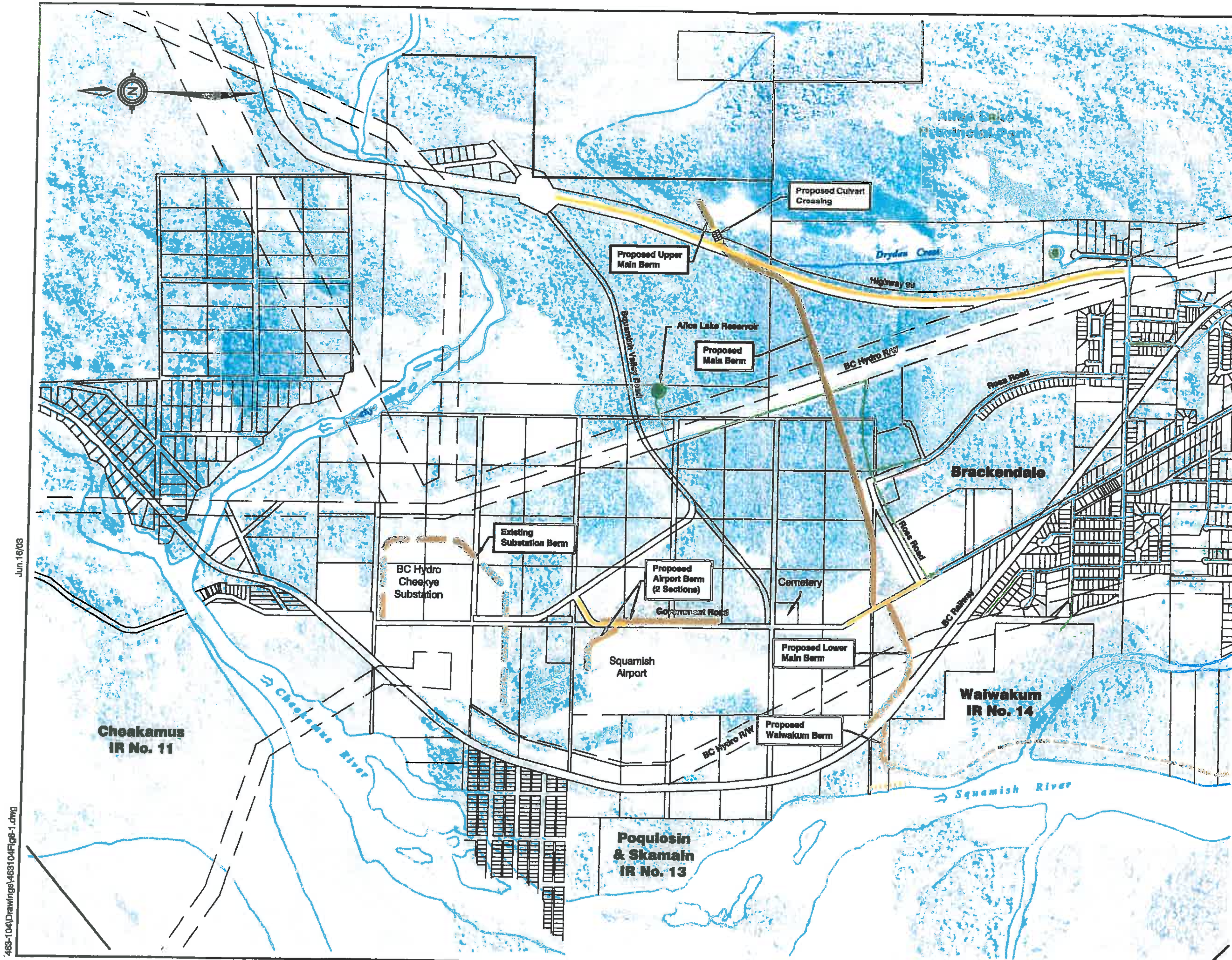
Debris Flow Modelling Results: Existing Conditions (Scenario 3)

Figure 3-3



District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms
Legend
Flow Depth (m)
Flow Velocity (m/s)
0 - 0.3
0.3 - 2
2 - 4
4 - 6
6 - 8
> 8
0-2
2-4
4-6
6-8
>8
Existing Dyke
Fan Boundary
Proposed Berms
Notes:
Debris deposition areas shown on this figure are generalizations of model results.
Local avulsions could change the distribution, depth and velocity of debris flows.
Debris flow reaching Cheakamus River and Squamish River may cause temporary blockage or diversion. Debris deposition is purposely ended on the east bank of the two rivers.
KERR WOOD LEIDAL
associates limited
CONSULTING ENGINEERS
500
0
500
Scale in Metres
Project No.
463-104
Date
June 2003
Debris Flow Modelling Results: With Proposed Deflection Berms
Figure 3-4
Highway Raised 8 m Above Existing Elevation
Road Profile Raised 2 m Above Existing Location
Input Parameters:
Debris Flow Volume: 7,000,000 m³
Debris Flow Peak Discharge: 15,000 m³/s
River
Stump Lake
Alice Lake
Dryden Creek
Highway 99
Ross Road
BRACKENDALE
Squamish Valley Road
BC Hydro Cheekye Substation
Government Road
Squamish Airport
BC Hydro R/W
Cheakamus I.R. No. 11
Cheakamus River
Waiwakum I.R. No. 14
Poquiosin & Skamain I.R. No. 13
Squamish River
Judd Slough
Jun.16/03
463-104\Drawings\463104Fig3-4.dwg

District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms



Legend

- Proposed Deflection Berm
- Existing Deflection Berm
- Proposed Dyke
- Existing Dyke
- Proposed Riprap
- Existing Watermain
- Existing Sanitary Sewer
- Proposed Road Regrading (Approximate Extents)

Note:

This figure represents a revision of the original deflection berm concept that is illustrated on Figure 1-1.

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300 0 300
Scale in Metres

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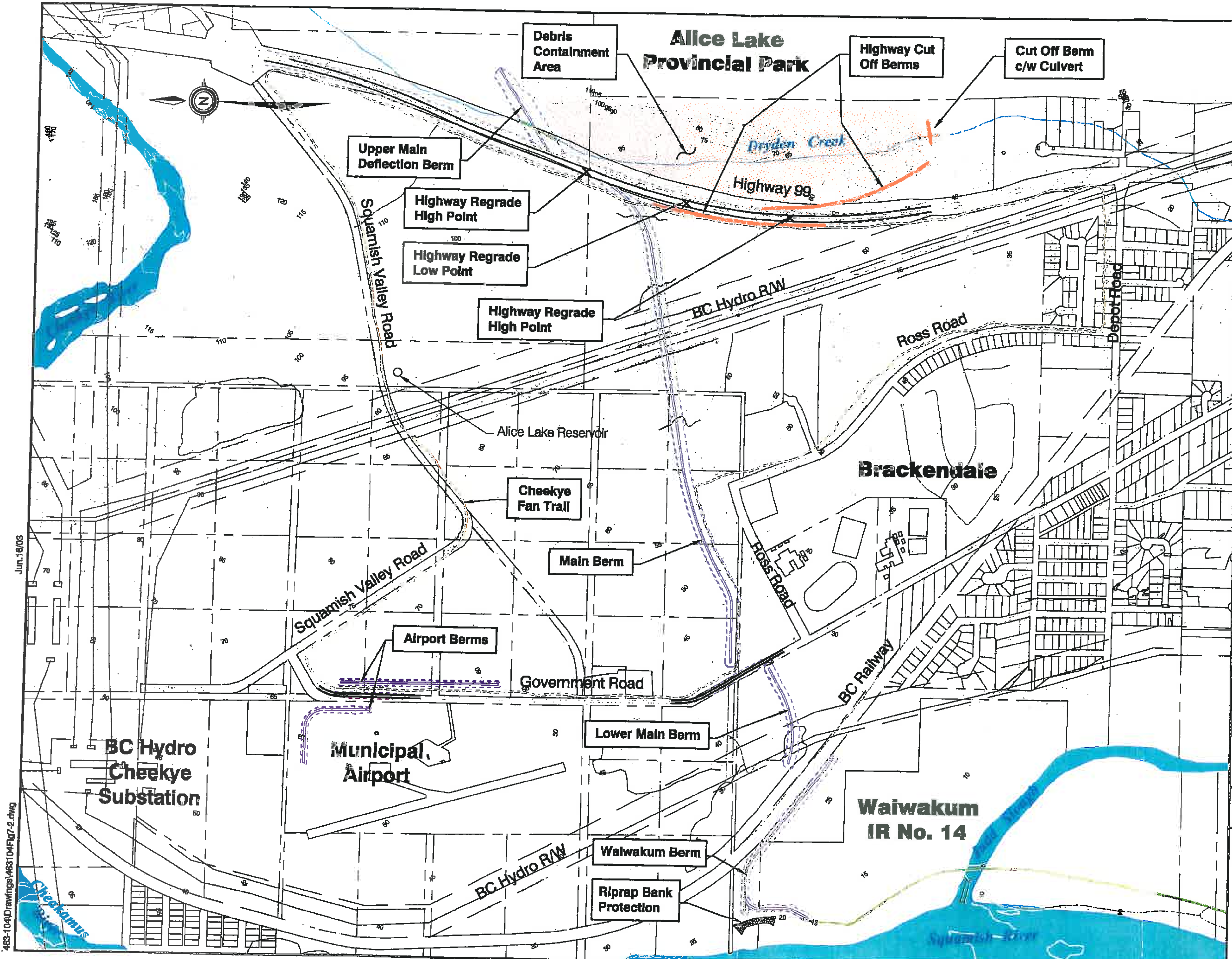
463-104	June 2003

Updated Deflection Berm Concept

Figure 6-1

Jun.16/03

463-104\Drawings\463104Fig6-1.dwg



District of Squamish
Preliminary Design Report for
Cheekye Fan Deflection Berms

Legend

- Proposed Deflection Berm
- Proposed Cut Off Berm
- Proposed Cheekye Fan Trail
- Existing Dyke
- Existing Path
- Debris Containment Area

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250 0 250
Scale in Metres

Project No.	Date
463-104	June 2003

Highway Cut-Off Berms and Debris Containment Basin Concept Plan

Figure 7-2