Province of
British Columbia

Ministry of
Transportation
and Highways

940 Blanshard Street
Victoria
British Columbia
V8W 3E6

DATE: April 19, 1995
BRANCH: Geotechnical & Materials
PHONE: 387-1199
FILE: 01-63-18

Andrew Rushforth, P.Eng.
Graeme & Murray Consultants Ltd.
1137 Yates Street
Victoria, B.C.
V8V 3N1

RE: Millstream Creek Culvert No. 7208 Extension

Dear Mr. Rushforth,

As per your request of April 12, 1995, I can report on the current state of design for the proposed Millstream Creek culvert extension.

Geotechnical Investigation

Subsurface investigations carried out to date has consisted of two bore holes (TH93-55 at creek level and TH93-56 up on the west bank), and one test pit (east bank). The exact location of the bore holes and test pit are shown in Figure 1. The summary logs are also attached.

TH93-56, at a ground elevation of 69.7m was drilled to a depth of 23.8 metres. Standard Penetration Testing (SPT) was carried out at 1.5m intervals and three undisturbed Shelby samples were recovered from the clay layer near the bottom of the hole. TH93-55, at a ground elevation of 61.9m, was drilled using an X-Ray drill incapable of SPT testing. Three samples were recovered, allowing classification of the soil types.

The soil stratigraphy at the culvert location, as indicated by the bore holes and test pit, along the east bank of Millstream Creek, consists of 2m of silty sand on the surface, followed by 1.4m of clay and 2.5m of gravel till. Bedrock was encountered at a depth of 5.9m below surface (elevation 56.0m). Based on test pit TP94-57 and field observations, as you move east away from the creek bedrock elevations undulates between surface exposures and depths in excess of 4.5 meters. To the west of Millstream Creek, bedrock is found at a much lower elevation (21.9m below surface - elevation 47.8m). The soil sequence between the surface and bedrock consists of 4.2m of very dense gravel, 3.1m of stiff clay, 1.4m of dense sand, 9.9m of hard to very stiff clay, and 3.3m of very dense gravel till.

The laboratory testing program consisted of visual identification and moisture content determination of the granular soil and fine grained soils. In addition, index property testing, laboratory vane shear testing, unconfined compression testing and consolidation testing was conducted on selected fine grained soils.

The laboratory testing, described above, was conducted to determine the characteristics of the clay layers. Results form samples recovered in the clay layer had a range of laboratory shear strengths of 51-96kPa while the range of undrained shear strengths, taken for the unconfined compression test, of 69-76kPa. The index properties ranged from 23-36% for the liquid limit, 17-30% for the plastic limit and 20-36% for the natural moisture content. Settlement characteristics for the clay were determined by consolidation testing. The Coefficient of Consolidation of the clay (C_c) is 0.39 while the initial void ration is 0.89. The rate of consolidation (C_v) was determined to be 0.004cm^2/sec.

Geotechnical Design Considerations

As the highway is being widened to the north over Millstream Creek it is necessary to extend the existing culvert prior to construction of the new embankment.

Settlement

Due to the presence of a compressible clay layer, as noted above, settlement is an issue at this site. My letter of March 1, 1995 outlining the expected settlements at Millstream Creek is still applicable. The estimated settlements, as previously reported, are:

Settlement Parallel to Highway (o/s 20m Lt.)

Station	Estimated Settlement
114+05	200 - 300mm
114+10	250 - 350mm
114+15	250 - 350mm
114+20	250 - 350mm
114+25	250 - 350mm
114+30	250 - 350mm
114+35	100 - 150mm
114+40	100 - 150mm
114+45	75 - 125mm

Settlement Along Proposed Culvert

Off-Set	Estimated Settlement
5m Lt.	250 - 350mm
10m Lt.	225 - 325mm
20m Lt.	175 - 250mm
30m Lt.	100 - 150mm

It is estimated that 50% of the settlement will occur with in the first year with 90% completed with in 5 years.

Culvert Options

Several types of culverts have been considered for this project. Based on geotechnical factors alone, I have the following comments:

Flexible vs. rigid culverts: Based on the potential for differential settlement it is felt that rigid culverts should be avoided. It is recommended that a flexible culvert system that is capable of tolerating the settlements and differential settlements outlined above be selected.

Circular vs. rectangular: Again, based on estimated settlement values, a circular section would tolerate settlement and larger differential settlements better that a more rigid rectangular section.

Arch type culvert: To avoid large settlements and the potential for bearing failure an arch type culvert would have to be piled to bedrock.

It is my understanding that a 7m diameter circular culvert is being considered for this project. The main benefit of this type of culvert is its ability to tolerate settlement as it is relatively flexible. Concerns with using a culvert of this size centre around construction problems. The manufactures recommended construction procedure will have to be followed with great care to ensure that the culvert is installed properly. Any large imbalance of force on a culvert of this type may lead to failure.

Above the culvert, to conserve right of way requirements a vertical MSE retaining wall is proposed. Due to the limitations set by the Ministry's Bridge Branch, MSE type walls can not be placed below the 200 year flood level. Consequently, from creek elevation to an elevation equal to the 200 year flood level, mineral fill may be used. A slope angle of 1.5H:1V rising from creek elevation to the base elevation of the wall is permissible. A minimum 2m set back from the crest of the slope to the base of the wall will be required. In addition a minimum cover of 1m will be required between the top of the culvert and the base of the wall.

Bridge Option

Possibly worth considering at this site is the feasibility of crossing Millstream Creek with a bridge structure as opposed to a large diameter culvert. Problems associated with settlement, differential settlement and dependence on critical construction procedures could be avoided.

Allowable Bearing Capacity

The allowable bearing capacity, for the MSE wall, founded in properly compacted granular material would be 300kPa.

If you have any further questions concerning this project please contact me.

Sincerely,

Stephen Alexander, P.Eng.
Geotechnical Design Engineer
For:
Director, Geotechnical
and Materials Engineering

SPA/sa

cc: D. Lister, P.Eng - MOTH
I. Grof, P.Eng - MOTH
B. Kern, P.Eng - VIHPMT
D. Querengesser - VIHPMT

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Branch

TEST HOLE No. 93-55

Project MILLSTREAM CREEK CULVERT
Location STA. 10+11.0, 9.3m LT.
Driller D. SHILLINGFORD Method X-RAY

Elevation 61.9m
Dates 93-10-05/06

HOLE LOCATION: N 6875.215 E 12751.890

Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation % Gravel	Sand	Fines	Index Properties wL	wP	w	Classification	Description	Other Tests
1	C	-	-		0	85	15	-	-	10	SM1	SAND with some silt and trace organic material, brown	
2												2.0m	
3	C	-	-		-	5	95	36	17	34	CL	CLAY with trace fine medium sand, low plasticity, grey	
93-10-06												3.4m	
4	C	-	-		95	5	-	-	-	1	GC	GRAVEL with trace sand, gravel sub-round to sub-angular, maximum diameter 20mm, grey	
5	C	-	.10		-	-	-	-	-	-			
6	C	-	.10		-	-	-	-	-	-			
	C	-	.20		-	-	-	-	-	-			
	C	-	.50		-	-	-	-	-	-			
7	C	-	1.30		-	-	-	-	-	-	BR	BEDROCK	
8												7.9m END OF HOLE	
9													
10												Note: Soil sampled recovered with X-RAY rods and core barrel	
11													
12												EAST BANK	
13													
14													
15													
16													
17													

SAMPLE TYPE
A - Auger
C - Core
D - Denison
S - Split Spoon
T - Shelby Tube
W - Wash

SHEAR STRENGTH kPa
U - Unconfined Compression
Fv - Field Vane
Lv - Lab Vane
R - Remoulded

TESTS
M - Mechanical Analysis
Q,R,S - Triaxial Compression
C - Consolidation
DS - Direct Shear
wL,wP - Liquid, Plastic Limits
W - Moisture Content

Blowcount - Standard Penetration Test (ASTM 1586)

FILE No. 01-63-18
PREPARED BY: SPA/KLASSCAD
SHEET 01 of 02

Ministry of Transportation and Highways

ROCK CORE LOG

Geotechnical and Materials Branch

TEST HOLE No. 93-55

Project MILLSTREAM CREEK CULVERT
Location STA. 10+11.0, 9.3m LT.
Driller D. SHILLINGFORD Method X-RAY
Hole Orientation – Logged By J. PUNSHON

Elevation 61.9m
Dates 93-10-05/06
Date 93-11-30

Drilling Details	Depth (m)	Core Recovery %	Core Condition	Discontinuity Spacing	R.Q.D.	Intact Rock Strength	Weathering	Structural Discontinuity Description	Rock Symbol	Rock Mass Description (X-RAY CORE)	Tests
	4									HOLE LOCATION: N6875.215 E12751.890 40-50°\ BEDROCK BEDROCK AT 7.25m (?)	
	5	28%	SOLID	33.3	0%					GRAVEL (1-8cm, AVG 2cm) WARK GNEISS (WITH GRANODIORITE VEINS) GREENISH GREY, HARD TO MEDIUM HARD, IRON-STAINED FRACTURES & SLICKS, SOME CALCIFIED SLICKS WITH PYRITE, QUARTZ VEINS & FISSURES	
		18%	BR-SOL	41.7	0%						
	6	100%	SOLID	19.0	48%	R4	SW-MW	40-70°/CALCIFIED SLICKS 40-50°\ IRON-STAINED FRACTURES 40-50°\ &20°\ QUARTZ VEINS		BOULDERS (150-400mm SIZE) WARK GNEISS (WITH GRANODIORITE - AS ABOVE)	
		100%	SOLID	6.9	51%						
			BR-SOL	47.8		R2-R3	MW	SOME WEATHERED 30°/&50°\SLICKS		GRAVEL (1-8cm, AVG 3cm) WARK GNEISS	
	7	100%	SOLID	22.5	48%	R4	SW-MW	60°\FRACTURES & SLICKS 60-80°\FRACTURES & SLICKS 10-30°/VEINS		GRAVEL (1-14cm, AVG 3cm) WARK GNEISS WITH GRANODIORITE VEINS AS ABOVE, NO IRON STAINS	
			BROKEN	61.5		R2-R3	MW				
			SOLID	18.8		R3		10-20°/CALCIFIED SLICKS & QUARTZ VEINS & FISSURES			
			SOLID	12.2		R4		50°/CALCIFIED & PYRITIC SLICKS 50°\SLICKS 0-10°/FISSURES 30-40°\&10°/CALCIFIED & PYRITIC SLICKS		WARK GNEISS DARK GREY TO GREENISH GREY, MEDIUM HARD, SLICKENSLIDES & FISSURES, CALCIFIED & PYRITIC SLICKS	
			BROKEN	41.7		R2-R3					
	8									7.9m END OF HOLE EAST BANK	
	9										

CORE RECOVERY
$\frac{\text{Length of core}}{\text{core run}} \times 100$

R.Q.D.
$\frac{\text{Sum core lengths} > 100\text{mm}}{\text{length of core run}} \times 100$

DISCONTINUITY SPACING
No. of fractures/m

ROCK STRENGTH (MPa)

R0	Extremely weak	<1
R1	Very weak	1-5
R2	Weak	5-25
R3	Medium strong	25-50
R4	Strong	50-100
R5	Very strong	100-250
R6	Extremely strong	>250

WEATHERING

F	Fresh
SW	Slightly
MW	Moderately
HW	Highly
CW	Completely
RS	Residual Soil

FILE No. 01-63-18
PREPARED BY: IP/KLASSCAD
SHEET 02 of 02

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Branch

TEST HOLE No. 93-56

Project MILLSTREAM CREEK CULVERT
Location STA. 10+35.7, 13.4m RT.
Driller H. RAUHANEN Method ROTARY WASH
Elevation 69.7m
Dates 93-10-27/28

HOLE LOCATION: N 6841.715 E 12570.056

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation % Gravel	Sand	Fines	Index Properties wL	wP	w	Classification	Description	Other Tests
Blowcount Details	1	CS	>100	.08		70	30	0	–	–	5	GP	sandy GRAVEL with trace silt, gravel up to 25mm diameter, very dense, grey (FILL?)	
65/.15m	2													
69/.15m 79/.15m 55/.15m 40/.15m	3	S	>100	.25		65	30	5	–	–	5	GP		
	4												4.2m	
	5	S	15	.10		–	15	85	40	21	28	CL	CLAY with some sand, plastic, stiff, sand seams to 50mm thick, brown to grey	
	6	S	14	.51		–	20	80	29	16	26	CL		
	7												7.3m	
	8	S	32	25		–	85	15	–	–	21	SM1	SAND with some silt, medium coarse, dense, brown	
93-10-28 ▽	9	S	11	.50		–	10	90	36	17	36	CL	8.7m	
	10													
	11	T	–	.58		–	10	90	23	18	20	CL		
	12	S	15	.61		–	5	95	–	–	25	CL		
	13				Lv Su 51 76								CLAY with trace sand, low plastic, hard to very stiff, grey	
	14	T	–	.58	80 69 96	–	5	95	39	20	28	CL	Cc=0.39 e_o=0.89	C
	15	S	19	.61		–	–	100	–	30	–	CL		
	16													
	17													

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
Su – Unconfined Compression Strength
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
wL,wp – Liquid, Plastic Limits
W – Moisture Content
U – Unconfined Compression

Blowcount – Standard Penetration Test (ASTM 1586)

FILE No. 01-63-18
PREPARED BY: SPA/KLASSCAD
SHEET 01 of 03

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Branch

TEST HOLE No. 93-56

Project MILLSTREAM CREEK CULVERT
Location STA. 10+35.7, 13.4m RT.
Driller H. RAUHANEN Method ROTARY WASH
Elevation 69.7m
Dates 93-10-27/28

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation % Gravel	Sand	Fines	Index Properties wL	wP	w	Classification	HOLE LOCATION: N 6841.715 E 12570.056 Description	Other Tests
		T	-	.08		10	10	80	34	19	30	CL		
													18.6m	
Blowcount Details	19													
	20												GRAVEL with some sand, gravel up to 25mm, very dense, grey	
120/.13m	21	SS	>100	.15		85	10	5	-	-	2	GP		
	22												21.9m	
	23											BR	BEDROCK	
	24												23.8m END OF HOLE	
	25													
	26												s.22	
	27													
	28													
	29													
	30													
	31													
	32													
	33													
	34													
	35													

SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash

SHEAR STRENGTH kPa
Su – Unconfined Compression Strength
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
wL,wP – Liquid, Plastic Limits
W – Moisture Content
U – Unconfined Compression

Blowcount – Standard Penetration Test (ASTM 1586)

FILE No. 01-63-18
PREPARED BY: SPA/KLASSCAD
SHEET 02 of 03

Ministry of Transportation and Highways

ROCK CORE LOG

Geotechnical and Materials Branch

TEST HOLE No. 93-56

Project MILLSTREAM CREEK CULVERT
Location STA. 10+35.7, 13.4m RT.
Driller H. RAUHANEN
Method ROTARY WASH
Hole Orientation 90°
Logged By J. PUNSHON

Elevation 69.7m
Dates 93-10-27/28
Date 93-12-16

HOLE LOCATION: N6841.715 E12570.056

Drilling Details	Depth (m)	Core Recovery %	Core Condition	Discontinuity Spacing	R.Q.D.	Intact Rock Strength	Weathering	Structural Discontinuity Description	Rock Symbol	Rock Mass Description	Tests
	21										
	22									BEDROCK AT 21.94m 30-50°\ BEDROCK	
	23	69%	SHATT. 60.0 BR-SOL 16.7 SHATT. 60.0 BR-SOL 14.3 SH-BR 35.7	17%	R2 R3 R1-R2 R3-R4 R2	MW MW-HW	45°\&30-40°/SLICKS 60-70°/&30°/SLICKS VERTICAL & 60-80SLICKS		WARK GNEISS (METAMORPHOSED DIORITE) - DARK GREY & MOTTLED (CHLORITIC SPOTS WITH HORNBLENDS AND FELDSPAR), COARSELY CRYSTALLINE, MEDIUM HARD, SEVERELY SLICKENSIDED, 3cm DIAMETER & 30°\ GRANODIORITE SILL AT 23.16m	
	24	65%	SHATT. - BROKEN	45.0	0%	R1-R2	MW-HW	60-70°/&40-50°\ &10-25°/SLICKS		23.8m END OF HOLE s.22	
	25										
	26										

CORE RECOVERY = Length of core / core run x 100

R.Q.D. = Sum core lengths > 100mm / length of core run x 100

DISCONTINUITY SPACING
No. of fractures/m

ROCK STRENGTH (MPa)

R0	Extremely weak	<1
R1	Very weak	1-5
R2	Weak	5-25
R3	Medium strong	25-50
R4	Strong	50-100
R5	Very strong	100-250
R6	Extremely strong	>250

WEATHERING

F	Fresh
SW	Slightly
MW	Moderately
HW	Highly
CW	Completely
RS	Residual Soil

FILE No. 01-63-18

PREPARED BY: JP/KLASSCAD

SHEET 03 of 03

Ministry of Transportation and Highways

SUMMARY LOG

Geotechnical and Materials Branch

TEST PIT No. 94-57

Project MILLSTREAM CREEK CULVERT
Location STA. 10+41.7, 31.4m LT.
Driller S. ALEXANDER Method BACKHOE

Elevation 70.0m
Dates 94-06-22

Drilling Details	Depth (m)	Sample Type	Blowcount	Recovery (m)	Shear Strength (kPa)	Gradation % Gravel	Gradation % Sand	Gradation % Fines	Index Properties WL	Index Properties WP	Index Properties W	Classification	HOLE LOCATION: N 6865.4640 E 12788.5017 Description	Other Tests
												TS	TOPSOIL, brown, dry	
													0.3m	
	1.0	G				+	45	55	-	-	15	ML		
	2.0											SM2	SILT and SAND with trace gravel to 25mm, compact, branches and organic matter, brown, below P.L.	
	3.0													
	4.0													
	5.0												4.5m END OF HOLE	
	6.0												* stake 99+00, 20m LT. (OLD CHAINAGE) @ break in slope (East Approach)	
	7.0												(between Millstream Cr. & Bellamy Rd.)	
	8.0													

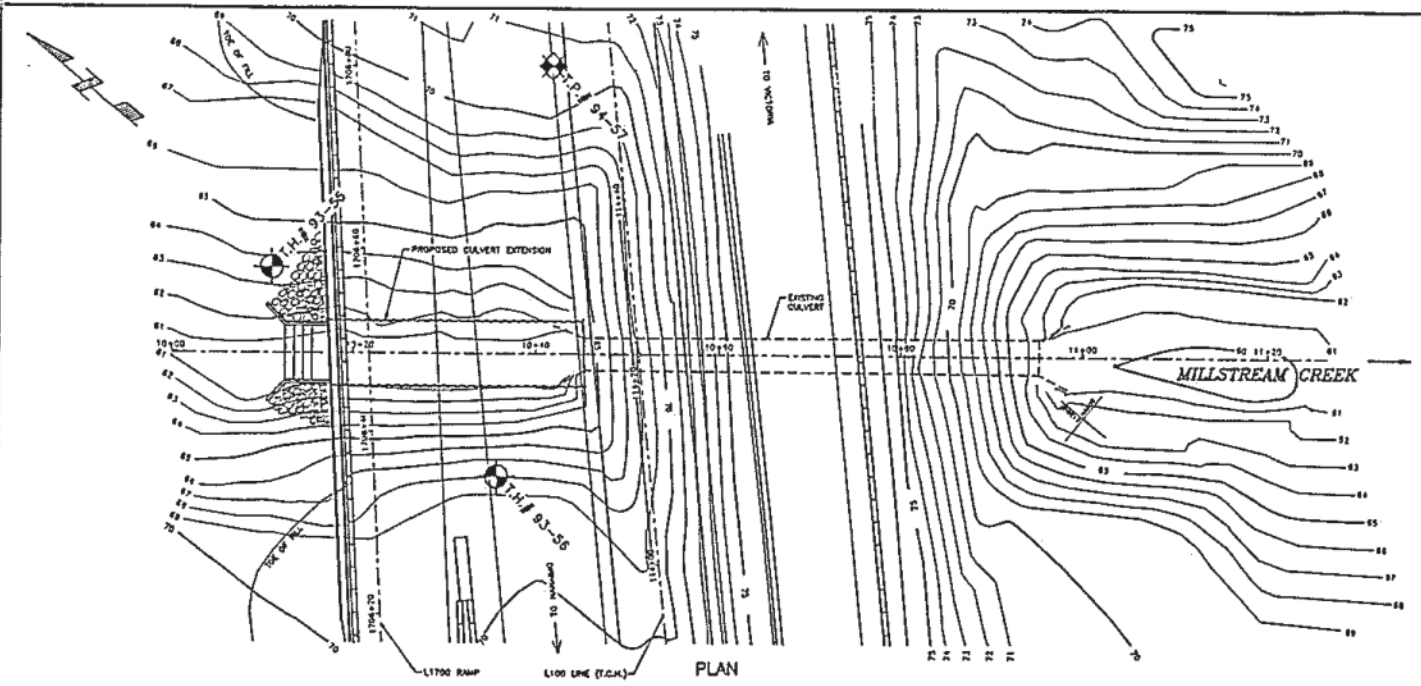
SAMPLE TYPE
A – Auger
C – Core
D – Denison
S – Split Spoon
T – Shelby Tube
W – Wash
G – Grab

SHEAR STRENGTH kPa
U – Unconfined Compression
Fv – Field Vane
Lv – Lab Vane
R – Remoulded

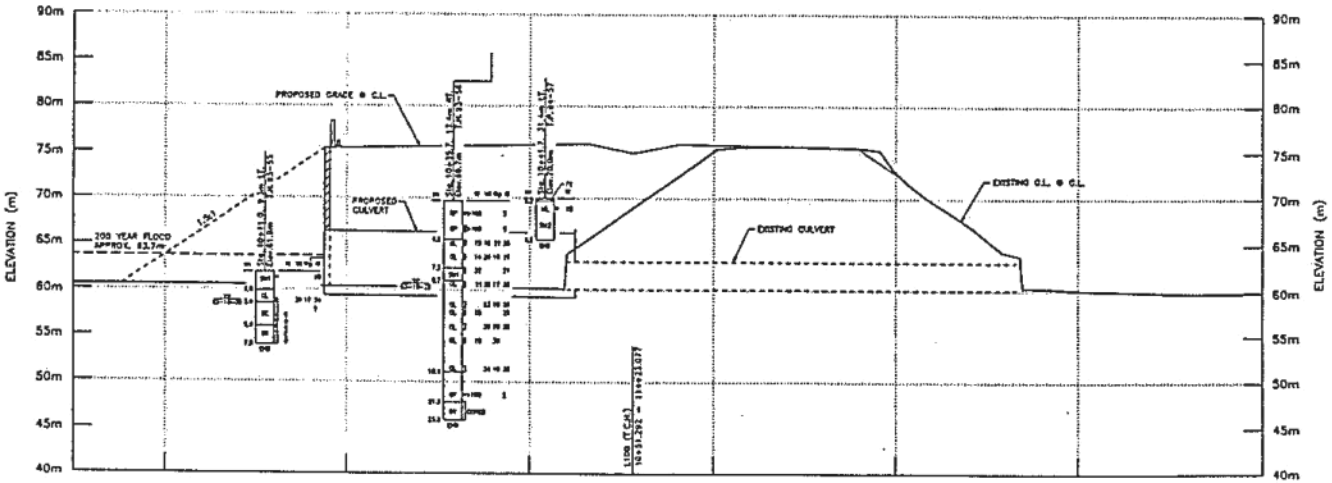
TESTS
M – Mechanical Analysis
Q,R,S – Triaxial Compression
C – Consolidation
DS – Direct Shear
WL,WP – Liquid, Plastic Limits
W – Moisture Content

Blowcount – Standard Penetration Test (ASTM 1586)

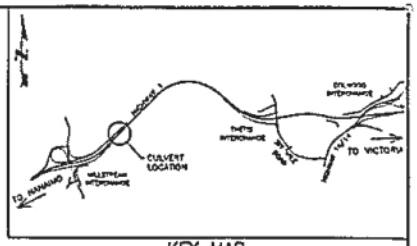
FILE No. 01-63-18
PREPARED BY: SPA/KLASSCAD
SHEET 01 of 01



PLAN



PROFILE



KEY MAP
SCALE: N.T.S.

MATERIALS CLASSIFICATION LEGEND

MAJOR DIVISIONS		SYMBOL	SOIL TYPE
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	GW	WELL GRADED GRAVELS OR GRAVEL-SAND MIXTURES, < 5% FINES
		GP	POORLY-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, < 5% FINES
		GM*	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
		GC*	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	SW	WELL-GRADED SANDS OR GRAVELLY SANDS, < 5% FINES
		SP	POORLY-GRADED SANDS OR GRAVELLY SANDS, < 5% FINES
		SM*	SILTY SANDS SAND-SILT MIXTURES
		SC*	CLAYEY SANDS SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS W_L < 50	ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
		CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
		OL	ORGANIC SILTS AND ORGANIC SILT-CLAYS OF LOW PLASTICITY
	SILTS AND CLAYS W_L > 50	MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, PLASTIC SILTS
		CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
		OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
ORGANIC SOILS		Pt	PEAT AND OTHER HIGHLY ORGANIC SOILS
TOPSOIL		TS	TOPSOIL WITH ROOTS, ETC.
COBBLES		SB	ROCK FRAGMENTS AND COBBLES, PARTICLE SIZE 75mm TO 300mm
BOULDERS		LB	BOULDERS, PARTICLE SIZE OVER 300mm
BEDROCK		BR	BEDROCK

FOR SOILS HAVING 5 – 12% PASSING .075 SIEVE, USE DUAL SYMBOL
*GW1; GC1; SW1; SC1: 12 – 20%
GW2; GC2; SW2; SC2: 20 – 30%
GW3; GC3; SW3; SC3: 30 – 40%
GW4; GC4; SW4; SC4: 40 – 50%
} PASSING .075mm SIEVE

REV. 89-12-01

INFORMATION NOTES

NOTE 1) The test holes shown on the profile are a graphical representation of subsurface conditions at the locations indicated. Interpolation between test holes is not implied. This drawing is to be read in conjunction with the Summary Log Contract Drawing(s) for this project.

NOTE 2) In the event, the bridge layout on this drawing differs from the bridge layout on the General Arrangement Drawing, the General Arrangement Drawing takes precedence.

SCALE 0 1:250 10m

Province of British Columbia
MINISTRY OF TRANSPORTATION AND HIGHWAYS
GEOTECHNICAL AND MATERIALS ENGINEERING

SOUTH ISLAND; VANCOUVER ISLAND HIGHWAY PROJECT
MILLSTREAM CREEK CULVERT
FOUNDATION INVESTIGATION
AT L100 LINE (T.C.H.) STA. 114+23

7208-