New file Swift Current Ck. Bridge
M46-18-14

J. Alton,
Sr. Bridge Engineer,
Department of Highways,
Victoria.

E.E. Readshaw, Sr. Materials Engineer, Victoria, B.C.
April 12, 1966.

Regional Engineer's Office
DEPARTMENT OF HIGHWAYS
APR 13 1966
KAMLOOPS, B.C.

M-699

Foundation conditions at Swift Current Creek Bridge -Yellowhead Highway

New file

Herewith is our report on soil conditions at this site.

Owing to settlement and low strength properties of the deep, weak sediments, it is suggested that the bridge work be postponed for a year following the completion of the fill, to allow for some consolidation.

Construction of the fill will have to be controlled by instrumentation which has already been put in hand.

As Drawing No. 1501 won't be ready for a week, it will be forwarded at that time.

E.B. Wilkins,
Design and Planning Engineer.

E.E. Readshaw
E.E. Readshaw,
Sr. Materials Engineer.

FDL/ek
encl.
cc-E.B. Wilkins
cc-L. DeBoer, Kamloops

FOUNDATION INVESTIGATION - SWIFT CURRENT CREEK BRIDGE

Following a request by the Bridge Engineer, a subsurface investigation was made for a bridge where the Yellowhead Highway crosses Swift Current Creek near Mount Robson station.

Site Conditions

Swift Current Creek follows a ten mile course from its source in glaciers on a 11,000 foot mountain to its junction with the Fraser River. It is retained by canyons along its steep course in the mountains, then emerges onto a fan 1000 feet above the bridge site.

During a stage of the Pleistocene epoch valley glaciers from the Fraser and the Robson River valleys probably joined here and the rapidly moving ice overdeepened the valley floor. In post glacial times this depression contained a lake which eventually filled with accumulated clay and silt sediments. Swift Current Creek is now building a thin fan out over these deposits.

This creek probably has flashy runoffs and on occasions has velocities sufficient to move three foot diameter rocks at the fan's apex and eighteen inch rocks at the bridge site. On such large peaks the creek would pick up gravels along its steep course and dump them where its grade flattens out; at the same time it would change its course, eroding new channels and transferring accumulations of gravels to other parts of its fan. During recent highway construction-work gravel was borrowed from the creek bed leaving a deepened and streamlined channel which in large runoffs may aggravate bed scour and bank erosion.

The creek channel crosses the highway location a 37°angle requiring a fairly long bridge with two intermediate skew piers.

Drilling investigation

Four test holes drilled along the site showed about ten feet of gravel and boulders overlying over 150 feet of weak compressible combinations of highly plastic, sensitive clays (clays which lose up to 90% of their strength with disturbance) and silts. From the top these are generally very soft for 30 feet, soft for 20 feet, medium stiff for 40 feet and then stiff, probably preconsolidated materials to at least 150 feet depth. These results are illustrated on Drawing No. 1501, sketch 1 and the drill logs.

The seasonal layers in the fine grained sediments are about a half inch thick separated in some cases by very thin layers of sand. As the efficiency of this sand for drainage is difficult to determine, precise consolidation times are unavailable.

Foundation Considerations

A simply supported bridge design having its abutments founded in the fills with latitude for jacking is suggested.

(a) Fills - It is suggested that the fills be constructed, then surcharged and allowed to consolidate for a year before the commencement of the bridge construction. Although piezometers, movement hubs and bearing plates will be required to control the fill construction it is considered that the fills can be raised twelve feet above the creek bed, then after a wait to allow the soils to gain more strength, raised to grade and possibly surcharged. These fills are expected to settle about 1½ feet.

(b) Piers - For the piers, long, small-diameter piles grouped in long narrow piers for minimal settlements and maximum streamlining, are recommended.

To adapt the pile driving program to the soils the following procedures are advised:

1. Drive the center piles of a group first, then progress to the outsides. This will assist in keeping the piles vertical when

the soils remould.

2. In the case of displacement piles check the elevation of each pile after driving and again after the group is completed. Re-drive any piles that may have heaved.
3. Once started, continue to drive each pile until its design depth is reached.
4. Give each pile group a month to allow the soils to regain strength before constructing the remainder of the bridge.
5. Provide a grade beam at the ground level to stiffen each group.

Preferably a pile test should be made a month after driving to determine a pile's capacity, but in lieu of this, the following allowable loadings are suggested:

	EL. 2570 (ℓ 60)	2560 (ℓ 70)	2550 (ℓ 80)	2530 (ℓ 100)	2520 (ℓ 110)
8" ø wood	9 T	13 T	15		
12" ø concrete	14 T	19 T			
15" ø concrete	21 T	28			
Spliced wood piles					29
Wood piles spliced to 12" steel pipe					32
Wood piles spliced to 15" steel pipe					39
12 x 12 WF steel				52	

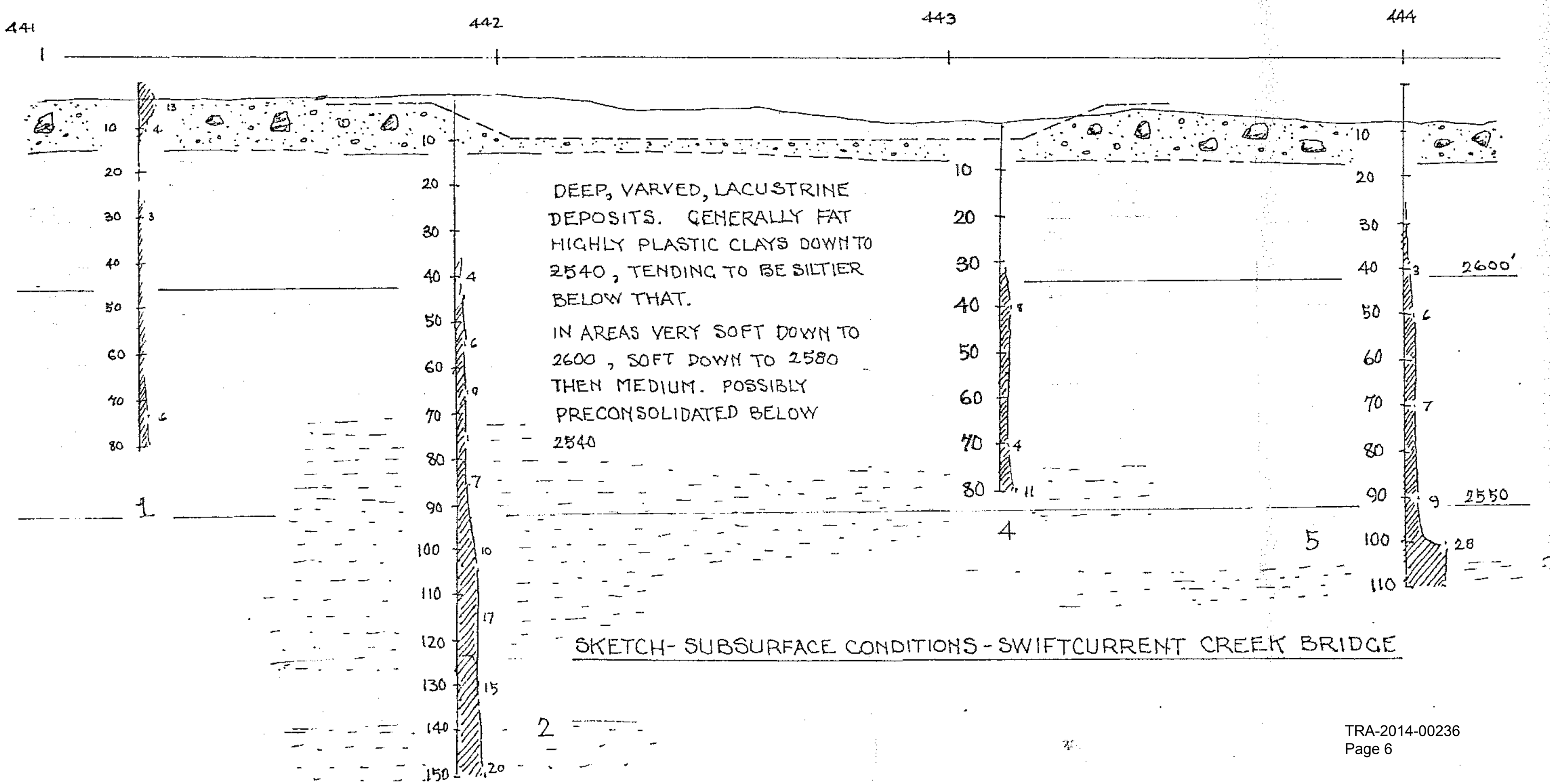
Settlements for piers with piles driven to El. 2560 (i.e. 70' pile embedment) was computed to be $3\frac{1}{2}$" but is considered more likely will be about 2", and to El. 2520 computed to be $1\frac{1}{2}$" but more likely will be about 1".

Scour

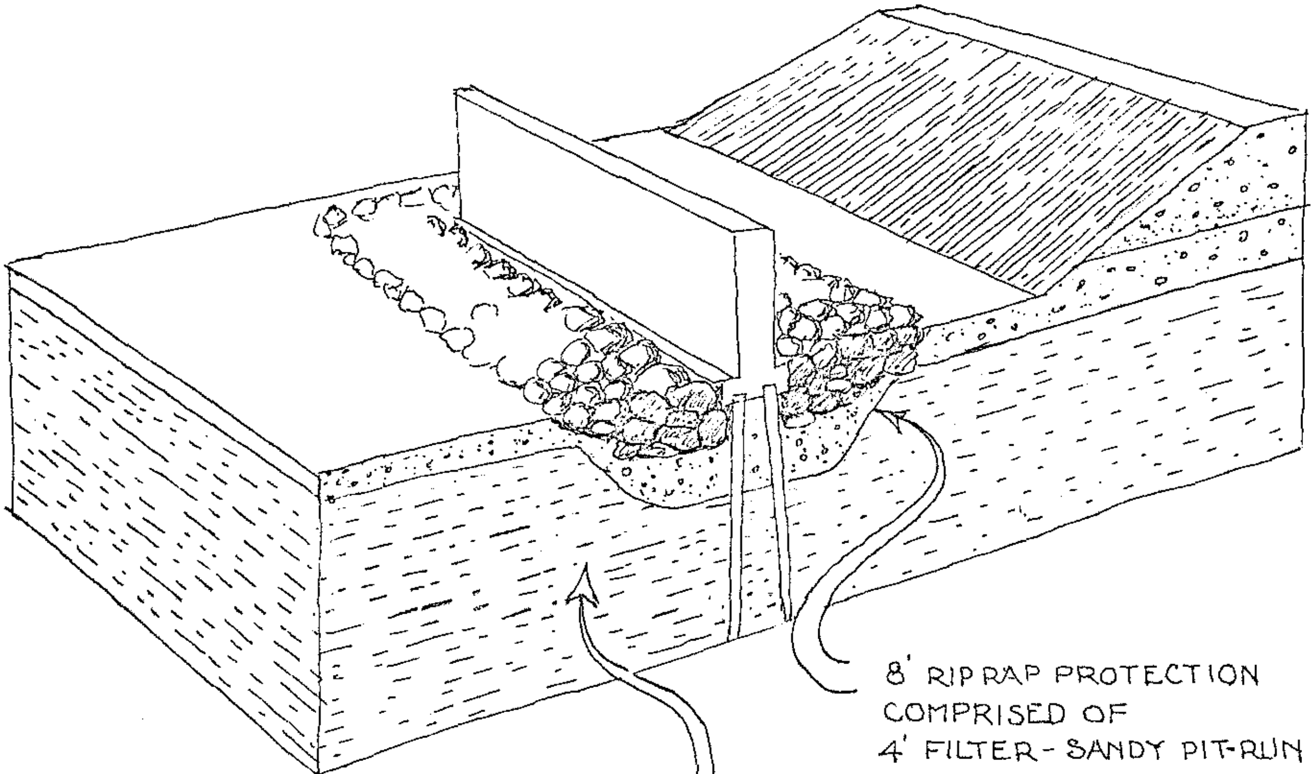
A letter to the Superintendent of Construction on March 28th dealt with protection against general scour. Briefly it recommended that a shot-rock blanket with stones up to 2' be laid over the channel and partly up the sides of the creek from 100' upstream of the bridge to 100' downstream, following the completion of the bridge. This was to counteract erosion in the vicinity of the bridge itself. The long term erosion characteristics posed by superimposing a highway location across a fan can only be determined by experience.

To guard against local scour it is suggested that rip rap be placed around the piers as shown in Sketch 2.

It is suggested that stockpiles of heavy building materials be kept back 50 feet from the creek side.



SKETCH - SUBSURFACE CONDITIONS - SWIFTCURRENT CREEK BRIDGE



VERY SOFT MATERIALS TO PROTECT. ANY DEEP SCOUR HOLES COULD THREATEN THE STABILITY OF THE FILLS.

8' RIP RAP PROTECTION COMPRISED OF
4' FILTER - SANDY PIT-RUN GRAVEL
4' SHOT ROCK + COBBLES TO AT LEAST 2'Ø
EXTEND 15' OUT FROM THE PIERS AT THE CREEK-BED LEVEL.

SKETCH 2 - SUGGESTED RIP RAP PROTECTION AGAINST LOCAL SCOUR IN THE VERY SOFT CREEK BED.

H-448

441 + 20 (1)

TEST HOLE LOG

Type of Equipment DEC 11, 1965 Project SWIFT CURRENT CR BR.

Date of Drilling BBS EL HOLE 45.4 GROUND 41.0

Undisturbed Sample — Water Table — N - Standard Penetration Test 140# hammer - 30" drop

Disturbed Sample — ( ) Visual Estimate

	Depth (ft)	Plot	Remarks	N	Clay	Silt	Sand	Gravel	L.L.	P.L.	P.I.	Field M.C.
			SAND GRAVEL BOULDERS	13	(	20	50	30)				
	10			4	(55	35	10	)				61.3
Cc = .42 Cu = 144 (DISTURBED?)				–	50	50			79.3	28.6	50.7	61.0 71.7
	20	CH		4	(60	40		)	59.5	24.2	35.3	63.3
Cc = .35		ML-CL		–	32	68			<MC.			41.7
	30	ML	SOFT, LOW TO HIGHLY PLASTIC CLAYS,	3	(10	60	30	)	25.1	23.2	1.9	34.1
Cu = 272 560 MC 48.5 457 Cc = ~~445~~			SOME SILTS IN VARVES		49	51			58.1	25.5	32.6	57.0
	40	CH	MEDIUM STIFF BELOW 70'	4	(60	40		)				67.1
Cc = .74 Cu = 570 835 MC 66.5 62.7				–	40	60			52.4	25.1	27.3	66.5 ~~59.7~~
	50			4	(55	30	15	)				61.0
Cc = .58 Cu = 425 MC	60			–	84	16			59.7	27.8	31.9	56.2
	70	CL-CH		6	(60	40		)	53.4	26.0	27.4	54.3
	80	CL		6	(20	80		)	34.9	23.2	11.7	38.4

H-448

441+90 ②

TEST HOLE LOG

Type of Equipment BBS

Project SWIFTCURRENT CR BR

Date of Drilling FEB. 7, 1966

EL HOLE 42.0
EL GROUND 38.9

Undisturbed Sample
Disturbed Sample

Water Table
( ) Visual Estimate

N - Standard Penetration Test 140# hammer - 30" drop

∅' = 20°
C' = 6.5

Depth (ft)	Plot	Remarks	N	Clay	Silt	Sand	Gravel	L.L.	P.L.	P.I.	Field M.C.
		SAND GRAVEL BOULDERS									
10											
	CL		4	43	57			49.4	23.8	25.6	45.5
20	ML CL	SOFT TO -40 MEDIUM TO -60' THEN STIFF, FINE-GRAINED SEDIMENTS. MICACEOUS SILTS AND SENSITIVE, HIGHLY PLASTIC CLAYS.						39.1 32.0	24.9 20.0	14.2 12.0	
			4	(30	70		)				34.0
30	CH							[illegible]	24.1	44.2	
	CL		4	(50	50		)	30.4	21.3	9.1	58.0
40	CH							51.6	22.2	35.4	
	CH		5	(50	50		)				51.5
50				82	18			65.3	28.4	36.9	
			6	(50	50		)				53.8
60											
	CH		[illegible]	56	44			50.5	26.5	24.0	48.0
70	CL							35.3	23.5	11.8	
	ML		8	(35	65		)				42.5
80								28.3	22.7	5.6	
			7	(30	70		)				30.0
90	CL							37.9	24.6	13.3	
			10	(10	90		)				30.7
100								NP			
110											
	ML		17	(15	85		)				33.1
120											
130											
	CL		15	(35	65		)	43.3	24.5	[illegible]	44.0
140											
150	ML		20	11	52	37					31.7

H-448

TEST HOLE LOG

443+12 (4)

Type of Equipment BBS 17A

Project SWIFTCURRENT CR BRIDGE

Date of Drilling FEB.16,1966

EL HOLE 35.2
GROUND 32.7

Undisturbed Sample
Disturbed Sample

Water Table
( ) Visual Estimate

N - Standard Penetration Test 140# hammer - 30" dro

Depth (ft)	Plot	Remarks	N	Clay	Silt	Sand	Gravel	L.L.	P.L.	P.I.	Field M.C.
		GRAVEL & BOULDERS									
10	ML-CL		2	(30	70		)	41.1	23.7	15.4	46.8
20	ML	WEAK COMPRESSIBLE SILTS AND CLAYS IN VARVES WITH MOISTURE CONTENTS ABOUT OR ABOVE THE LIQUID LIMIT.	2	12	88						33.0
$C' = 435$ $\phi' = 25°$ $C_c = .38$ $c_w = 245$ w_c 51.9 135 54.0 30								45.7	[illegible]5.5	20.2	
40	CH	8'-40' VERY SOFT 40-60' MED STIFF 60-75' SOFT 75- STIFF	8	(35	65		)	52.4	24.0	28.4	52.[illegible]
50	CL		9	(30	70		)	36.9	23.6	13.3	47.5
c_w 174 MC 44.4 120 41.4 60				52	48			46.5	24.8	21.7	
70	ML-CL		4	41	59			41.0	26.0	15.0	39.3
80			11	31	69			31.0	19.5	11.5	34.0

H-448

TEST HOLE LOG

444+00 (5)

Type of Equipment BBS

Project SWIFTCURRENT CR BR

Date of Drilling FEB. 11, 1966

EL HOLE 45.0
GROUND 34.4

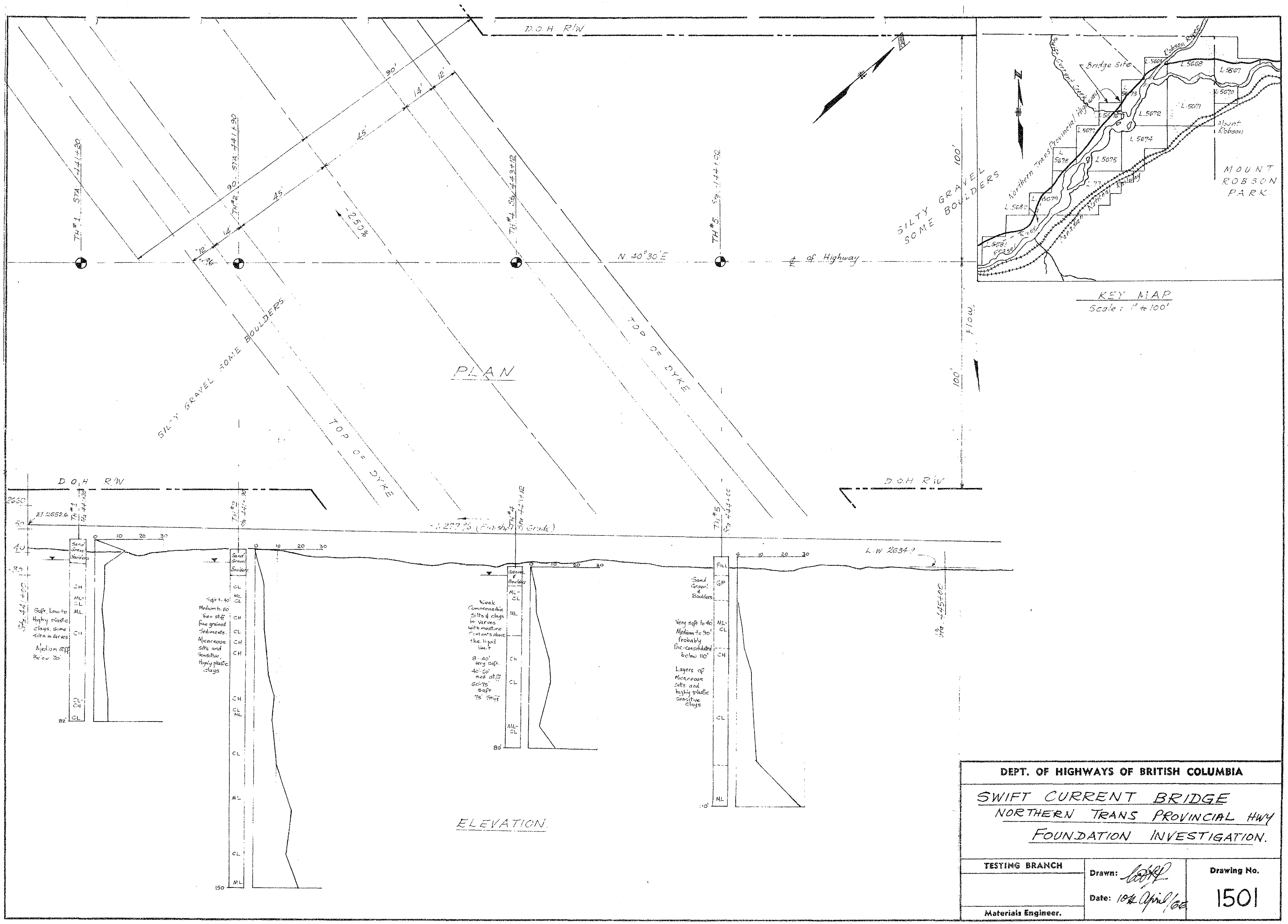
Undisturbed Sample
Disturbed Sample

Water Table

( ) Visual Estimate

N - Standard Penetration Test 140# hammer - 30" drop

Depth (ft)	Plot	Remarks	N	Gradation % Clay	Silt	Sand	Gravel	L.L.	P.L.	P.I.	Field M.C.
		FILL									
10	GP	SAND GRAVEL BOULDERS	100	(		5	95)				
20			1	38	62						45.0
30	ML CL	VERY SOFT TO -40' MEDIUM TO -90' PROBABLY PRE CONSOLIDATED BELOW 110'	2	(30	70		)				41.7
40	CH		3	64	36			70.6	25.8	44.8	58.1
50		LAYERS OF MICACEOUS SILTS AND HIGHLY PLASTIC SENSITIVE CLAYS	[illegible]	(55	45		)				54.5
60											44.9
70	CL		7	46	54			42.7	26.7	16.0	
80											



DEPT. OF HIGHWAYS OF BRITISH COLUMBIA

SWIFT CURRENT BRIDGE
NORTHERN TRANS PROVINCIAL HWY
FOUNDATION INVESTIGATION.

TESTING BRANCH	Drawn:	Drawing No.
Materials Engineer.	Date: 10th April/68	1501

146-18-14

Victoria, B.C.

April 7th, 1966.

J. Rath,
Diamond Drill Foreman,
General Delivery,
Red Pass, B.C.

Regional Engineer's Office
DEPARTMENT OF HIGHWAYS
APR 13 1966
KAMLOOPS, B. C.

M-699

Swift Current Creek Bridge site - instrumentation

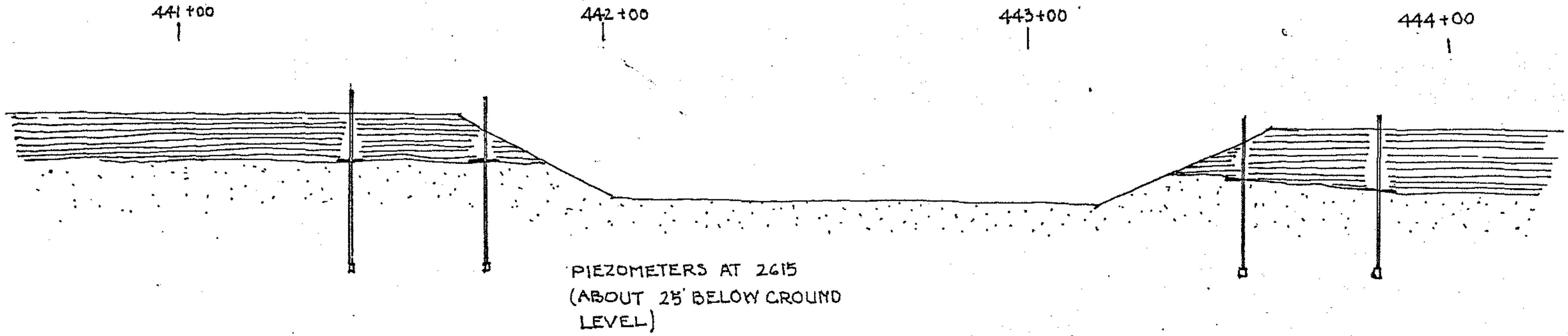
Attached are instructions for piezometer and settlement plate installations at the above site.

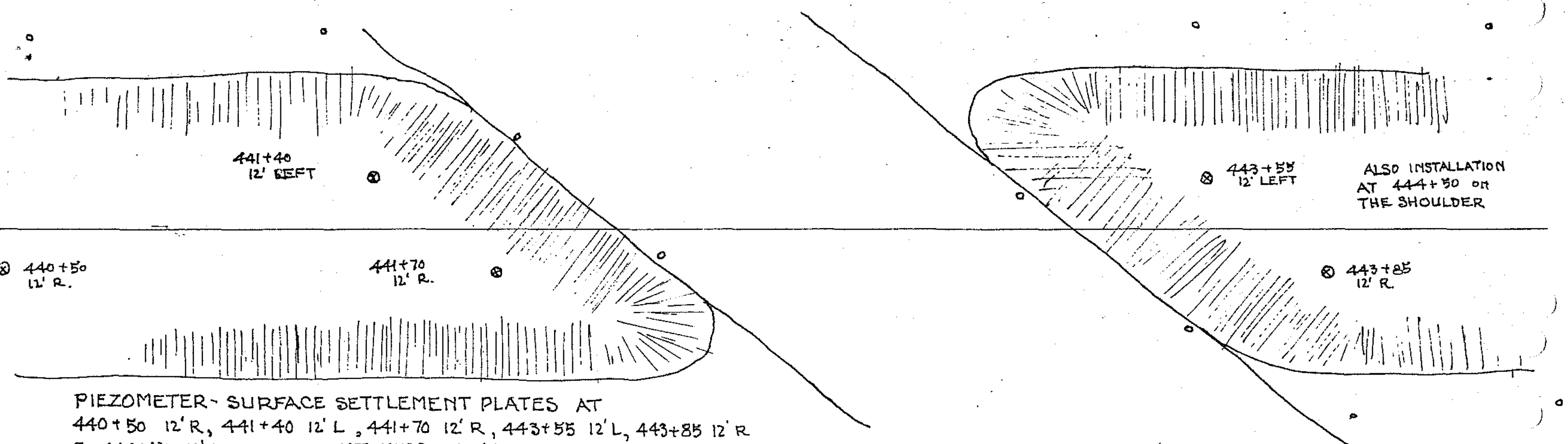
Tom Reid will be sending you the piezometers and settlement plates. Backfill around the piezometer tip with clean coarse sand and put a seal of about 2' bentonite two or three feet above the piezometer tip. The settlement plate and the extension pipes are to be installed over the piezometer pipe. Level the ground under the settlement plate before placing it. Please check with the Resident Engineer for priority of placement as the work of the road building contractor depends upon it.

Please ask the Resident Engineer to mark out the locations of the piezometers.

J.D. Austin,
Drilling & Exploration Engineer.

JDA/ek
encl.
cc-Drilling Superintendent
cc-E.E. Cummings, Resident Engineer
cc-L. DeBoer, Kamloops
cc-F. Laronde





PIEZOMETER - SURFACE SETTLEMENT PLATES AT 440+50 12'R, 441+40 12'L, 441+70 12'R, 443+55 12'L, 443+85 12'R & 444+50 12'L. MOVEMENT HUBS ≈ 50' APART, 10' OUT FROM TOE OR WHERE CONVENIENT AT THE CREEKS EDGE. WHEN THE FILLS ARE 12' ABOVE THE STREAM BED READ THE PIEZOMETERS AND MOVEMENT HUBS EVERY 2 HOURS. CEASE WORK IF THE PIEZOMETRIC LEVELS REACH HALF THE HEIGHT OF THE FILL AT THE TIME OR THE MOVEMENT HUBS MOVE 2 INCHES

INSTRUEMENTATION DETAILS AT SWIFTCURRENT CREEK BRIDGE

BASED ON BRIDGE DRAWING 2275-2

M46-18-14

Regional Engineer's Office
DEPARTMENT OF HIGHWAYS
FEB 23 1966
KAMLOOPS, B. C.

Mr. E.C. Webster,
Director of Construction,
Department of Highways,
Victoria.

E.E. Readshaw, Sr.Material
Engineer, Victoria, B.C.
February 22, 1966.

M-699

Swift Current Bridge - Yellowhead Route

Drilling at this site showed deep deposits of compressible materials. It would be of later benefit if the construction of the approach fills could be given priority. It is also suggested that enough surcharge be added to bring the elevation to 15 feet above the existing terrain for the final 100 feet on both sides; this is about the limit that the soils can stand.

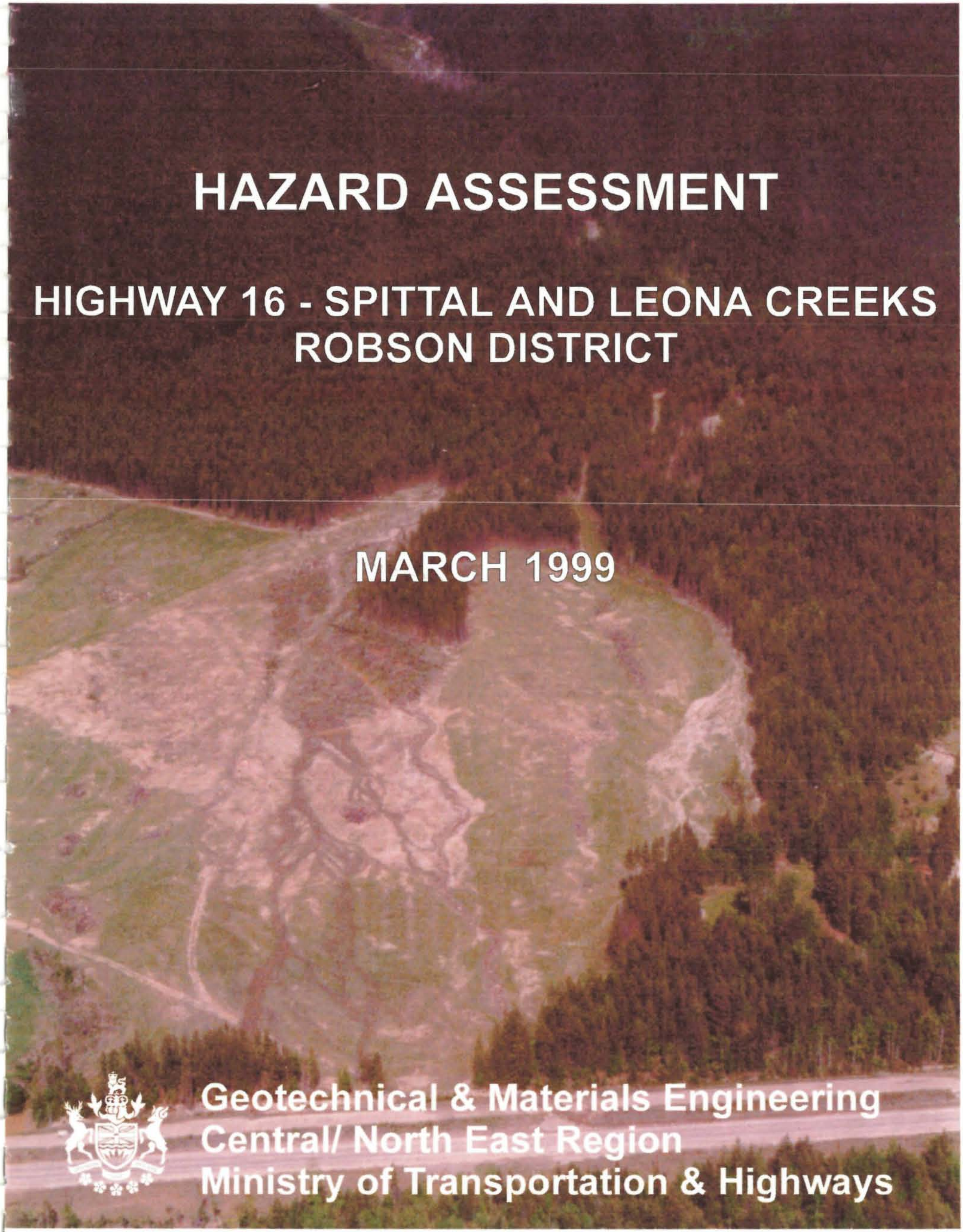
It appears advisable to control the channelling of the creek using dikes rather than to excavate into the thin layer of boulders. These suggestions are based on a preliminary assessment as no laboratory tests have been made yet.

E.B. Wilkins,
Design and Planning Engineer.

E E Readshaw

E.E. Readshaw,
Sr.Materials Engineer.

FDL/ek
cc-J. Alton, Sr. Bridge Engineer
cc-L. Dehmer, Kamloops
cc: J.W. Nelson, Kamloops



HAZARD ASSESSMENT

HIGHWAY 16 - SPITTAL AND LEONA CREEKS
ROBSON DISTRICT

MARCH 1999

Geotechnical & Materials Engineering
Central/ North East Region
Ministry of Transportation & Highways

Geotechnical and Materials Engineering
Central/North East Region

Ministry of Transportation and Highways
532–4th Avenue
Prince George, B.C. V2L 3G9
(250) 565-6195
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BRITISH COLUMBIA

HAZARD ASSESSMENT
HIGHWAY 16 - SPITTAL AND LEONA CREEKS
ROBSON DISTRICT

Prepared for:
Rick Blixrud
Robson District Highways Manager

Ministry of Transportation and Highways
Box 279, McBride, B.C.
VOJ 2E0

Prepared by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA G.W.T. HUNTER MARCH 31, 1999

Gord W. Hunter, P.Eng.
Geotechnical Engineer
Central/North East Region

Reviewed by:

PROFESSIONAL ENGINEER PROVINCE OF BRITISH COLUMBIA N. C. POLYSOU MAR 31/99

Nick Polysou, P.Eng.
RGME
Central/North East Region

Distribution:

2 Copies	MoTH, Robson District Office
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1 Copy	MoTH, Central/North East Regional Office

March 1999

File No.: M46-16-40

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LIST OF FIGURES

1.0 TERMS OF REFERENCE

The Ministry of Transportation and Highways (MoTH), Central/Northeast Region, Geotechnical and Materials Engineering office has carried out preliminary channel assessments of Spittal and Leona Creeks within the Robson District. A Contract for Services No. 3178 was initiated on September 26, 1998 by Rick Blixrud, Robson District Highways Manager.

Previous debris flow and debris flood activity within Spittal and Leona Creeks has resulted in periodic closures to Highway 16 (Hwy. 16). The study objective is to evaluate the potential for such events to cause similar and potentially greater detriment to Hwy. 16 and to provide recommendations for suitable protection of the highway infrastructure. Although the study was carried out for the purposes of the evaluating the risk to Hwy. 16, the results herein provide useful information applicable to hazard assessments for adjacent properties.

2.0 INTRODUCTION

2.1 General

The project area is located within the Robson Highway District and approximately 48 km southeast of the McBride, B.C., see Figure 1. Spittal and Leona Creeks are two of many streams within the Robson District which have high elevation headwaters situated within the mountainous terrain flanking the Rocky Mountain Trench. Figure 2 shows Spittal and Leona Creeks initiating within the Rocky Mountains and flowing southward beneath Hwy. 16 to the Fraser River. The natural channel conditions and the characteristics of the upper elevation terrain within the Spittal and Leona Creek drainages, provides conditions favourable for the development of stream hazards referred to as debris flows. Vandine (1996) defines debris flows as rapid, downslope mass movements of water-charged, predominantly coarse-grained, inorganic and organic material which flow within or outside the confines of a pre-existing channel.

The extensive area of deposition commonly located at the foot of the mountain slopes within mountainous terrain areas is referred to as an alluvial fan. Development of an alluvial fan requires a.) a constant source of upslope material, b.) central stream channel conditions adequate to promote downstream transport of supplied material, and c.) the presence of low gradient terrain within the valley bottom to support ultimate deposition of transported materials.

The upper drainage terrain throughout the Robson Valley characteristically comprises oversteepened, sparsely vegetated terrain exposed to seasonally high snowpack and concentrated subsurface/surface water flow. The combination of these terrain characteristics coupled with the exacerbating effects of unpredictable weather conditions (including intense rainfall and warm weather snowmelt) and site specific localized maninduced surficial ground disturbance (including access road construction and logging) aid in initiating slope instabilities such as landslides, snow avalanches and debris flows. The presence of deeply incised, well-confined and steep gradient central stream channels within many of the upper drainages provides a mechanism (via periodic debris flows and seasonal peak flows) for downstream transport and progressive entrainment of source materials. This material ultimately deposits at the foot of the mountain where channel gradients and channel confinement are insufficient to permit continued material transport.

The alluvial fans within the Robson Valley are the result of thousands of years (post-glacially) of periodic debris flows and peak flow material deposition. Man has only witnessed the most recent results of this long-term process.

An additional stream hazard that is closely associated with channels prone to accumulations of large woody debris is the debris flood. Debris floods are predominantly water flow events that have incorporated within them significant quantities of transported sediment and organic debris. Debris floods differ from debris flows in the significantly decreased abundance of transported sediment. In a strict sense, a debris flood could be characterized as a debris flow having extremely high water content to sediment ratio.

The following table provides a summary of the documented hazard events which have occurred in the vicinity of the study area since 1986.

TABLE 1: Robson Valley/Alluvial Fan Event Summary

Drainage	Event Date	Event	Event Consequence	Probable Trigger
Spittal	26-May-86	Debris flow	Flooding of Hwy. 16	Warm weather
Spittal	Jul-96	Debris flow	Flooding of Hwy. 16	Warm weather
Spittal	6-Aug-97	Debris flood	Flooding of Hwy. 16	Intense rain
Leona	25-Jul-91	Debris flow	Residential property and Hwy. 16 flooding	Warm weather
Leona	13-May-93	Debris flow	Residential property and Hwy. 16 flooding	Warm weather
Leona	6-Jul-97	Debris flow	Residential property and Hwy. 16 flooding	Warm weather
Goslin	26-May-86	Debris flow	Residential property and Hwy. 16 flooding	Warm weather
Goslin	13-May-93	Debris flow	Residential property and Hwy. 16 flooding	Warm weather
Bevier	26-May-86	Debris flow	Culvert crossing and residence destruction	Warm weather
L'Heureux	Jan-89	Snow Aval.	Run-out into residential properties	Unknown
Bevier	12-Jun-90	Debris flow	Crossing destruction and adjacent flooding	Intense rain
Eustis	26-May-86	Debris flow	Residential property and Hwy. 16 flooding	Warm weather

Table 1 includes events taking place on Bevier Creek (located approximately 6 km northeast of McBride), Eustis Creek (located approximately 1.5 km northwest of Leona Creek), L'Heureux Creek (located about 4 km southeast of Spittal Creek) and Goslin Creek (located about 3 km southeast of Spittal Creek). It should be noted that other non-documented events have likely occurred during and previous to this time period within the Robson Valley.

2.2 Characteristics of Alluvial Fans and Debris flows

VanDine (1996) in a publication entitled *"Debris Flow Control Structures for Forest Engineering"* provides a summary the existing debris flow and debris fan literature. The following information regarding the characteristics of debris flows and debris fans are excerpted from this paper. It should be noted that reference to the term fan below relates to a *debris fan* which is defined as the depositional portion of the debris flow path. A *debris fan* does not include the distal portions (gradients typically less than 4 degrees) of the overall alluvial fan which is dominated by the low gradient deposition of fine particulate.

- Vandine (1996) reports that initiation areas for debris flows typically have channel gradients greater than 47 % (25 degrees), areas of material accumulation (entrainment) have gradients greater than 27 % (15 degrees) and material deposition on the alluvial fan occurs at gradients less than 18 % (10 degrees).

- In 1983 Thurber Consultants reviewed 15 Howe Sound streams prone to debris flows and concluded that the average fan gradient was 21 % (12 degrees) and ranged between 9 and 32 %. A similar review in 1985 by Thurber Consultants of 73 debris flow prone streams from the Hope-Coquihalla area indicated that the average fan gradient is 23 % (13 degrees) and ranged between 7 and 45 %.

- A review of British Columbia streams by Hungr et al. (1984) concluded that channelized debris flow deposition within streams initiates at gradients between 14 and 21 % (8 and 12 degrees). For unconfined debris flows (open slope failures) the review concluded that deposition begins at gradients between 18 and 25 % (10 and 14 degrees). Hungr et al. (1987) states for channel gradients less than 32 % (18 degrees) that channel confinement plays a greater factor in determining material deposition than channel gradient.

The wide ranges of debris flow deposition gradients in the literature stems from the dependence of debris flow dynamics on variable factors such as channel configuration (confinement), parent material composition, channel surface roughness and water/debris ratio. Variations in these factors can significantly change the flow and deposition characteristics of the debris flows.

The variability in the dynamics of debris flows makes it difficult to estimate potential run-out distances and flow paths. Numerical modelling techniques have been developed to aid in prediction of debris flow paths however these models require the determination of field parameters which are often difficult to accurately quantify. One of the most useful tools for debris flow path and runout prediction is gained through the observations of previous events within the same drainage. As a first hand approximation in the absence of detailed field information Hungr et al. (1987) suggests that the widening of a debris flow on a debris fan can be estimated utilizing a ratio of 1 (width) to 2 (length). The 1:2 ratio technique is standard Swiss practice for estimating debris flow extent on debris fans.

Figure 2 shows the approximate extent of the Spittal and Leona alluvial fans based on field observations and airphoto review.

3.0 WORK CARRIED OUT

Work carried out for the project comprised a review of available topographic, geologic and aerial photographic information and a field investigation. The following information was used during report preparation.

- Robson District MoTH and Central/North East Regional MOE Water Management working files;
- Province of British Columbia Aerial Photographs
  - Series BC976 No. 71-73 & 100-102, dated 1948, approx. scale 1:35,000;
  - Series BC2512 No. 44-48, dated Aug. 15, 1958, approx. scale 1:15,000;
  - Series BC5361 No. 89-90, dated August 23, 1969, approx. scale 1:30,000;
  - Series BC7523 No. 112-113 & 228-231, dated Aug. 11, 1973, approx. scale 1:16,000;
  - Series 15BC79150 No. 18-20, dated Aug. 9, 1979, approx. scale 1:30,000;
  - Series 15BC86009 No. 173-175, dated Jun. 4, 1986, approx. scale 1:20,000;
  - Series BC87027 No. 48-50, dated July 29, 1987, approx. scale 1:20,000;
  - Series 30BCB91102 No. 242-245 & 30BCB91103 No. 15-17, 101-104, Aug. 22, 1991, approx. scale 1:15,000, and;
  - Series 15BCB96106 No. 57-59 & 182-183, dated Sept. 11, 1996, approx. scale 1:50,000;
- Non-provincial airphotos, Series SRS30C955454 No. 136-140, dated May 5, 1995, est. scale 1:11,000;
- Map 1499A *"Geology: Mount Robson"*, Geological Survey of Canada, Bedrock Geology Map, dated 1980, scale 1:250,000;
- Geotechnical report entitled, *"Geotechnical Hazard Assessments for Goslin and L'Heureux Creeks, Tete Jaune Cache, British Columbia"*, by Piteau Associates, dated November, 1993.

- Geotechnical report entitled, *"Debris Flow Control Structures for Forest Engineering"*, by D.F. VanDine, dated 1996.

The field work was carried out on November 17 and 18, 1998 by Gord Hunter, P.Eng and Steve Alexander, P.Eng. (MoTH Geotechnical and Materials Engineering) in the accompaniment of Duane Neufeld (MoTH, Robson Highway District). Foot traverses (shown on Figure 2) were roughly surveyed using hip-chain, compass and inclinometer. The traverses focused on the alluvial fan areas located upstream of Hwy. 16. The field reconnaissance comprised a visual assessment of channel features including near surface soil, surface water conditions, vegetation, slope gradients and geomorphic processes.

The estimated field time at each of streams was 5 hours. The weather on site comprised overcast/rain and the ground surface was mantled with approximately 100 to 200 mm of snow. Thirteen (13) site photographs are included herein and the remainder are on file in the MoTH Geotechnical and Materials Engineering Prince George Office.

4.0 REVIEW OF AVAILABLE INFORMATION

The following is information obtained from a review of available topographic, geologic and climatic information.

Available topographic information indicates that the Spittal and Leona catchment areas extend to elevations as high as 2606 m above geodetic datum (Mt. Goslin). Approximate catchment areas for Spittal and Leona Creeks are 1,540 and 440 hectares, respectively. Goslin Creek located approximately 3 km southeast of Spittal Creek has a catchment area of approximately 385 hectares.

Based upon Geological Survey of Canada mapping *Map 1499A, "Geology: Mount Robson"*, the general area is underlain by bedrock from the Upper and Middle Miette Group. Bedrock from these groups comprises mudstone, siltstone, argillite, sandstone and pebble conglomerate.

There was no available surficial geology mapping for the study area during report preparation however surficial materials exposed within the banks of the alluvial fans comprise a poorly sorted mixture of gravely silts to clayey sands with variable quantities of cobbles and boulders. The poorly sorted and variable nature of the exposed materials is characteristic of alluvial fans. Based on our airphoto observations of relict river terraces within the distal portion of the fans, we anticipate that the fans are underlain by Fraser River alluvium and glaciofluvial silts and clays. Upper elevation surficial materials comprise predominantly colluvium (including landslide debris, debris flow material, talus and scree) and morainal soils.

Based on 30 years of Environment Canada weather data at the McBride weather station (some 20 km northwest of the project area) the average annual rainfall is 407 mm and the average total annual precipitation is 625 mm. Extreme daily rainfalls range between 17 mm (April) and 50 m1m (January). The data indicates that rainfall typically increases between the months of May and October. The temperature data indicates that the minimum daily temperatures are greater than 0 degrees Celsius between May and October. The maximum recorded daily temperature for the months of April and May are 29 and 33 degrees Celsius, respectively. The combination of high snowpacks, potentially warm temperatures and localized high intensity rainfall can produce high fluctuations in stream flows throughout the Robson Valley. The greatest snowmelt volume appears to occur between April and June. The weather station data provides general information for the area, however, it is possible that topography and the existence of local storm cells may cause significant variations in actual site weather conditions.

A review of snowpack data from the high elevation McBride snow station was carried out. The data exhibits a strong correlation between years of documented debris flow activity (Table 1) and years maintaining a high snowpack into the late spring months. The most critical snowpack data in terms of debris flow initiation prediction appears to be that from mid-May. The high snowpack carry-over into mid-May is susceptible to extreme temperature fluctuations that could induce rapid snowmelt and subsequent stream flow surges which could mobilize pre-existing debris jams or initiate extensive channel erosion. Debris jam and channel erosion activity could ultimately initiate debris flow activity.

The measure of equivalent water within the snowfall or snowpack is termed the "snow water equivalent" and is measured in millimeters. Table 2 provides the historical mid-May equivalent snowpack data and indicates whether documented debris flow activity occurred that spring.

Table 2: Summary of Snowpack Data

Year	Snow Water Equiv. (mm)	Known Event	Year	Snow	Known Event	Year	Snow Water Equiv. (mm)	Known Event
1970	394*	None	1980	24	None	**1990**	**456***	**Yes**
1971	No data	None	1981	328	None	**1991**	**505***	**Yes**
1972	579*	None	**1982**	**517***	**Yes**	1992	201	None
1973	470*	None	1983	174	None	1993	230	Yes
1974	549*	None	1984	355	None	1994	302	None
1975	330	None	1985	475*	None	1995	358	None
1976	551*	None	**1986**	**411***	**Yes**	1996	376*	None
1977	361*	None	1987	249	None	**1997**	**408***	**Yes**
1978	338	None	1988	285	None	1998	74	None
1979	476*	None	1989	285	Yes			

The average mid-May snow water equivalent for the period between 1970 and 1998 is 359 mm. In Table 2, the years in which the snow water equivalent surpassed the average are annotated with an asterisk (*) while years having both higher than average snow water equivalent and debris flow activity are **bolded**. It should be noted that Table 2 only includes documented events and it is likely that other non-documented events occurred within Robson Valley during this observation period. The data also supports the fact that debris flow activity does not always coincide with periods of heavy snowmelt. This is evidenced by the 1993 events on Goslin, Leona, Spittal and Eustis Creeks, (snow water equivalent well below the average value) where intense rainfall is thought to have been the triggering mechanism.

5.0 SPITTAL CREEK

5.1 Field Traverse Observations

The Spittal Creek traverse extended from Hwy. 16 upstream along the channel centerline a distance of approximately 1850 m. The traverse was terminated at the apex of the alluvial fan. Numerous observations of abandoned stream channels were noted at horizontal distances of 30 to 80 m from the existing stream channel. The abandoned stream channels are more abundant on the east side of the existing channel and are testament of previous fan activity which took place more than 80 year ago (estimated from the age of coniferous timber within the channels).

The existing channel has been categorized below into four sections possessing significantly different characteristics.

5.1.1 Stream Section 1

The first stream section (Section 1) is located between Hwy. 16 and the first small timber walking bridge associated with the Ministry of Forest *"Spittal Creek Interpretive Forest"*. This section of the stream is approximately 180 m long. Channel gradients range between 1 and 5 % with the exception of the 10 % gradient portion leading directly into the 1500 mm diameter metal culvert at Hwy. 16. The weighted average channel gradient is 4 %. The existing culvert is shown in Photograph 1. Channel entrenchment ranges between 0.6 and 1.5 m and the channel crest to crest width varies between 6 to 9 m. Photograph 2 shows the typical channel configuration, overbank deposition and the presence of a 2.5 m high large woody debris jam at approximately 160 m upstream from the highway culvert. With the exception of the debris jam area which has a stream flow width of about 6 m, the remainder of this section has a flow width of 2.5 to 4 m.

5.1.2 Stream Section 2

The stream Section 2 is about 480 m in length and located between the first walking bridge and approximately 80 m upstream of the second walking bridge. Through this section the channel gradient ranges between 2 and 9 % (weighted average channel gradient is 5 %). Channel material and levees include boulders to 1 m diameter. Deposition areas located through this stream section have channel widths to some 15 m as shown in Photograph 3. Photograph 4 shows the poor channel entrenchment and overbank deposition observed adjacent to the second walking bridge. Entrenchment can be as little as 100 mm in localized areas. Adjacent to the second bridge, waterline clearing west of the stream has created a potential pathway for redirected stream flows. Short stream segments having increased entrenchment varying between 2 and 3.5 m separate the poorly entrenched deposition areas.

5.1.3 Stream Section 3

Stream Section 3 is located between 660 and 1170 m from Hwy. 16. Included within this section is an approximately 200 m long and 75 to 120 m wide depositional area. The extensive area of deposition is located between 1000 and 1170 m from Hwy. 16 and includes mobilized boulders to 3 m in diameter. Photograph 5 shows the previous debris flow deposition amidst standing timber and mud-wash height of 1.2 m above the existing ground surface. The thickness of the most recent depositional material through this area is approximately 600 mm. The existing stream channel is located along the eastern side of the overall deposition area and has a crest to crest width of 5 to 7 m. Channel gradients were observed to range between 2 and 15 % with a weighted average gradient of 7 %. The stream channel has entrenchment of 1 to 1.5 m within the deposition area while other areas within this section are entrenched 2 to 4 m. Depositional levees adjacent to the stream have heights of 1 to 1.2 m.

5.1.4 Stream Section 4

Stream Section 4 is located between distances of 1170 and 1840 m upstream from Hwy. 16. Photograph 6 shows the channel characteristics within Section 4 at approximately 1600 m upstream of Hwy. 16. Depositional thickness of some 4 to 5 m is evident within Photograph 6. The channel gradient within this section ranges between 8 and 12 % with the weighted average gradient being 9 %. The upper portion of this stream section includes rechannelling works carried out in July 1997 that has increased entrenchment to between 4 and 5.5 m. The remainder of this section has channel entrenchment typically ranging between 1.5 and 3.5 m. The western access road located along the margin of deposited debris within Photograph 6, could be utilized to concentrate flows should the channel banks become breached. The presence of an additional linear track located east of the overall fan apex indicates significant overbank deposition from a previous debris flow event. The track rejoins the main channel some 200 m further downstream.

5.2 Airphoto and Working File Review

Airphotos of the upper elevation source areas of Spittal Creek show abundant evidence of naturally occurring slope instabilities including landslides, snow avalanches and debris flows. The magnitude of these events typically ranges between 50,000 and 500,000 cu. m. however there is some evidence of event magnitudes in the order of a million cu.m. We could discern no evidence of the high magnitude (greater than 500,000 cu.m.) events having occurred within the last 50 years.

Our review of existing MoTH and MOE files for Spittal Creek indicate debris flow/flood events occurred in 1986, 1993, and 1996. It is likely that similar events occurred prior to 1986 but were not documented. These events resulted in flooding, localized erosion and material deposition along the Hwy. 16 ditchlines. Maintenance work at the highway has included culvert cleaning, re-establishment of highway ditchline grades and eroded shoulder areas. Previous stream works included selective stream rechannelizing and debris cleaning. From the available records, we understand that rechannelizing activities within Spittal Creek have been carried out in 1982, 1986, 1993 and 1997.

Available airphotos spanning 1948 to 1996 were examined to aid in determining estimates of event frequency and magnitude within the Spittal fan. Based on the airphotos, the Spittal Creek channel has not significantly shifted over the observation period, however, there is evidence of periodic debris flow/flood activity. The 1948 airphotos indicate the pre-existence of destructive debris flow activity through stream Section 3. It is uncertain whether the 1948 depositional material is the result of a single or multiple events. Based on the visible 1948 airphoto vegetation disruption and our November 1998 site observations, the destructive activity area has increased in width from about 40 m to some 120 m over the past 50 years. In addition, the activity has extended an additional 120 to 140 m further downstream.

Utilizing the MoTH and MOE maintenance records and the succession of airphotos, we estimate that relatively small debris flow/flood events (magnitude less than 5,000 to 10,000 cu.m.) have a return period of 2 to 4 years within Spittal Creek. It appears that larger debris/flow events have occurred in 1986, 1991, 1996 and sometime between the years 1973 and 1979. Based on our rough measurements of debris aerial extent and thickness of deposited material, we estimate that the larger events have magnitudes ranging between 15,000 and 25,000 cu.m. The observation period indicates that the return period for these larger events is between 5 and 15 years.

The Spittal Creek events have resulted in non-destructive activity (including flooding, overbank deposition and minor channel shifts) through stream Sections 1 and 2. Photographs 2, 3 and 4 show recent evidence of material deposition in Sections 1 and 2.

6.0 LEONA CREEK

6.1 Field Traverse Observations

The Leona Creek traverse extended upstream from Hwy. 16 along the channel centerline for a slope distance of approximately 2200 m. The traverse was terminated at the upper mouth area of the Leona Creek valley. As similarly noted in the Spittal Creek traverse, there is evidence of abandoned stream channels located some 20 to 100 m horizontal distance from the active stream channel. The timber within the abandoned channels indicates that these channels are at least 60 to 80 years old.

For purposes of description below, the channel has been divided into four sections possessing different characteristics.

6.1.1 Stream Section 1

The first stream section (Section 1) initiates at the Hwy. 16 culvert (Photograph 7) and continues upstream for approximately 400 m. Observed channel gradients through this section typically range between 7 and 9 percent and the entrenchment is 1.5 to 3 m. As shown in Photograph 8, a residential structure is located approximately 20 m east of the existing stream channel at an upstream distance of about 200 m from Hwy. 16. Depositional material associated with the 1993 and 1997 debris flow events has flowed around the foundation areas of the structure and through the grassed yard area.

The channel crest to crest width ranges from 3 to 5 m upstream to approximately 200 m and the maximum boulder size within 200 m of the Highway is 600 to 700 mm. Between 200 and 400 m the channel crest to crest width is variable and ranges between 3.5 and 20 m. A channel widening area located between 200 and 275 m has a crest to crest width of 10 to 14 m before being terminated with a short section (20 m long) having a width of 3.5 m. Between 275 and 300 m from the highway culvert a previous blockage has produced a width of about 20 m and previous overbank deposition has occurred along the west side. Maximum size of transported boulders has increased to 1 m diameter. Between 300 and 400 m from the highway culvert, the stream channel has a width of 6 to 10 m and has transported material to 1.5 m diameter.

6.1.2 Stream Section 2

The stream Section 2 is located within the previously bermed "S-Turn" area and extends between 400 and 600 m from the Hwy. 16 culvert. The observed channel entrenchment is 2 to 3.5 m and the crest to crest width is approximately 10 to 12 m. The channel gradient through this section is 10 to 14 %. Abundant overbank deposition was observed on the east and west sides of the channel throughout this section. Flows related to the 1993 and 1997 events appear to have caused the deposition of some 300 to 500 mm of silty sand and gravel material on the east side of the channel for a downslope distance of

150 m and width of about 100 m. The maximum transported boulder size is approximately 2 m. West bank deposition resulted in the flow of material onto the adjacent agricultural land.

6.1.3 Stream Section 3

Stream Section 3 is located between 600 and 1350 m from the highway culvert. Channel gradients were observed to range between 12 and 14 %. The channel is entrenched between 3 and 4 m with the exception of a channel breach area located at distance 750 to 800 m. Through the channel breach area the stream entrenchment is 1 to 1.5 m. Additional channel overbank deposition areas are located at distances of 1100 (see Photograph 10) and 1300 m. Overbank deposition at 1300 m resulted in the destruction of timber in path approximately 60 m wide and 100 m long. Depositional levees with heights to 1 m commonly flank the stream channel through this section.

As shown in Photograph 11, boulders with maximum dimension of approximately 4 m were observed in a rock jam located at 1215 m upstream of the highway. Previous berming works through Section 3 were carried out at the breach areas located at distances 750 to 800 m and 1260 to 1360 m from the highway. The berming works carried out in these areas has created access roads immediately adjacent to the stream channel.

6.1.4 Stream Section 4

Increased channel width and entrenchment characterize section 4. Photograph 12 shows a large rock jam located within a channel crest to crest width of about 20 m at a distance of approximately 1465 m upstream of Hwy. 16. The channel entrenchment progressively increases to greater than 10 m upstream of the rock jam area. The channel gradient is variable through this section due to local debris accumulations. The average channel gradients are 14 to 18 %. We did not observe any evidence of overbank deposition through Section 4.

6.2 Airphoto and Working File Review

Similar to Spittal Creek, airphoto review of the Leona Creek source areas indicates the presence of failure scarps from naturally occurring slope instabilities including landslides, snow avalanches and debris flows. The magnitude of these events ranges from several hundred thousand cubic meters to the order a million cubic meters. We could discern no evidence of the high magnitude (greater than 500,000 cu.m.) events having occurred within the last 50 years.

Existing MoTH and MOE files for Leona Creek indicate debris flow/flood events have previously occurred in 1991, 1993, and 1997. These events have resulted in similar highway impacts as compared Spittal Creek including flooding, localized erosion and material deposition. Maintenance work at the highway has included culvert cleaning, re-establishment of highway ditchline grades and eroded shoulder areas. Stream work has included selective stream rechannelling and cleaning carried out in 1993 and 1997.

Examination of the available site airphotos (1948 to 1996) indicates that above approximately 1000 m elevation (approximately 1150 m upstream of Hwy. 16) the channel has not migrated significantly. Downslope of elevation 1000 m, the stream channel shows evidence of overbank deposition occurring in or slightly prior to 1948, 1986 and 1991. There also appears to have been some minor activity between 1973 and 1979. More recent events including 1993 and 1997 are also known to have occurred and are included within Table 1. An old stream channel which flowed to the east of the existing channel is visible within the 1948, 1958 and 1979 airphotos. The channel carried flows to the east of the existing residential structure prior to being abandoned and partially utilized for an access road constructed in the early 1980's.

The airphotos indicate that increased fan activity is related to significant snow avalanche activity occurring within the mouth of the Leona Creek valley between 1979 and 1991. Snow avalanches occurring between 1979 and 1986 resulted in the downslope destruction of standing timber for a distance of approximately 400 m (width approximately 130 m). Further timber destruction for an additional downslope distance of some 150 m (width approximately 90 m) is noted to have occurred between 1986 and 1991. The timber on both sides of the existing stream channel was destroyed through these areas. The disruption would have undoubtedly resulted in significant quantities of sediment and woody debris being introduced to Leona Creek. The development of related debris jams and subsequent failure within the upper stream sections at the mouth of the valley may have partially contributed to the increased fan activity noted post-1986.

The airphotos indicate minor channel disturbance between 1948 and 1986 with events likely involved volumes of less than 5,000 cu. m. In 1986 and subsequent years, the magnitude of the events appears to have significantly increased. Rough field measurements of the 1993 and 1997 deposition areas located east and west of the "S-Turn" and estimates downslope deposition (including highway, agricultural and residential property) suggests that these events have magnitudes ranging between 7,000 and 15,000 cu.m. The post-1986 events of this magnitude have a return period of 3 to 7 years.

Non-destructive activity comprising overbank deposition, erosion and flooding has occurred downslope of the "S-Turn" area. Destructive activity within and adjacent to the stream is generally located upslope of the "S-Turn" area at distances greater than 600 m upstream of Hwy. 16.

7.0 PROJECT COMPARISONS TO LITERATURE AND GOSLIN CREEK

The terrain conditions within the source areas and the characteristics of the central stream channels for Spittal and Leona Creeks are consistent with the conditions promoting the development of alluvial fans and debris flow activity discussed in the existing literature. It is also important to note that the climatic conditions within the Robson Valley in terms of snowpack, sporatic high intensity rainfall and sudden temperature fluctuations are favourable to the development of source area instabilities and debris flow initiation.

The upper drainage slope gradients within Spittal and Leona Creeks are consistently greater than 27 degrees (50 %) and show abundant evidence of past and possibly future slope instabilities. As such, the conditions within the upper drainage areas are consistent with those of drainages prone to debris flows in other areas of British Columbia.

The following table provides a summary of the literature data with respect to debris flow and alluvial fan development and a comparison with characteristics of Spittal, Leona and Goslin Creeks.

Table 3: Channel Characteristics Summary

Literature Source	Data Location	Source Area Gradients (deg.)	Transport Zone Gradients (deg.)	Deposition Initiation Gradients (deg.)	Observed Avg. Fan Gradient (deg.)
Vandine	Not specified	>25°	>15° (confined)	<10° (un/confined)	
Thurber (1983)	Howe Sound	Not specified	>12° (confined)	Avg. 12°(un/confined)	
Thurber (1985)	Hope-Coquihalla	Not specified	>13° (confined)	Avg. 13°(un/confined)	
Hungr (1984)	General B.C.	Not specified	>12° (confined)	8 - 12° (confined) 10 - 14° (unconfined)	
Piteau (1993)	Goslin Creek	>25°	Avg. 22° (confined)		10° (confined) 5° (unconfined)
Piteau (1992)	Bevier Creek	>25°	Avg. 18° (confined)		10° (confined) 5° (unconfined)
MoTH (1998)	Leona Creek	>25°	Avg. 25° (confined)		8° (confined) 7° (unconfined)
MoTH (1998)	Spittal Creek	>25°	Avg. 13° (confined)		8° (confined) 5° (unconfined)

By comparison of the summary data it is evident that the characteristics of the Spittal and Leona Creek channels are consistent with the characteristics exhibited by debris flow prone streams within B.C. The increased potential for downstream debris flow transport at Leona Creek in comparison to Spittal Creek is evident by virtue of the relatively high transport zone average gradient of 25 degrees (compared with 13 at Spittal Creek).

Channel profiles for Spittal and Leona Creeks are shown on Figures 3a and 3b, respectively. Average overall channel gradients noted on the figures are measured via a straight line from Hwy. 16 to the summit of the drainage. Figure 3c shows a profile comparison between Spittal, Leona and Goslin Creeks.

The average gradient shown on Figure 3c is determined by straight line extrapolation from Hwy. 16 to the summit of the respective drainages. Figure 3c shows a significantly greater Leona Creek average gradient in comparison to both Spittal and Goslin Creeks. For the case of Spittal Creek, the average channel gradient may be somewhat misleading due to the potential for sidevalley drainages located closer to the apex of the fan to act as material sources (this would tend to increase the average gradient to Hwy. 16 from the source summit). However, the ability of the sidevalleys to cause direct debris transport through the central axis of the Spittal Creek main channel is significantly diminished by the skew angle of the sidevalleys with respect to the main channel axis.

To aid in showing the relative risk of debris flow impact to Hwy. 16, Figure 3c shows the horizontal distance for which channel gradients on the respective fans are less than 10 % before encountering Hwy. 16. Based on the available literature, the 10 % channel gradient is representative of gradients within the deposition area for unconfined and confined debris flows. Figure 3c indicates that Spittal Creek has the shallowest overall average channel gradient of 18 % (10 degrees) and the longest horizontal distance (about 1900 m) with channel gradients less than 10 % (6 degrees) before encountering Hwy. 16. The decreased average channel gradient and similar runout distance compared to Goslin Creek (1750), suggest that the risk of debris flow activity and potential highway impact is less for Spittal Creek than Goslin Creek. By comparison, at Leona Creek the short horizontal distance of 400 m with channel gradients less than 10 % indicates the relative increased risk of debris flow impact to Hwy. 16.

7.1 Geotechnical Summary

The following is a summary of the main geotechnical issues with respect to Spittal and Leona Creek fan areas.

- Upper drainage instabilities within Spittal and Leona Creeks have and will continue to serve as sources of sediment and organic debris for the main stream channel debris flows. As such, future debris flow activity onto the respective fans should be anticipated.

- Due to the limited channel entrenchment across the Leona and Spittal Creek fans, we consider there to be a *High* potential for future channel migration and related flooding upon the fans. The stream works carried out previously have aided in maintaining the existing channels however, should this work be discontinued, channel migration and flooding should be anticipated on the alluvial fans.

- In light of the observed fan characteristics and previous debris flow activity (1948 to 1998) at the subject sites, we consider the potential for Hwy. 16 to be significantly impacted by destructive debris flow/flood activity to be *Low*. However, under the current highway ditchline configurations we consider there to be a *High* likelihood that future events at Spittal and Leona Creeks will result in flooding similar to that which has previously occurred. The work carried out at the two sites indicates that given an event does occur on Leona and Spittal Creek, it is more likely that depositional material will be transported to Hwy. 16 at Leona Creek as compared to Spittal Creek.

- It is important to point out the fact that the upper drainage areas show evidence of several deep-seated old bedrock related landslides with magnitudes ranging from several hundred thousand to millions of cubic meters. Regardless of the fact that the probability of such an event occurring over the next 50 years is *Low*, it can not be disregarded that high magnitude/low frequency (100 to 500 year return period events) events may occur within the study areas. These long return period events are not distinguishable from the current study 50 year observation period. Should a high magnitude event occur, it is possible that destructive debris flow activity would extend beyond Hwy. 16. The results of our study suggest that the likelihood of a resulting high magnitude debris flow following such an upslope event is significantly greater for Leona Creek than compared to Spittal Creek.

- Within Spittal Creek, we estimate that relatively small debris flow/flood events (magnitude less than 5,000 to 10,000 cu.m.) have a return period of 2 to 4 years within Spittal Creek. Larger debris/flow events with magnitudes ranging between 15,000 and 25,000 cu.m. have an estimated return period of 5 to 15 years.

- The available airphotos and field observations indicate that events occurring on the Leona Creek fan have magnitudes ranging between 7,000 and 15,000 cu.m. and return periods of 3 to 7 years.

8.0 GEOTECHNICAL RECOMMENDATIONS

8.1 Discussion of Previous Impacts to Hwy. 16

As summarized in Section 5.2 and 6.2, the problems associated with Spittal and Leona Creeks at the intersection with Hwy. 16 have involved culvert blockage by transported woody debris and sediment which subsequently produced overtopping of the ditches and flooding of the roadway. In addition to flooding, the increased stream flows during previous events have caused local ditchline erosion and extensive deposition of transported silt, sand and gravel. Our review of the existing information and airphotos over the past 50 years indicate there has not been any destructive debris flow activity extending downstream to Hwy. 16.

8.2 Discussion of Suitable Level of Mitigation

The current location of Hwy. 16 upon the Spittal and Leona fans is at sufficient distance to have limited previous debris flow highway impact to localized flooding and erosion. The activity that MoTH has become accustomed to occurring over the past 50 years is associated with the low magnitude/high frequency (less than 15 years return period) events. Based on our work at the site, the potential for high magnitude/low frequency events (100 to 500 year return period events) is considered to be *Low*. The ability to control high magnitude events on an alluvial fan is difficult due to the physical size of the necessary works and the uncertainty associated in attempting to predict event paths across the fan. Effective control structures for high magnitude/low frequency destructive events are prohibitively expensive and can only be justified under specialized circumstances (high population density/high infrastructure value). In light of these factors, we do not consider it warranted to attempt engineered upstream systems for the protection of Hwy. 16 from the *Low* hazard (high magnitude) events. Based on the consequences to date and the *Low* potential for destructive debris flow/flood activity extending to Hwy. 16, it is our opinion that the existing hazard can be adequately addressed using relatively minor construction works within the MoTH right-of-way.

It is important to realize that irrespective of the minor works being carried out within the right-of-way of Hwy. 16, there is a potential (albeit *Low*) that the highway could be impacted by a low frequency/high magnitude debris flow event.

Although berming and rechannelizing activities previously carried out at the two sites have been effective in maintaining the existing stream channel, we do not consider such work to be necessary for adequate protection of the highway infrastructure. Although a detailed hazard assessment for the adjacent private properties was not carried out on the fans, it is our opinion that the adjacent property owners have an increased concern with respect to the potential for channel migration than does MoTH.

In-stream works such as those previously carried out require continual maintenance and operating expenditures. Benefits to MoTH as a result of discontinuing berming and upstream channeling works would include decreased maintenance costs and liability exposure. The liability exposure to MoTH for being associated with periodic maintenance of unengineered debris flow control works is currently not known. However, it is our recommendation that future channel works at the sites not be carried out unless reviewed by personnel having extensive experience in debris flow/flood mitigation. The incorrect application of berming and channeling can in some cases actually increase the risk to downslope structures.

8.3 Recommended Mitigative Works

The majority of previous problems at the highway have resulted from blockage of the existing culverts as opposed to exceedance of the unobstructed culvert design discharge. A reduction in the potential for flooding at both sites can be provided by implementation of a combination of the strategies outlined below:

- provision of multiple culverts at several different invert elevations along the ditchline. The location and elevation of the culverts should be determined with respect to site grades and anticipated debris accumulation areas. It will be necessary to carry out a site survey of the highway and ditchline areas prior to finalizing the culvert/containment design.
- use of debris control devices, such as trash racks or grizzlies, will also aid in reducing the risk of culvert blockage. The straining devices will prevent the passage of woody debris while permitting the passage of water and fine-grained materials into the culvert or containment pond area. It is important that debris control devices be constructed to permit easy access for periodic maintenance.
- increasing the ditch capacity through the widening/deepening of the existing ditches or by construction of a containment pond. If a containment pond is to be utilized, the system should be backed up with additional culverts located within the ditchline beyond the pond area.

It should be noted that if upstream rechannelling and berming work is to be discontinued that there is a *High* likelihood that the existing streams channel will change. To provide adequate protection against potential channel changes we recommend that the ditching works extended for some 300 m either of the existing stream culverts. Due to the unpredictable nature of channel migrations (see Photograph 13), increasing the containment capacity via the ditch widening option is preferred as opposed to containment pond construction at a specific discharge location.

Based on the amount of material previously deposited at the highway, we estimate that the capacity of the ditchline/catchment areas should be a minimum of 3000 cu.m. Schematic ditch and containment pond sketches are provided as Figure 4.

8.4 Additional Geotechnical Concerns

We anticipate that future events within Spittal and Leona Creeks will cause overbank deposition, flooding and possible channel redirection within existing channel areas exhibiting limited channel entrenchment. The areas observed to have poor channel entrenchment include:

Spittal Creek:

- adjacent to the two (2) existing timber bridges at approximately 230 and 590 m upstream of the Hwy. 16 culvert.
- the debris jam sites located at about 160 and 440 m upstream of the Hwy. 16 culvert, and;
- the sharp channel turn area near the apex of the fan at approximately 1570 m upstream of the Hwy. 16 culvert (see Photograph 6).

Leona Creek:

- the previous blockage area within a narrow channel section located some 220 m upstream of the Hwy. 16 culvert.
- throughout the "S-Turn" area located some 600 m upstream of Hwy. 16
- the previous channel breach area located near the sharp channel turn at approximately 800 m upstream of Hwy. 16.

Overbank channel flows within the above mentioned areas could result in significant redirection of stream flows. The dispersement of unconfined overbank flows resulting from the 1993 debris flow event within Leona Creek are shown in Photograph 13. The presence of adjacent access roads, waterlines and agricultural clearings within these areas could increase the potential for flows to be redirected from the existing channel. The resulting stream redirection may increase the risk of flooding and material deposition in adjacent residential areas.

We recommend that permanent or temporarily inhabited structures within the Spittal and Leona Creek fans be reviewed by qualified geotechnical personnel to establish suitable siting constraints and assess the need for mitigative measures to reduce the potential of upstream hazards to acceptable levels. In addition, we recommend that the periods of usage for the Ministry of Forests *'Spittal Creek Interpretive Forest'* be reviewed to limit public access during periods of increased debris flow/flood activity.

As discussed within Section 4.0 the snowpack data for McBride in the May and June periods can serve as a useful indicator of the potential for debris flows to occur in the Robson District. This information can be utilized in preparation for potential highway maintenance works at the ditchline/containment areas for Spittal and Leona Creeks. This information can also serve as a useful debris flow hazard indicator for owners of the adjacent private properties and users of the Interpretive Forest.

PHOTOGRAPH 1: (Spittal Creek, Nov. 17, 1998): Metal Culvert (1500 mm diam.) at Highway 16.

PHOTOGRAPH 3: (Spittal Creek, Nov.17, 1998): Stream Section 2 deposition area located at approximately 560m upstream from Hwy. 16. Transported boulders to 2m diameter.

PHOTOGRAPH 2: (Spittal Creek, Nov. 17, 1998): Upstream view of stream Section 1 debris jam and overbank deposits located about 160m upstream of the Hwy. 16 culvert.

PHOTOGRAPH 4: (Spittal Creek, Nov.17,1998): Downstream view of stream Section 2 deposition area. The photo was taken from the second timber bridge located at 590m upstream of Hwy.16.

PHOTOGRAPH 5: (Spittal Creek, Nov. 17, 1998): Debris flow wash within 120m wide deposition area of stream Section 3.

PHOTOGRAPH 6: (Spittal Creek, Nov. 17, 1998): Stream Section 4 deposition area located at approximately 1550m upstream from Highway 16. Existing access road is located along the right side of the photo. Photo is taken looking downstream.

PHOTOGRAPH 7: (Leona Creek, Nov. 18, 1998): Deformed metal culvert (1500mm diameter) at Highway 16.

PHOTOGRAPH 8: (Leona Creek, Nov. 18, 1998): Residence located at approximately 200m upstream of Highway 16 and offset 20m east from stream.

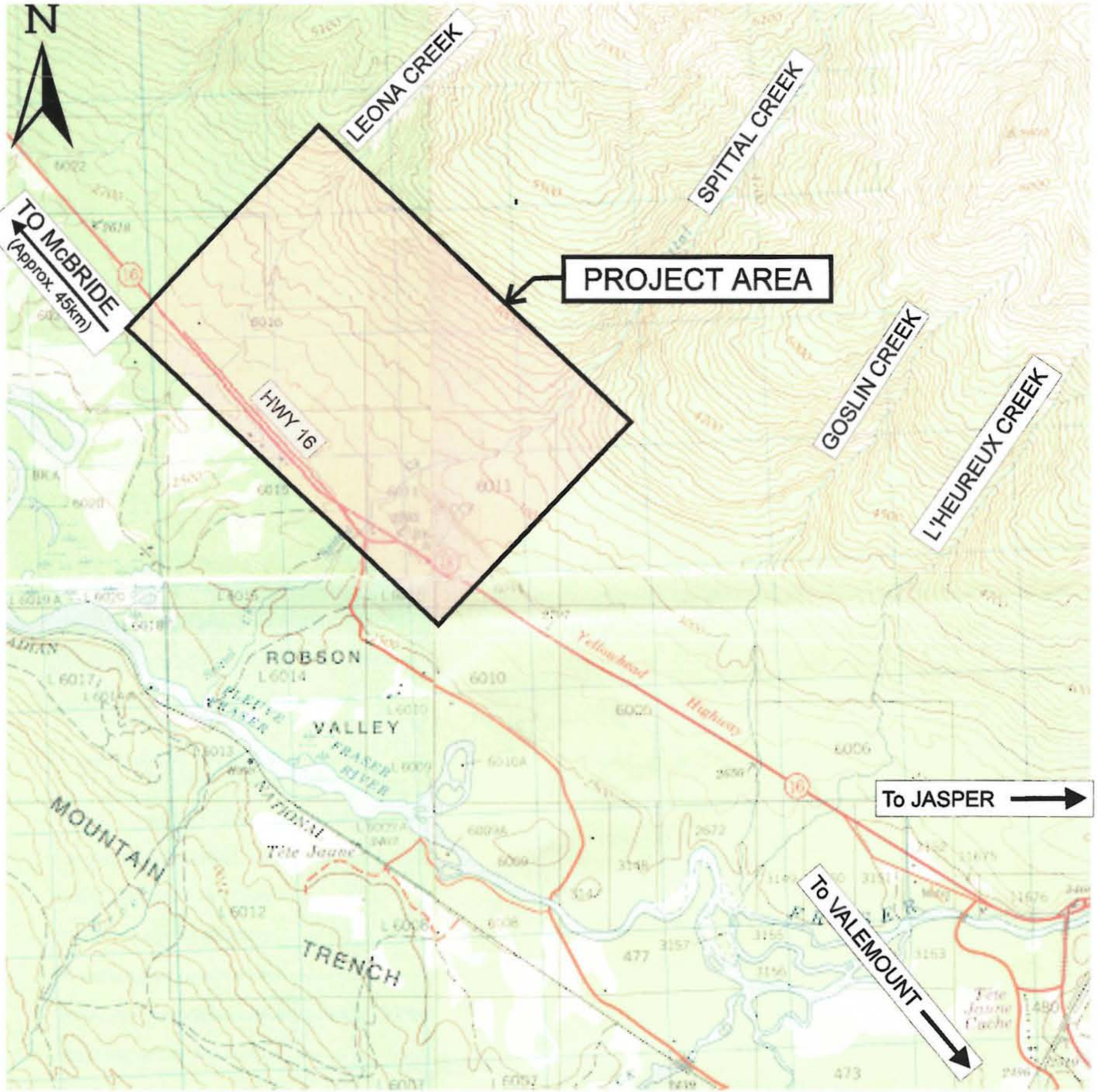
PHOTOGRAPH 9: (Leona Creek, Nov. 18, 1998): Rechannelized (July 1997) stream section within "S–Turn" area at 450-550m upstream of the Highway 16 culvert.

PHOTOGRAPH 10: (Leona Creek, Nov 18,1998): Sharp channel turn at approximately 1150m upstream of Highway 16. Note overbank timber destruction from previous debris flow event.

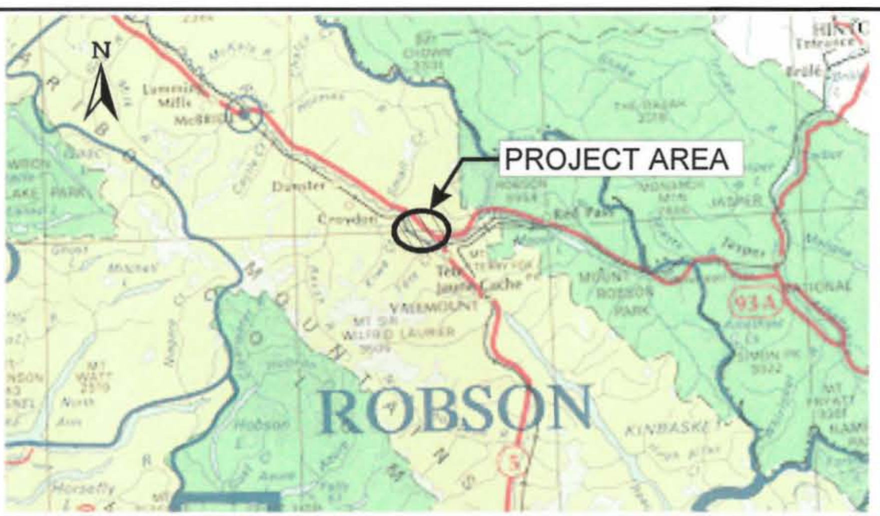
PHOTOGRAPH 11: (Leona Creek, Nov. 18, 1998): 3m high rock dam comprising boulders to 4m diameter at 1215m upstream of Highway 16.

PHOTOGRAPH 12: (Leona Creek, Nov. 18, 1998): 5m high rock dam located at 1465m upstream of Highway 16.

PHOTOGRAPH 13: (Leona Creek, May 1993): Dispersement of flows across agricultural land immediately west of Leona Creek during the May 1993 debris flow event.



NTS Map: 83E/3,4
& 83D/13,14



KEY MAP

N.T.S. Map No. - 1JV

Scale - 1:2,000,000

Scale 1:50,000

0km 1 2 3km

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
GEOTECHNICAL & MATERIALS ENGINEERING

Figure 1

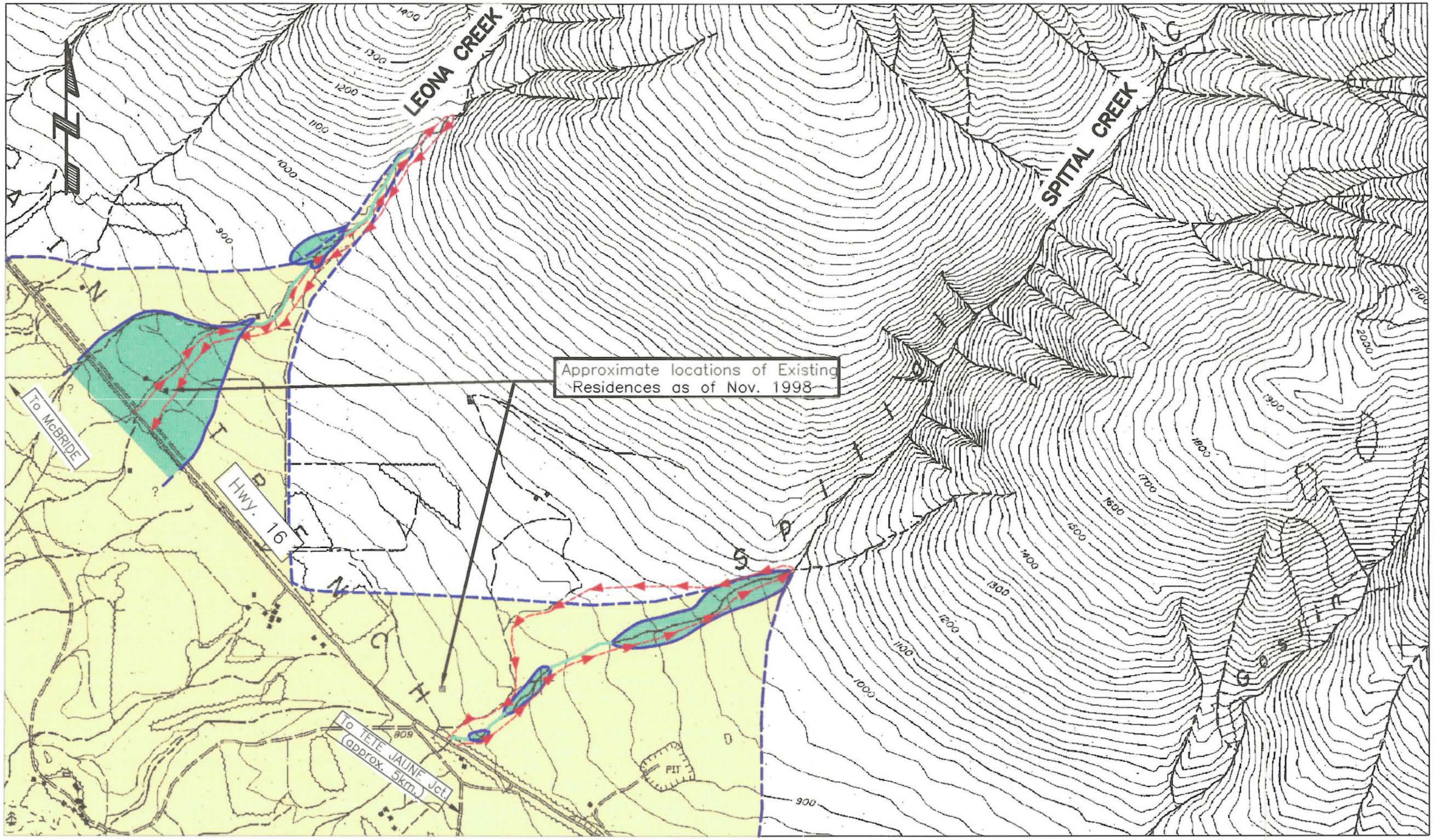
LOCATION MAP

SPITTAL & LEONA CREEKS

ROBSON HIGHWAYS DISTRICT

Drawn: DRB	Date: Feb 99	Scale: As Shown
File No.: M46-16-40		Comp. File: SP-LOC.cdr

MAR. 25. 1999



LEGEND:

- Foot Traverse
- Approx. Historical Extent of Alluvial Fan
- Recent Documented Deposition and Transport Areas

T.R.I.M. NOTE :

1) Contour Interval @ 20 metres
2) Base Map derived from T.R.I.M. Digital Map Data:
Map No.: 83E.003
Flown: Aut 1986

Scale – 1:20,000

0 | 0.5km | 1.0km

GOVERNMENT OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
Geotechnical & Materials Engineering

Figure 2

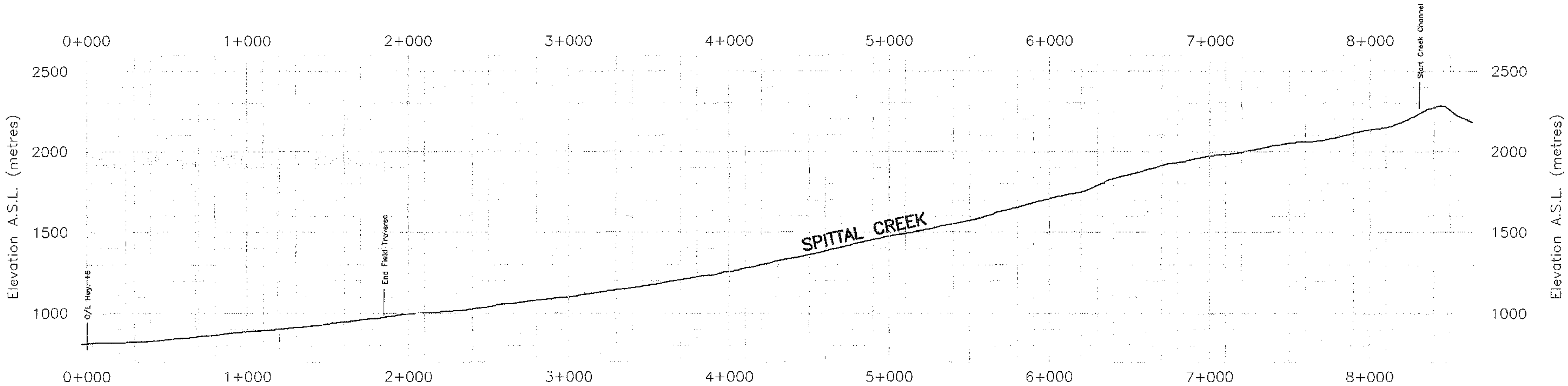
SITE PLAN

SPITTAL & LEONA CREEKS

ROBSON HIGHWAYS DISTRICT

Drawn: drb\GH	Date: Mar 99	Scale: As Shown
File No.: M46-16-40		ACAD File: ENGINEER\SPITTAL GPLAN

MAR. 25. 1999



SPITTAL CREEK PROFILE

DRAWING NOTE:

1) Spittal Creek profile derived from TRIM mapping (83E.003)
2) Start of Creek is based on TRIM mapping and was not field checked.

Scale - 1:20,000 (H&V)

0 0.5km 1.0km

GOVERNMENT OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
Geotechnical & Materials Engineering

Figure 3a

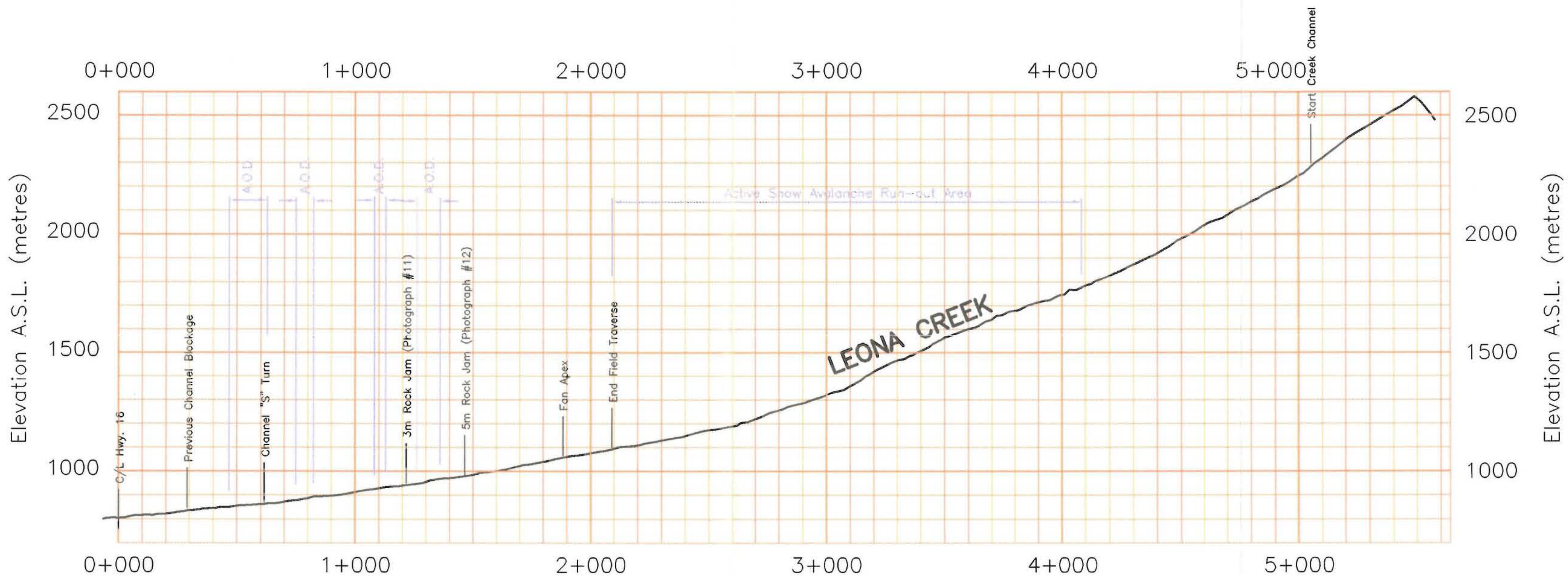
SPITTAL CREEK PROFILE

SPITTAL & LEONA CREEKS

ROBSON HIGHWAYS DISTRICT

Drawn: drb/GH	Date: Mar 99	Scale: As Shown
File No.: M46-16-40		ACAD File: ENGINEER\SPITTAL GPR-SPIT

MAR. 25. 1999



LEONA CREEK PROFILE

DRAWING NOTE:

1) Leona Creek profile derived from TRIM mapping (83E.003) & CAiCE DTM
2) Start of creek is based on TRIM mapping and was not field checked
3) A.O.D. denotes "Abundant Overbank Deposition"

Scale – 1:20,000 (H&V)

0 0.5km 1.0km

GOVERNMENT OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
Geotechnical & Materials Engineering

Figure 3b

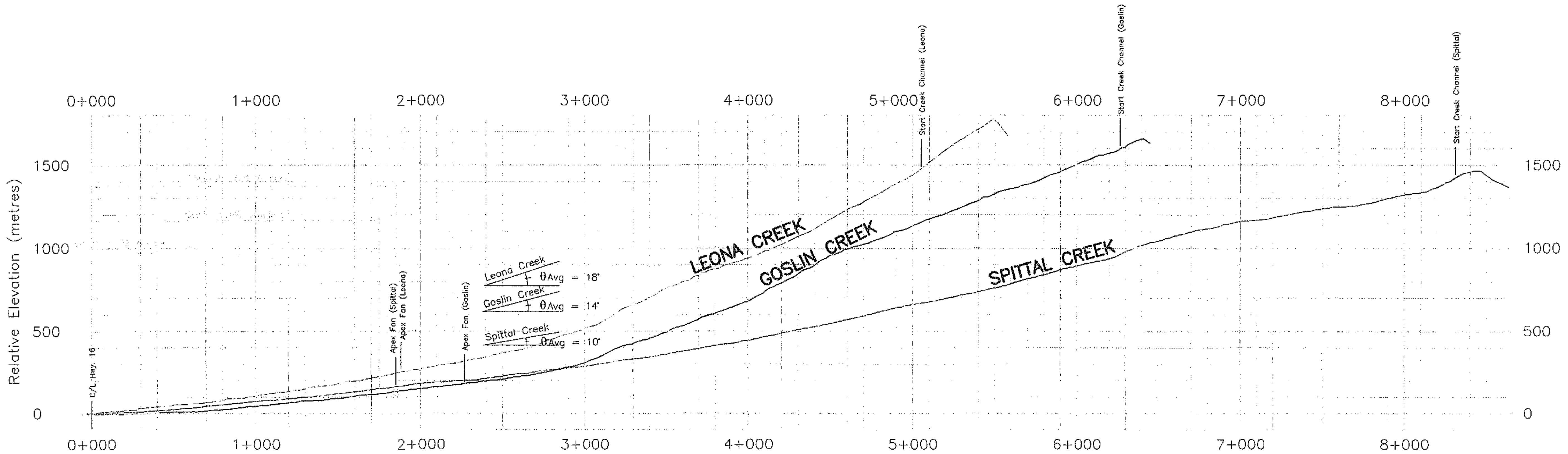
LEONA CREEK PROFILE

SPITTAL & LEONA CREEKS

ROBSON HIGHWAYS DISTRICT

Drawn: drb/GH	Date: Mar 99	Scale: As Shown
File No.: M46-16-40		ACAD File: ENGINEER\SPITTAL GPR-LEON

MAR 25 1999



LEGEND

- GOSLIN CREEK PROFILE
- SPITTAL CREEK PROFILE
- LEONA CREEK PROFILE

Drawing Notes:

1) A,B,C denote points of commencement for less than 10% (6°) downstream Average Channel Gradients.
2) θ Avg. denotes Average Stream Gradients above Hwy. 16 to Catchment Summit
3) Goslin profile digitized from "PITEAU ASSOCIATES" drawing "Fig 3 – Profile Along Centreline and Debris Lobes of Goslin Creek" – Oct 93
4) Spittal and Leona profile extracted from T.R.I.M. mapping (83E.003) and CAiCE DTM Modelling

Scale – 1:20,000 (H&V)

0 | 0.5km | 1.0km

GOVERNMENT OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
Geotechnical & Materials Engineering

Figure 3c

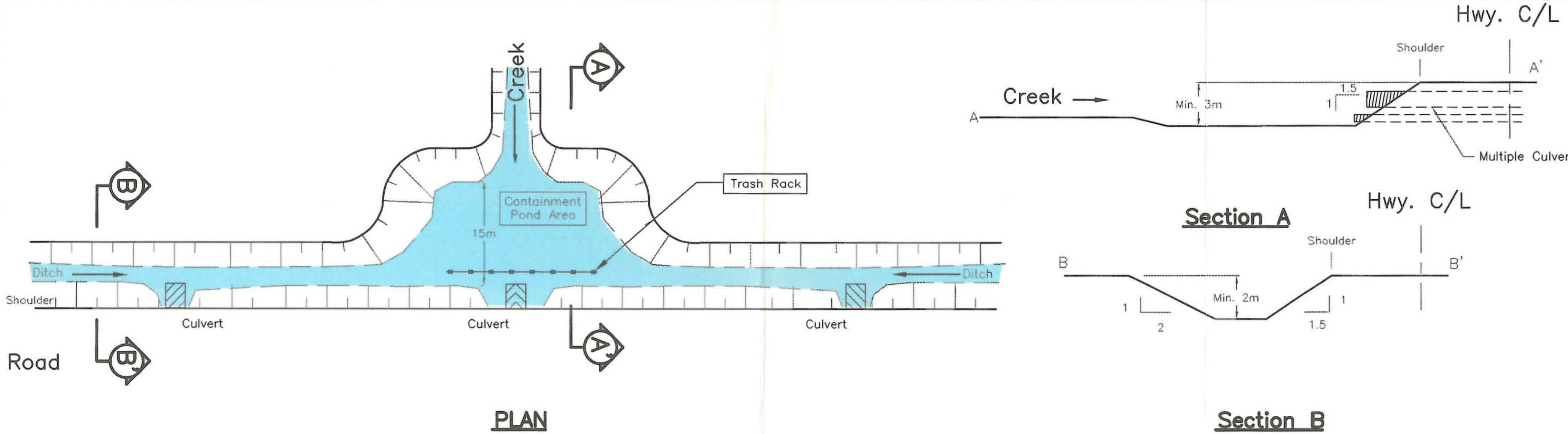
CREEK PROFILE OVERLAY

SPITTAL & LEONA CREEKS

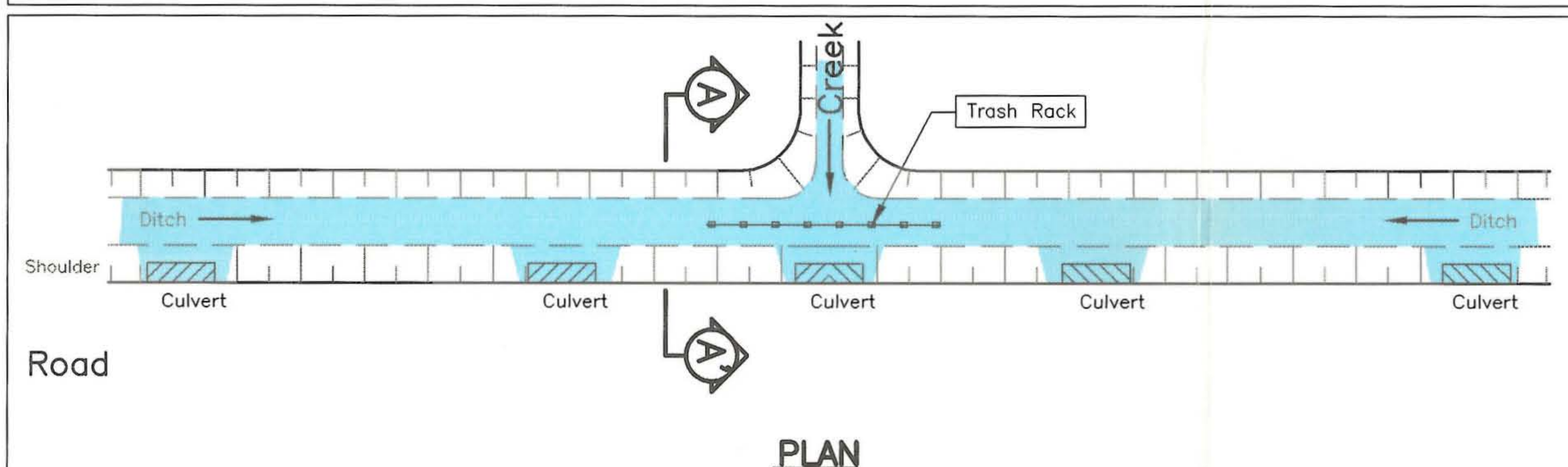
ROBSON HIGHWAYS DISTRICT

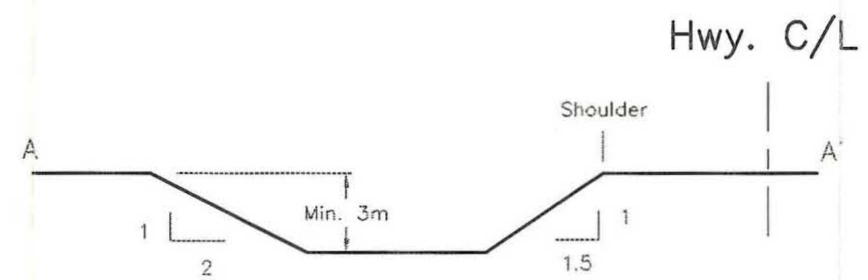
Drawn: drb\GH	Date: Mar 99	Scale: As Shown
File No.: M46-16-40		ACAD File: ENGINEER\SPITTAL GPR-CRKS

MAR. 25. 1999



CONTAINMENT POND SCHEMATIC (N.T.S.)





NOTE:

1) Ditch and containment pond dimensions and culvert locations to be determined following completion of ditchline/adjacent ground survey

Section A

DITCH SCHEMATIC (N.T.S.)

GOVERNMENT OF BRITISH COLUMBIA
MINISTRY OF TRANSPORTATION & HIGHWAYS
Geotechnical & Materials Engineering

Figure 4

DITCH AND CONTAINMENT POND SCHEMATIC

SPITTAL & LEONA CREEKS

ROBSON HIGHWAYS DISTRICT

Drawn: drb/GH	Date: Mar 99	Scale: N.T.S.
File No.: M46-16-40		ACAD File: ENGINEER\SPITTAL GDE-CATC

MAR 25 1999

BF

PROVINCE OF BRITISH COLUMBIA

DEPARTMENT OF HIGHWAYS

TO: E.C. Webster.
Director of Construction,
Department of Highways,
Victoria, B.C.

ATTENTION:

SENDER'S ADDRESS: E.E. Readshaw, Sr. Materials Engineer, Victoria, B.C.

DATE: March 28th, 1966.

ELECTORAL DISTRICT:

HEADQUARTERS FILE: M-699

REGIONAL FILE:

DISTRICT FILE:

SUBJECT: Swift Current Creek

REFERENCE: DATED:

It is reported that gravel for highway fills was borrowed from the bed of Swift Current Creek.

Drilling indicates that this area is the site of a post glacial lake now filled with over 150 feet of weak compressible silts and clays. The ground on the surface and on the stream bed is misleading for it is only 8-12 feet of fan materials laid by the creek over the older lake deposits.

When a stream is aggrading a fan, it tends to change its course frequently, also, in periodic severe runoffs it may incise deep channels through its fan.

In this case the creek's velocity and consequently its scour potential may be worsened by the streamlining of its channel, and possibly by constriction at the bridge site. The clays may have a fair amount of resistance to this scour but some layers near the surface contain up to 88% silt which have poor resistance. The road and bridge therefore may have some risks.

When the bridge is completed it is suggested that a blanket of shot-rock containing boulders up to 2' in diameter be laid on the floor and partly up the walls of the creek for 100 feet both up and downstream. This rock should preferably be placed without the aid of a bulldozer.

E.B. Wilkins,
Design and Planning Engineer.

EE Readshaw

E.E. Readshaw,
Sr. Materials Engineer.

FDL/ek
3cc-Bridge Engineer
cc-E.C. Webster, Director of Construction
cc-E.B. Wilkins
cc-N.R. Zapf, Director of Location, attention J. Blackey

Swift Current Crk (Robson R?)

Mr. E. E. Readshaw,

Senior Materials Engineer,

Department of Highways.

Bridge Engineer,

Victoria, B.C.

July 15, 65.

Drilling - Bridge Sites N.T.P.
Tete Jaune - Alberta Border

A reassessment of our drilling requirements for this section of highway has recently been made. The following test hole locations supercede those of my memo of May 14, 1964.

As site plans for Moose River Bridge and Moose Lake Overhead have not yet been received the test hole locations will be forwarded at a later date.

As design of these structures is about to commence for construction later this year and next year this work must be given top priority.

Test hole locations are listed below.

Fraser River Bridge East

1235
1235 + 50 or as close to water as possible
1237 or as close to water as possible
1237 + 50

Fraser River Bridge West

1074 + 50
1075
1076 + 50
1077

Swift Current Creek

441 + 20
441 + 90
442 + 60
443 + 30
444 + 00

Rockingham Creek

1422 + 40
1423 + 20

Grantbrook Creek	Robson River
873 + 00	519 + 90
873 + 50	520 + 12
874 + 00	520 + 84
	520 + 56
	522 + 28
	523 + 00

J. Alton,
Bridge Engineer.

By:

L. C. Johnson,
Bridge Design Engineer.

LCJ:lh