Geotechnical Investigation Lake Geraldine Water Reservoir City of Iqaluit, Nunavut

Prepared for:

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Notes On Sample Descriptions

1. All sample descriptions included in this report follow the Canadian Foundations Engineering Manual soil classification system. This system follows the standard proposed by the International Society for Soil Mechanics and Foundation Engineering. Laboratory grain size analyses provided by Trow Associates Inc. also follow the same system. Different classification systems may be used by others; one such system is the Unified Soil Classification. Please note that, with the exception of those samples where a grain size analysis has been made, all samples are classified visually. Visual classification is not sufficiently accurate to provide exact grain sizing or precise differentiation between size classification systems.

CLAY		SILT			SAND			GRAVE	L	COBBLES	BOULDERS
	FINE	MEDIUM	COARSE	FINE	MEDIU	M COARS	E FINE	MEDIU	M COARSE		
	0.002	0.006	0.02	0.06	0.2	0.6	2.0	6.0	20	60 2	200
	-		-	OLUB/ALI	ENT CDA	IN DIAMETE	D IN MILI	IMETRES		•	
			E	QUIVALI	ENT GRA	IN DIAMETE	R IN WILL	LINETRES			
	LASTIC) TO	-		FINE		MEDIUM	I CRS.	FINE	COARSE		
		3		LINE		MILL DY DIE	Ono.	1 11.45	O'GO'H COL		

UNIFIED SOIL CLASSIFICATION

- 2. Fill: Where fill is designated on the borehole log it is defined as indicated by the sample recovered during the boring process. The reader is cautioned that fills are heterogeneous in nature and variable in density or degree of compaction. The borehole description may therefore not be applicable as a general description of site fill materials. All fills should be expected to contain obstruction such as wood, large concrete pieces or subsurface basements, floors, tanks, etc., none of these may have been encountered in the boreholes. Since boreholes cannot accurately define the contents of the fill, test pits are recommended to provide supplementary information. Despite the use of test pits, the heterogeneous nature of fill will leave some ambiguity as to the exact composition of the fill. Most fills contain pockets, seams, or layers of organically contaminated soil. This organic material can result in the generation of methane gas and/or significant ongoing and future settlements. Fill at this site may have been monitored for the presence of methane gas and, if so, the results are given on the borehole logs. The monitoring process does not indicate the volume of gas that can be potentially generated nor does it pinpoint the source of the gas. These readings are to advise of the presence of gas only, and a detailed study is recommended for sites where any explosive gas/methane is detected. Some fill material may be contaminated by toxic/hazardous waste that renders it unacceptable for deposition in any but designated land fill sites; unless specifically stated the fill on this site has not been tested for contaminants that may be considered toxic or hazardous. This testing and a potential hazard study can be undertaken if requested. In most residential/commercial areas undergoing reconstruction, buried oil tanks are common and are generally not detected in a conventional geotechnical site investigation.
- 3. Till: The term till on the borehole logs indicates that the material originates from a geological process associated with glaciation. Because of this geological process the till must be considered heterogeneous in composition and as such may contain pockets and/or seams of material such as sand, gravel, silt or clay. Till often contains cobbles (60 to 200 mm) or boulders (over 200 mm). Contractors may therefore encounter cobbles and boulders during excavation, even if they are not indicated by the borings. It should be appreciated that normal sampling equipment cannot differentiate the size or type of any obstruction. Because of the horizontal and vertical variability of till, the sample description may be applicable to a very limited zone; caution is therefore essential when dealing with sensitive excavations or dewatering programs in till materials.

A 15 m borehol	efore use t m diamete le upon co	r piezometer was installed into the	Elapse Time On Comp	ed e	1	Water evel (m) 0.1		Hole Ope To (m)		Run No.	Dep (m	th	% Re		RO
OTES:	la data er	Continued Next Page		WATER	10 ^L	VEL RE	CORD	s			co	RE DRI	ILLING R	ECORD	-
						3013		2122			2012			2010	II
						3013		2132	3213	1001	2002	130	10100	3010	
	-		-		9	3313		3133	3313	1000	3113	355	10100	3013	
	-		-												II
	-		-		8	3013		3133			3111			3010	П
											2112				
	Grey	medium grained mica rich gn inclined joints below 7.0 m de	eiss with epth.			2012		2112		11121	2012	1200	11111	2010	H
					7	32.13		10100			01110	10000	10100	0000	
	-		_					2100	3013	10000	0000	300		0010	$\ $
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	varie	s from very close to moderate to excellent quality).	e, (very			3 5 1 3		21.33		1000		1101		2000	H
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	*	Sand and gravel, grey.		110.40 110.30 110.1	0		0 1	100 1	50 :	200	idais	10	20	30	2
W M BO		SOIL DESCRIPTION		Assumed Elevation m	DWPHH	Shear S	strength	10.00		80 kPa	Na	bural Moi	sture Control	r50 ent % Weight)	SAMO JES
· c						Vane Te	st	netration 1	S			ometer T	est pour Read	ing (ppm)	S
Datun		Depth below grade				Shelby T Shear St		y	+		Shear S	n at Faili Strength	by		
Date i Drill T		October 21st, 2004 Portable				SPT (N) Dynamic		est			Undrain	rg Limits ned Triax	rial at	F	
Data I	را الما	0.414044.0004				Split Spo Auger Sc		ple					pour Rea e Content		
Locati	ion:	Iqaluit, Nunavuit			_					-	Oncor			_	
Projec	A.	Geotechnical Investigation -	rioposedi	Danis o	-	0.00111				-	Sheet	No	1 of	2	Ti

Trow Borehole Log 1

Project No. OTGE00017616B

Project: Geotechnical Investigation - Proposed Dams of Water Resovoir Figure No. 3

Sheet No. 2 of 2



G	SYM	COIL DESCRIPTION	Assume	- 1 E	Sta			Test N Va	lue 80	2	50 5	500 7	ng (ppm) 50	M	Nat U
G W L	SYMBOL	SOIL DESCRIPTION	Elevation	PIH	Shear S	Strength			kPa	Attert	berg Limit	ture Conte s (% Dry V	Veight)	L	We
H			100.40	10		0 1	00 1	50 2	100	03:30	10	20 :	0 0 0 0 0	S	
	M		99.9		3013	1331	13133	333		3553		18138	33131	ı	
1	111	Borehole terminated at 10.52 m dep		1	1									1	
												18888			
							11111		1	1	11111	1			
					11111			11111	11111		1	1			
1					13333		11111	11111	1	1	1	18888	188881	1	
					1000	1111	11111	11111	1::::	11111	1::::	10000	10000		
		For Core Drilling Record please refe	er to		1000	1111	11111	11111	1::::	11111	1::::	1555	18888		
1		next page			11111	1111	1::::	1::::	1	1	1::::	1000	1000	1	
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1							1333	1	1	1	1	1		1	
1					1	1000		1	11111	11111	1	1		1	
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Bo	TES: prehole now bed	data requires interpretation assistance from one use by others			EVEL RE					0.000		LING R			
		diameter piezometer was installed into the	Elapsed Time		Water evel (m)	1	Hole Ope To (m)	en	Run No.	Dept (m)	th	% Rec	2	RQ	D
bo	orehole	upon competion	On Completion		0.1					(114)					
F	eid wor	k supervised by a Trow representative													
		s on Sample Descriptions													
		wing to be read with Trow Consulting s Ltd. report OTGE00017616B													
	ngineer	s Ltd. report OTGE00017616B													

Elapsed Time	Water Level (m)	Hole Open To (m)
On Completion	0.1	

Run No.	Depth (m)	% Rec.	RQD %

+Trow Field Coring Log

BH 1

Date: October 21, 2004

Jale: October 21, 2004	Rock Characteristics	sand and gravel fill (ran casing)	milky brown igneous bedrock, green-grey	milky brown ligneous bedrock, green-grey	milky brown igneous bedrock, some qtz veins, green-grey,	milky brown Igneous bedrock, some qtz veins, some pyrite, green-grey.	milky brown igneous bedrock, grey	milky brown igneous bedrock, grey							
ams, lqs	H ₂ 0 Colour		milky brown	milky brown	milky brown	milky brown	milky brown								
sovoir D	Water Return %		100	100	100	100	100	100	100	100	100				
e: Water Re	RQD		100	45	97	88	91	66	92	77	96				
Project Name: Water Resovoir Dams, Iqaluit, NU	TCR		100	92	. 100	100	97	99	100	100	95				
	Measured Depth		0.53	1.39	2.69	4.06	5.44	7.14	7.92	9.17	10.52				
0001761	End Depth	0.3	0.53	1.32	2.77	4.11	5.61	7.26	8.28	9.22	10.52				
Project No.:OTGE00017616B	Start Depth	0	0.3	0.53	1.39	2.69	4.06	5.44	7.14	7.92	9.17				
Project N	Run#		1	2	3	4	5	9	7	8	6				

Project:	Geotechnical Investigation - P	roposed Dar	ms of	Water R	esovoi	г			Figure N		4		Tro
Location									Sheet I	No	1_ of _	2_	
_00000				0-00	oon Sarr	role	×	1	Combine	tible Ve	pour Readin	10	
Data Dr	illed: October 15th and 16th, 2004			Auger S		pie	OI.				Content	9	×
				SPT (N) Dynamic	Value Cone T	est		-		g Limits ed Triax		-	-0
Drill Typ				Shelby 1				1	% Strain	at Failu trength	re		0
Datum:	Depth below grade			Shear S Vane Te		у	+ s			meter To			•
s		44	naumed	D St	andard P	enetration	Test N V	alue			our Reading	(ppm)	S Nat
G M W B	SOIL DESCRIPTION		evation		20 Strength	40	60	80 kPa	Nat	tural Mois	500 750 sture Content is (% Dry We	(% sight)	L We
i i	BOULDERS AND COBBLES	102	2.20	0	50	100 1	150	200		10	20 30		§ kN
	BOOLDERO AND GODDELO		101.80	2000		3133	1301		3638	1300			11
.01		100	1.3	3275	100						10100		П
3	GNEISS BEDROCKGrey to light gre	ev	13	1		0100	1000			10000	10000	5515	Ru
	fine to coarse grained with some join cross joints are rough planar to rough	nting, ph		0.010	1000	2100	3 0 1 1				10000	0010	Ru
	undulating commonly with oxidized surfaces, spacing varies from close	7		0.010	1100	3133	13333		2112	1000			Н
	moderate, massive to foliated, some	e mica		2	1100	12333	1000						Ru
	rich lenses, (very good to excellent	quanty).		2010					3113				П
		-		3010	1132	10100	1331					1212	Rı
		_		3		12:33	1300						Ш
				2000		2 1 2 2			2012	10000			Ru
		-		3313	1000	13133			2111		18188	30101	H
	More joints between 3.8 m and 5.3	m _		4	100		13333		2112	1333	10100	28131	R
	depths.			2000					3143	1335			H _{Ru}
		-					1		2111				Ru
				53333	1111	3:50					10100	3333	н
				2010	Hill								Ru
	Dark grey to black, medium grained rich gneiss from 5.3 m to 6.9 m dep	mica th.		0.000	11000	-0100	1331		10000		-0100	00101	Ru
				2233		25.00	13.5		3630	133			- Ru Ru
				3000	100	0000	10000	1000	33.33		10100	3013	H
		-		0.010	-100	0.000	1904	11.6	0000	-1000		0010	
	District on the second			2233		3133	351			110000			Ru
	Pink and grey, fine to medium grain gneiss, some mica rich lenses, relat			2210	ies	01110	liei:		3000			2010	H
	less joints.	-		2000					2 2 2 2 2				Ru
				2013	100	10133	13000				10100	0010	1
		1		8		2111	333	Hija	3113	1000	10158	0010	Ru
		-		2012		121113	1333	1113	13113	1000	10100		Ru
	Mara ininte halaur 9 9 m donth			0010		leise Esta						00-10-	Ru
	More joints below 8.8 m depth.	-		9 33333	133	2133							Ru
				3010		1000	30.10	103	0100	115 (1)	6100		
				3213				1113	2000		1000		Ru Ru
18774	Continued Next Page			10	10000	40000	Tage:	+11111	S 0 4-1-0	heatt	10000		Nu
NOTES: 1. Borehole Trow befo	data requires interpretation assistance from we use by others		WATER	LEVEL R	ECORE	Stranger Land					LLING RE		000
2.A 15 mm	diameter piezometer was installed into the	Elapsed Time		Water Level (m		Hole Op To (m		Run No.	Dep (m		% Rec.		RQD 9
borehole	upon competion	3 Days		0.4									
3. Field worl	supervised by a Trow representative												
	s on Sample Descriptions												
5. This Draw	ring to be read with Trow Consulting Ltd. report OTGE00017616B												

Trow Borehole Log 2

Project No. OTGE00017616B

Project: Geotechnical Investigation - Proposed Dams of Water Resovoir Figure No.

2 of 2 Sheet No.

Combustible Vapour Reading (ppm) 250 500 750 SYMBO. Unit Weight kN/m³ Natural Moisture Content % Atterberg Limits (% Dry Weight) SOIL DESCRIPTION Elevation 92.2 Borehole terminated at 10.05 m depth. For Core Drilling Record please refer to next page. NOTES:

1. Borehole data requires interpretation assistance from Trow before use by others

2. A 15 mm diameter piezometer was installed into the borehole upon competion

3. Field work supervised by a Trow representative

4. See Notes on Sample Descriptions

5. This Drawing to be read with Trow Consulting Engineers Ltd. report OTGE00017616B

WAT	TER LEVEL RECO	ORDS
Elapsed Time	Water Level (m)	Hole Open To (m)
3 Days	0.4	

	CORE DE	RILLING RECOR	RD O
Run No.	Depth (m)	% Rec.	RQD %
		1 5 7 2	



BH 2

page 1 of 2

Date: October 15 and 16, 2004

Project	No.:OTGI	E000176	16B	Project Nam	e: Water Re	esovoir D	ams, Iqa	lluit, NU
Run#	Start Depth	End Depth	Measured Depth	TCR	RQD	Water Return %	H₂0 Colour	Rock Characteristics
CBS1	0	0.51	-	-	-	100	milky with sand	0-9" boulder, 9"-1'8" sand, no recov.,
CBS2	0.51	0.86	-	-	-	100	milky with sand	stone pieces
CBS3	0.86	0.89		-	-	100	milky with sand	stone pieces
4	0.89	1.45	1.22	100	31	100	clear	poss. Igneous bedrock, green-grey and red
5	1.22	1.68	1.68	100	100	100	clear	Igneous bedrock, green-grey and red
6	1.68	2.21	2.13	82	61	100	clear	Igneous bedrock, green-grey and red, v.hard
7	2.13	3.18	3.09	97	97	100-25	milky to clear	Igneous bedrock, pink/grey, loss of h2O at 10'
8	3.09	3.68	3.66	100	91	100	brown	Igneous bedrock, pink
9	3.66	4.34	4.29	37	0	100	brown	Igneous bedrock, pink
10	4.29	4.59	4.52	67	0	100	brown	Igneous bedrock, pink
11	4.52	4.90	4.88	47	0	100	brown	Igneous bedrock, pink, loss of all h2O at 16.5', all natural fractures are rust
12	4.88	5.31	5.31	65	0	0-25	brown	Igneous bedrock, grey-white, some h2O return
13	5.31	5.48	5.48	100	0	0-10	brown to clear	Igneous bedrock, grey-white, lost h2O at 18'8"
14	5.48	5.79	5.74	83	0	0-20	brown to clear	Igneous bedrock, grey-white, all natural fractures are rusty
15	5.74	6.48	6.25	88	. 0	0-20-0	brown to clear	Igneous bedrock, grey-white, all natural fractures are rusty
16	6.25	7.64	7.16	99	83	0-20-0	brown to clear	Igneous bedrock, grey-white, all natural fractures are rusty
17	7.16	8.08	8.03	99	99	0-20-0	brown to clear	Igneous bedrock, grey-white, all natural fractures are rusty
18	8.03	8.38	8.36	88	0	0-10	brown to clear	Igneous bedrock, grey-white, all natural fractures are rusty



BH 2

page 2 of 2

roject	No.:OTG	E000176	16B	Project Name	e: Water Re	sovoir Dan	ns, Iqalu	it, NU
Run#	Start Depth	End Depth	Measured Depth	TCR	RQD	Water Return %	H ₂ 0 Colour	Rock Characteristics
19	8.36	8.71	8.67	100	77	0		igneous bedrock, grey-white
20	8.67	8.99	8.99	92	83	0	-	igneous bedrock, grey-white
21	8.99	9.45	9.42	92	36	0-5	milky	igneous bedrock, grey-pink
22	9.42	9.70	9.70	50	0	0-5	milky	igneous bedrock, grey-pink
23	9.70	10.06	10.05	89	41	0-5	milky	igneous bedrock, grey-grey

Pro	oject	Geotechnical Investigation - Propo	osed I	Dams of	W	ater Re	sovoi	г			Figure	_	5	-	Tre
Lo	catio	n: Iqaluit, Nunavuit	10000								Sheet	No	1_ of	2	
Da	te D	rilled: October 19th, 2004			-	Split Spo Auger Sc	mple	ple	0)	Natural	Moisture	pour Rea e Content		>
	ІІ Ту					SPT (N) Dynamic		est				rg Limits ned Triax		,	
	tum:				-	Shelby T Shear St		v			Shear S	n at Failt Strength	by		-
						Vane Te			+ 0		Penetro	ometer T	est		
GWL	SY-MISO-	SOIL DESCRIPTION		Assumed Elevation m	DWOLT	Shear S	0 Brength		60	80 kPa	Na Na	tural Moi	pour Read 500 3 sture Cont its (% Dry)	750 ent %	SAMP-Jus
H		GNEISS BEDROCKGrey, fine to	into	104.30	0	3013	0 1	00	150	200	13833		1	Ĭ.	Ů
		medium grained gneiss, some angled jo _(fair to very good quality).	oirius —			3313		10.00			10.111			1000	11.
	%					2013		3100						1331	11
	M				1						0.030			0000	H
		 Massive coarse grained porphyritic gnei significant jointing between 1.4 m to 2.0 		102.70		33.33		31.55			0.000	1000	1333	0010	11
		depths. Dark grey to black, fine to medium grain			2	-55.65	-1-0-1	- 21:32 - 21:33	1021	2.1.1.1		-1-2-1-	2.55		#
		mica rich gneiss, some vertical jointing, lightly jointed around 2.6 m depth.				2013		3103	121	1000	31111	100	10100	3313	Ш
		Coarse grained prophyritic gneiss below	v			2010		2100	1001	1.501	01110	1000	10000	2011	11
	X	-2.7 m depth.	-		3			0111		1.512.015	2 1112	ilei:		233	H
			-									-1	1000	1 3 3 3 3	11,
					4			13133	1000						
		Massive mica rich gneiss to 5.9 m depth some quartz mineralization, some vertice								1000	300	1000	10100	1000	H
	***************************************	-joints.	1										2123	2 8 1 8	∐R
	%		+		5	5515	-1001	0100	12.00	11101	4111	11.5	1000		HR
	M		4			3013	-1001	0100	0.010		01110	1000		3015	R
						3013		3133			0.000	1000	10100	3010	R
			1		6	33131	-1-1-1-1	3133	3011	10101	31113	1000	10000	3511	R
	***		-			20101	1000	2100	9010	111111	0100	120	0100	2010	1
Η·Κ	M	Fine to medium grained gneiss below 6. m depth, frequently fractured.	7		7	3213		0100	9010		0000	1000		0000	R
													1000		HR
1						38131			3333						HR
			-		8	38131			1330	1:::3:	300			3517	∐R
	X		-			33131	1331	3133	1335	11131	3000		10100	3313	II _R
	X	Fine to medium amined miss sisk assista				3513		0100	0000		0140	-101		3513	H
82111841118411184118411		 Fine to medium grained mica rich gneiss below 8.9 m depth. 	• 1		9	2012		101111						2010	R
R			+			*****		0100	1011	10000	01110	1000	10100	0000	H.
4	22	Continued Next Page		94.4	H					1			1		LIR.
.Bo	rehole	data requires interpretation assistance from one use by others				EVEL RE							LLING R		
2.A 1	15 mm	diameter piezometer was installed into the	Time			Water evel (m)		Hole Op To (m		Run No.	Dep (m		% Re	C	RQD
DO	renole	upon competion	2 Day	S		1.6									
		k supervised by a Trow representative s on Sample Descriptions													
		s on Sample Descriptions wing to be read with Trow Consulting										1			

Trow Borehole Log 3

Project No. OTGE00017616B

Project: Geotechnical Investigation - Proposed Dams of Water Resovoir Figure No.

Sheet No. 2 of 2



GW L	SYMBOL	SOIL DESCRIPTION	Assum Elevat m 94.30	ion	Shear S	o Strength		0	80 kPa	Nat Attert	50 5 ural Moist perg Limits	ture Conte 3 (% Dry V	50	SAMPLES	Nati Ur Wei kN/
		For Core Drilling Record please refer next page.													
IOTE Bor															
OTI	ES:	data requires intermediation essicians from	WAT	ERI	EVEL RE	CORDS				COS	E DPII	LING RE	COPD	_	
	- Inmat	data requires interpretation assistance from one use by others diameter piezometer was installed into the upon competion	Elapsed Time 2 Days		Water evel (m)		iole Ope To (m)	n	Run No.	Dept (m)	h	% Rec		RÓ	D 9
.Fiel	id wor	k supervised by a Trow representative s on Sample Descriptions wing to be read with Trow Consulting s Ltd. report OTGE00017816B	- 55,5												

Elapsed Time	Water Level (m)	Hole Open To (m)				
2 Days	1.6					

Run No.	Depth (m)	% Rec.	RQD %

+Trow Field Coring Log

BH 3

page 1 of 2 Date: October 19, 2004

П			1.5m			2.4m			grey				rock)	pink					
uit, NU	Rock Characteristics	milky-grey Igneous bedrock, green-grey and pink	milky-grey Igneous bedrock, rusty, green-grey and pink, lost h2O at 1.5m	rock fragments, some h2O comes back at 2.0 m	rock fragments	milky-grey Igneous bedrock, rusty, green-grey and plnk, h2O return at 2.4m	rock fragments	Igneous bedrock, green-grey	Igneous bedrock, some quartz, gamet, pyrite, green-grey	Igneous bedrock, some garnet, green-grey	milky-grey Igneous bedrock, trace pyrite, green-grey	Igneous bedrock, trace pyrite, green-grey	Igneous bedrock, trace pyrite, green-grey, (drilled thru some soft rock)	Igneous bedrock, some partings, some garnet, grey and plnk	Igneous bedrock, trace pyrite, green-grey	Igneous bedrock, trace garnet, green-grey	Igneous bedrock, trace garnet, green-grey	Igneous bedrock, trace garnet, green-grey	Igneous bedrock, green-grey
ams, Iqa	H ₂ 0 Colour	milky-grey	milky-grey	,	,	milky-grey					milky-grey	1	black	grey	grey	grey	1		
sovoir Da	Water Return %	100	100-5	0	0	0-20	0	0	0	0	0-5	0	10	09	09	09	0	0	0
: Water Re	RQD (%)	80	41	0	0	54	0	41	51	69	64	0	0	60	0	46	0	40	44
Project Name: Water Resovoir Dams, Iqaluit, NU	TCR (%)	96	61	100	50	96	100	86	91	100	100	06	52	100	58	80	100	80	81
	Measured Depth (m)	1.3	1.85	1.9	2	2.03	2.46	3.18	4.06	4.27	4.8	4.95	5.49	6.04	6.35	7.37	7.37	7.67	8.23
0001761	End Depth (m)	1.3	1.98	2	2.08	2.92	3.09	3,46	4.06	4.27	4.83	5.05	5.54	6.22	6.53	7.37	7.49	7.75	8.28
Project No.:OTGE00017616B	Start Depth (m)	0	1.3	1.85	1.9	2	2.03	2.46	3.18	4.06	4.27	4.8	4.95	5.49	6.04	6.35	7.37	7.37	7.67
Project N	Run#	1	7	3	4	2	9	7	8	0	10	11	12	13	14	15	16	17	18

Froject No.:OTGE00017616B | Project No.

ВН 3

page 2 of 2 Date: October 15 and 16, 2004

_		_	_	_	_	_		_	_		_	_	_	_	_	
t, NU	Rock Characteristics	igneous bedrock, some garnet, green-grey	igneous bedrock, some gamet, green-grey	igneous bedrock, some gamet, green-grey												
ns, Igalui	H ₂ 0 Colour		,													
voir Dan	Water Return %	0	0	0												
Water Resc	RQD (%) Return Colour	74	79	85												
Project Name: Water Resovoir Dams, Igaluit, NU	TCR (%)	68	68	100												
	Measured Depth (m)	8.86	9.63	9.88												
50001761	End Depth (m)	8.86	9.63	98.6												
roject No.:OTGE00017616B	Start Depth (m)	8.23	8.86	9.63												
roject h	Run#	19	20	21						-8						

Trow Borehole Log 4

	110	W Dordinoid Log		_
Project No.	OTGE00017616B		Figure No. 6	7
Project:	Geotechnical Investigation - Propo	osed Dams of Water Resovoir		Tro
Location:	Iqaluit, Nunavuit		Sheet No. 1 of 1	
		Split Spoon Sample 🗵	Combustible Vapour Reading	
Date Drilled:	October 13th, 2004	Auger Sample (II) SPT (N) Value O	Natural Moisture Content Atterberg Limits	× →
Drill Type:	Portable	Dynamic Cone Test ————————————————————————————————————	Undrained Triaxial at % Strain at Failure	0
Datum:	Depth below grade	Shear Strength by + Vane Test S	Shear Strength by Penetrometer Test	A
		1010 103		

e		_	T	Sta	ndard Pe	netration 1	Test N Va	lue	Combus	stible Vao	our Readi	ng (ppm)	S	Natu
SY-Maio	CON DESCRIPTION	Assumed	DEPT					80	2	50 5	00 7	50	Sem-ses	Vati
80	SOIL DESCRIPTION	Elevation	H		Strength	40 (kPa	Attert	urai Moisi serg Limit	ture Conte s (% Dry V	veight)	L	Wei kN/
L	SII TV SAND Same For annual beauti	110.00	0		50 1	100 1	50 2	00	1	10 :	20 3	30	S	N.N.
	SILTY SAND Some fine gravel, brown, wet, (compact).			0		13113	33.0	1000	300	1300	10100	2010	M	1
	- (compact).	109.60	11	×		15135	12011	11441	0.5.50	11001	10100	0000	IV	
			П	37.15	1551	13135	3365	10000	\$115	1000	11121	2513	M	1
		-	1,	0	-1-2-1	2100	-5-5-5-5	- 1-1-1-1	0000	-1001	- ::::::	2010	X	
			П	33:53	-1-5-1	Refusa		10000	2000	1000	0100	3013	()	1
		_	П	0010	-1001	: Q :	-201-2	-1-1-0-1-	01:10	1000	- 0.000	0010	Ă	
		108.1				2133	3313		2000	1333		3513	Ш	
	SAND AND GRAVELFine grained, some	7	2	0.010	1001	01110	2012	1111111	04-1-0			0000	H	
80	silt, grey, wet.	107.6		3513		2111	3313		3113			3000	Ш	
	SAND AND GRAVEL TILLSome silt,	7	H		1000	2120	12 2 1 1 1	10000	2000	15000	0300	0.000	П	
	grey, moist.						3313		3813	1000	3133	3313	Ш	
333		-	3	2010	11000	2000	10000		22.12	1.000	20000	2010	П	
			П	3213	1000	1000		1	0000			3813	П	
%		-	H						Contract Contract			2000	Н	
244	CUEICO DEDDOCKO:	106.2				21.50	3313	tiiiiii	2		12.50	3213	Ħ	
X	GNEISS BEDROCKPink and grey, fine to medium grained, massive to foliated,	-	4			2			4.1.1.5				П	
	some near vertical to inclined joints, (very			22.13		13133			200		12:22	200	H	
M	good quality).	1	H			11111		11111	11111		11111	1111	П	
			П			2132			3			33.3	H	
W		1	5			11111		111111	2111			4414	П	
K/A		104.5		0010	13301	2133	3011	111111	31113		11121	2000	Ш	
1111	Borehole terminated at 9.88 m depth.	1104.5	H	1111	1111	1111	11111	11111		11111	11111	11111	1	
								11111			11111		П	
			П											
													П	
											1111		П	
						11111	1111					1111		
					1111									
					11111					1111		3333	П	
						1								
								11111		1111	1111			
											1			
				::::	::::	1111	1111	11111	3333	1111	3333	3333		

NOTES:
U. Borehole data requires interpretation assistance from Trow before use by others

2. A 15 mm dismeter piezometer was installed into the

2. A 15 mm diameter piezometer was installed into the borehole upon competion

3. Field work supervised by a Trow representative

4. See Notes on Sample Descriptions

5. This Drawing to be read with Trow Consulting Engineers Ltd. report OTGE00017616B

WAT	TER LEVEL RECO	ORDS
Elapsed Time	Water Level (m)	Hole Open To (m)
6 days	0.4	

Run No.	Depth (m)	% Rec.	RQD %
1	3.84 - 5.54	93	79

Trow Borehole Log 5

	110	W Dorchold Log o		-
Project No.	OTGE00017616B		Figure No. 7	
Project:	Geotechnical Investigation - Propo	osed Dams of Water Resovoir		Tro
Location:	Igaluit, Nunavuit		Sheet No1_ of _1_	-
		Split Spoon Sample 🛛	Combustible Vapour Reading	
Date Drilled:	October 17th, 2004	Auger Sample III SPT (N) Value O	Natural Moisture Content Atterberg Limits	× ⊢—0
Drill Type:	Portable	Dynamic Cone Test Shelby Tube	Undrained Triaxial at % Strain at Failure	0
Datum:	Depth below grade	Shear Strength by + Vane Test S	Shear Strength by Penetrometer Test	

				1	Ste	ndard Pe	netration T	est N Va	due	Combus	stible Vao	our Readi	ng (ppm)	\$
3 3			Assumed	100						2	50 5	00 7	50	A Nati
G N N N N N N N N N N N N N N N N N N N	3	SOIL DESCRIPTION	Elevation	CWC-1	Shear S		40 E	0	80 kPa	Attert	ural Moisi erg Limit	ture Conte s (% Dry V	Veight)	M Ur Wei
1		SILTY SAND Some gravel, trace cobble	110.00	10		0	100 1	50 2	200	1	0	20 3	30	S
		brown, wet, (loose).	110.00		0	-1001	0.000	3333	10131	2112		18188	8010	XI
	1		-		2010		Refusal		111111	2112		10000		()
				1.	3813		0	3533	1000	3838	1333	18188	3813	X
	П			1	2010	1331	1000		11111	01110	1100	2121	0010	П
			- 108.4		2010	-1-1-1-1	0140	0.040	V 1 1 0 0 0	0000	1000		0010	Ш
	4	GNEISS BEDROCKGrey and pink, fine to medium grained massive to foliated,			0.010		12888	10000	Hist	200		18188	33131	Ru
	1	inclined joints, (very poor to good quality	y)	2	9019	-1-2-0-1	0000	2011	10000	0110	-1-2-1-1	10000	2010	Ru Ru
	A				2010		2000			21:12		0100	2010	Ru
	4				2010	122	0 1000	2012	11121	2012	1011	18888	3813	Ru Ru
	2		4000	2	1 1 1 1 1		1		1	2000		2000	2010	Ru
HVX	4	Borehole terminated at 3.20 m depth.	106.8	1	11111	3 3 3 3	1::::	::::	1::::	::::	1111	1		1
				1			1		1::::					
					1				1					
		For Core Drilling Record please refer to next page.												
		next page.			1									
							1		1					
					1				1					
									1			11111		
												1		
	1								1			1		
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									11111					
							1							
							1		1					
	1			-										
									1					
	_			J		1111	11111	1111	11111	11111	3111	:::::	1111	
NOTE:	hole	data requires interpretation assistance from	WATE	RL	EVEL RE	CORD	s			CO	RE DRIL	LING R	ECORD	-
Trow	bef	ore use by others	Elapsed Time	,	Water evel (m)		Hole Ope To (m)		Run No.	Dep (m)		% Re	C.	RQD %
		diameter plezometer was installed into the upon competion			ound surf	ace	10(111)		110.	(11)				
Finds	-	rk supervised by a Trow representative												
		s on Sample Descriptions												
		wing to be read with Trow Consulting is Ltd. report OTGE00017616B												
Engir	neer	's Ltd. report OTGE00017616B												

W)	WATER LEVEL RECORDS										
Elapsed Time	Water Level (m)	Hole Open To (m)									
2 days	At ground surface										

un lo.	Depth (m)	% Rec.	RQD %		
T					

+Trow Field Coring Log

BH 5

Date: October 17, 2004

								_			_	 	 		
aluit, NU	Rock Characteristics	clear to milky Igneous bedcok, grey, some pink	clear to milky Igneous bedcok, grey, some pink	clear to milky Igneous bedcok, grey, some pink	olear to milky Igneous bedcok, grey, some pink	clear to milky Igneous bedcok, grey, some pink	clear to milky Igneous bedcok, grey, some pink	clear to milky Igneous bedcok, grey, some pink							
ams, lqa	H ₂ 0 Colour	clear to milky	clear to milky	clear to milky	clear to milloy	clear to milky	clear to milky	clear to milky							
sovoir D	Water Return %	100	100	100	100	100	100	100							
e: Water Re	RQD	0	100	67	59	0	43	44							
Project Name: Water Resovoir Dams, Iqaluit, NU	TCR	78	100	87	98	100	86	94							
	Measured Depth	1.80	1.93	2.29	2.57	2.69	2.97	3.20							
000176	End Depth	1.83	2.06	2.31	2.57	2.74	2.97	3.20							
Project No.:OTGE00017616B	Start Depth	1.57	1.80	1.93	2.29	2.57	2.69	2.97							
Project N	Run#	7	2	က	4	2	9	7							

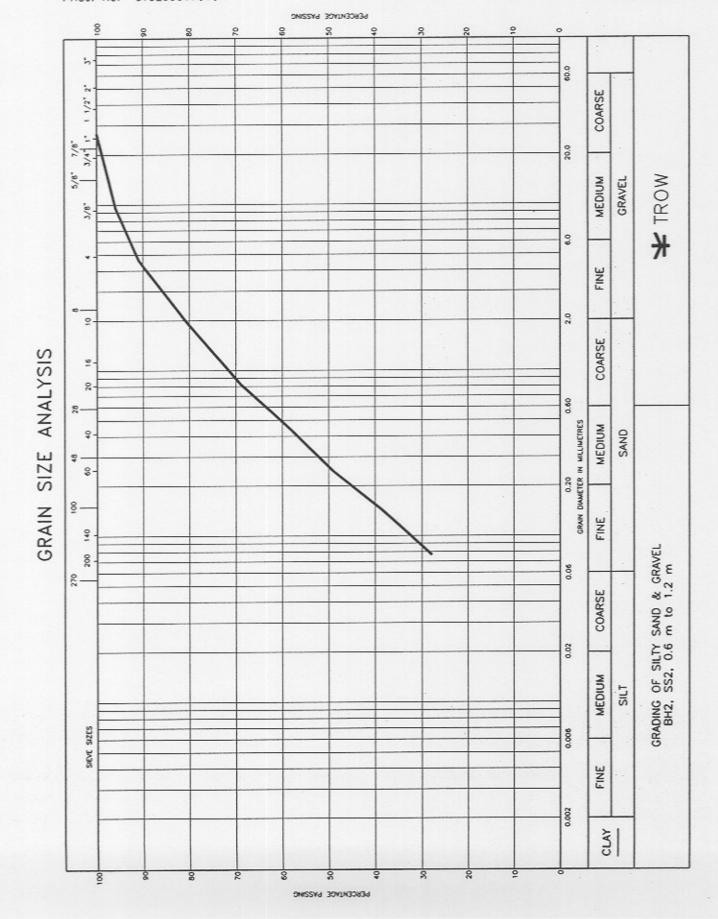
Borehol Trow be A 15 mr borehol	e data requires interpretation assistance from fore use by others in diameter piczometer was installed into the eupon competion ork supervised by a Trow representative	Elapsed Time 1 day	W: Leve	eter el (m)		lole Ope To (m)		Run No.	Dept (m)	h	LING RI		RQD
OTES:	Borehole terminated at 4.47 m depth. For Core Drilling Record please refer to next page.												
3	GNEISS BEDROCKSome quartz veins grey and pink, fine to medium grained massive to foliated, highly jointed, (very poor to poor quality).		3									0010	F
SYMBOL MININGS	SOIL DESCRIPTION SILTY SAND Some gravel, trace cobbl brown, wet. GRAVEL Grey.	Assumed Elevation m 110.00 1109.50 - 108.4	MP-TH 0	Shear S	0 Strength	100	50	80 kPa 200	Na Atter	tural Mois berg Limit	ture Controls (% Dry)	750 ent %	MANAGE NO.
Date I Drill T Datun			- S D S	uger Si PT (N) lynamic helby T hear St lane Te	Value Cone To ube rength b	est y	\$	0 - - - - - -	Natural Atterbe Undrain % Strain Shear S Penetro	Moisture rg Limits ned Triaxi n at Failu Strength tometer Te	ial at re by est	ŀ	(
Locat	ion: Iqaluit, Nunavuit							_	Sheet	No	1_ of	1	Tr

TTOW Field Coring Log

BH 6

Date: October 18, 2004

aluit, NU	Rock Characteristics	Igneous bedrock, green-grey	Igneous bedrock, green-grey	Igneous bedrock, some quartz veins, green-grey and pink	Igneous bedrock, some quartz veins, green-grey and pink	Igneous bedrock, some quartz veins, green-grey and pink							
ams, lq	H ₂ 0 Colour	milky	milky	milky	milky	milky							
Sovoir D	Water Return %	100	100	100	100	100							
e: Water Re	Rab	0	0	0	0	38							
Project Name: Water Resovoir Dams, Iqaluit, NU	TCR	99	09	94	100	100							
	Measured Depth	3.05	3.18	3.61	3.73	4.47							
0001761	End	3.09	3.20	3.61	3.76	4.47							
Project No.:OTGE00017616B	Start	2.84	3.05	3.18	3.61	3.73							
Project	Run#	7	2	3	4	2							



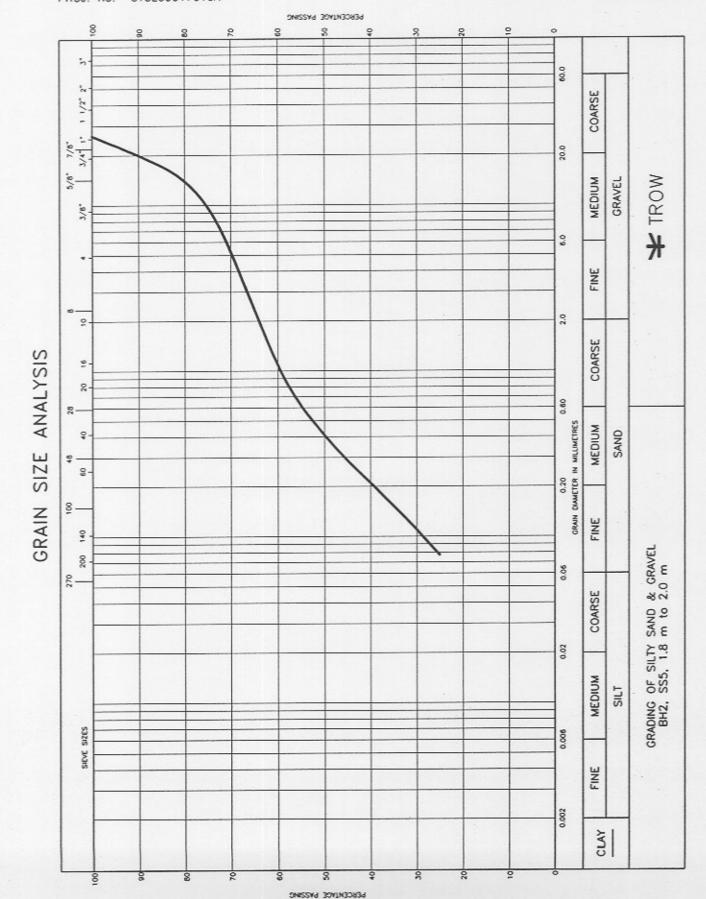
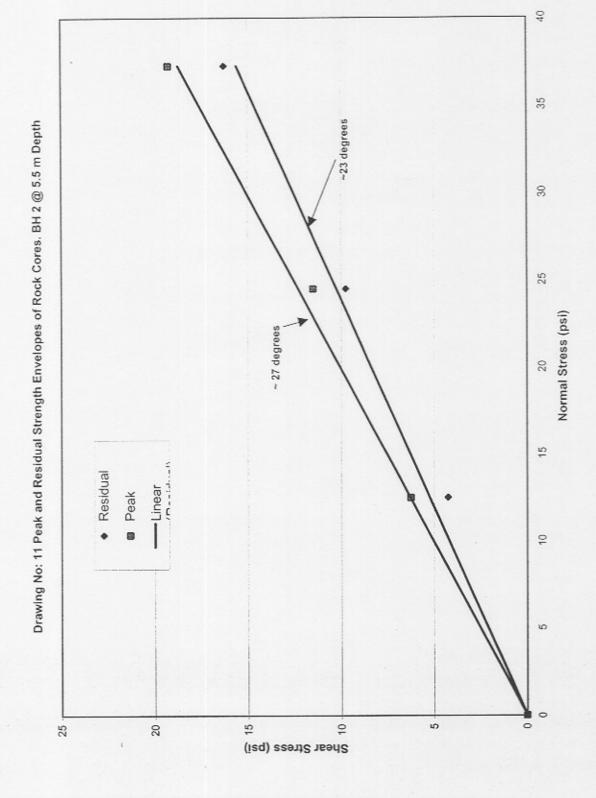
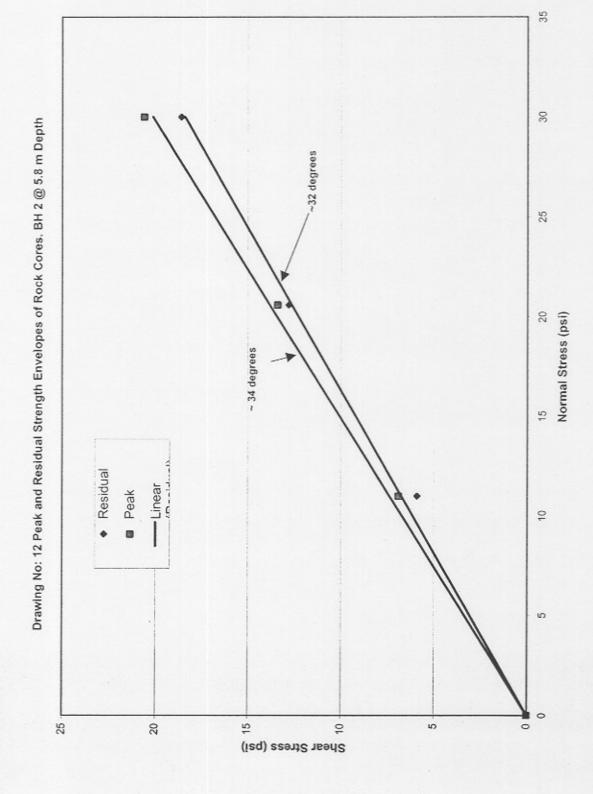


Chart1











Executive Summary

Trow Associates Inc. was retained by the City of Iqaluit to undertake a geotechnical investigation at the Lake Geraldine Water Reservoir located in the northwest part of the City. The water in the reservoir is retained by a cast-in-place concrete gravity dam incorporating a spillway section, and a cast-in-place concrete cut-off wall and embankment located on the north side of the dam. It is proposed to increase the height of the dam by 2 m. This would necessitate increasing the height of the concrete gravity dam and its extension to the south to abut the bedrock in the valley, increasing the height of the concrete cut-off wall and the berm located north of the dam and its extension northerly to abut the bedrock in the valley, and construction of a new concrete cut-off wall and berm in a valley along Lake Geraldine located southeast of the dam.

The geotechnical investigation consisted of drilling six boreholes to a depth of 3.2 m to 10.5 m. The boreholes were initially advanced in the overburden by performing standard penetration tests and retrieving soil samples by split barrel sampler. Once refusal to sampling was met, the boreholes were advanced by core drilling techniques. In the bedrock also the boreholes were advanced by core drilling techniques. Standpipes were installed in all the boreholes to monitor the groundwater table.

The investigation has revealed that in the vicinity of the dam, a shallow deposit of fill is underlain by bedrock. The bedrock is fine to coarse-grained gneiss. It is massive to foliated. It contains some near vertical and inclined joints. It is porphyritic to mica rich. A Total Core Recovery (TCR) of 37 to 100 percent and a Rock Quality Designation (RQD) of 0 to 100 percent was obtained when core drilling the bedrock. On this basis, the bedrock quality may be defined as very poor to excellent.

Water level observations made in the boreholes indicate that the groundwater table at the site is at a depth of 0 m to 1.6 m below the existing ground surface i.e. Elevation 101.8 m to 110.3 m.

The existing dam is founded on bedrock, which has adequate allowable bearing pressure to support the proposed increase in height of the dam. It is noted that the dam has a potential to fail either by sliding at the interface of the concrete and bedrock or along joints in the bedrock. The coefficient of friction between the concrete dam and the bedrock may be taken as 0.67 whereas the angle of friction due to sliding along the bedrock planes may be taken as 23 degrees for design purposes. It is anticipated that additional rock anchors would be required for the dam to overcome overturning moments due to the increased height. The rock anchors may be designed according to the criteria presented in the report. It is noted that the bedrock contains weathered zones. Therefore, grouting of the bedrock may be required prior to installation of the rock anchors.

The proposed dam extension to the south may be founded on gneiss bedrock and should be socketed into the bedrock at least 0.5 m at the base and at the southerly limit where it abuts the bedrock in the valley. The bedrock has an allowable bearing pressure of at least 480 kPa. It is

considered that this allowable bearing pressure would not be exceeded with the proposed increase in height of the dam.

The central berm located immediately north of the dam has an upstream slope of 1 to 1.5H to 1V and a downstream slope, which is steeper than the upstream slope. These slopes are currently unstable. It is recommended that rock fill should be used to stabilize the existing slope, raise the upstream height of the existing berm and construction of the new berm and that the finished slope should be at an inclination of 2H:1V. The advantage of using rock fill is that it would be stable at a steeper inclination compared to sand and gravel fill and its use would minimize siltation of the lake. The downstream slope of the berm may also be designed on an inclination of 2H:1V provided granular materials are used in the construction and the slope is covered with a 600 mm thick layer of 300 mm riprap as erosion protection.

The north and the south berms may also be constructed with slopes and materials similar to those recommended for the central berm. It is reported that a portion of the north concrete cut-off wall is founded in the overburden and not in the bedrock. The potential of seepage taking place beneath the concrete cut-off wall exists in this area with the increased height of the dam and the resultant increase in the hydrostatic pressure. It is recommended that the portion of the north cut-off wall, which is not founded in the bedrock, should be grouted to provide a positive cut-off between the underside of the concrete wall and the bedrock. The concrete cut-off wall for the south berm should be socketed at least 0.5 m into the bedrock at the base and at the two ends where it abuts the rock face in the valley.

The site was visually examined by a geotechnical engineer in an attempt to locate potential aggregate sources for construction of the berms. The visit revealed that the majority of the area comprises of bedrock outcrops and that potential aggregate borrow sources were not present in the vicinity of the dam. As such, it is likely that majority of the aggregate required for construction of the berms would have to be imported from the local gravel pit.

The above and other related considerations are discussed in greater detail in the body of the report.



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	2.3. Description of Structure	2
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Drawings

Drawing No. 1: Dam Components

Drawing No. 2: Site Plan

Drawing Nos. 3 to 8: Borehole Logs

Drawing Nos. 9 and 10: Grain Size Analysis

Drawing Nos. 11 and 12: Direct Shear Tests on Rock Joints

1.0 Introduction

Trow Associates Inc. was retained by the City of Iqaluit to undertake a geotechnical investigation at Lake Geraldine Water Reservoir located in the northwest part of the City of Iqaluit, Nunavut. This work was authorized by the City via letter dated September 29, 2004.

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a cast-inplace concrete gravity dam incorporating a spillway section and a cast-in-place concrete cut-off wall and embankment. It is proposed to increase the height of water storage in Lake Geraldine by 2 m. This would necessitate increasing the height of the existing dam and its extension to the south, increasing the height of the existing concrete cut-off wall and berm located on the north side of the dam and their extension to the north, and construction of a new berm and concrete cut-off wall in one of the valleys located southeast of the existing dam.

The geotechnical investigation was undertaken to:

- (1) Establish the geotechnical conditions below the existing dam, north and south of the existing dam for proposed dam extension and construction of concrete cut-off walls and at three valleys along the shores of Lake Geraldine where new concrete cut-off walls and berms may be constructed.
- (2) Provide geotechnical parameters for the design of the dam including those required to undertake stability analysis.
- (3) Make recommendations regarding extension of the dam to the south.
- (4) Make recommendations regarding increasing the height of the concrete cut-off wall and berm located on the north side of the dam (i.e. central and north berms) including recommended slope inclinations.
- (5) Provide comments on the availability of aggregate sources in the area of the dam.
- (6) Recommend geotechnical parameters for the construction of a new concrete cut-off wall and earth berm in a valley located southeast of the existing dam.

The comments and recommendations given in this report are based on the assumption that the above-described design concept will proceed into construction. If changes are made either in the design phase or during construction, this office must be retained to review these modifications. The result of this review may be a modification of our recommendations or it may require additional field or laboratory work to check whether the changes are acceptable from a geotechnical viewpoint.



2.0 History and Background

2.1. Reservoir

The City of Iqaluit derives its water supply from Lake Geraldine, which is retained by a structure consisting of a cast-in-place concrete gravity dam incorporating a spillway section and a cast-in-place concrete cut-off wall and embankment. All concrete structures are believed to be founded on rock, and engage rock at their abutments. The exception to this is a portion of the cut-off wall in the north berm where the rock is deep and this portion of the wall was founded in the overburden.

Lake Geraldine is a natural body of water in an irregularly shaped basin. It is fed by rainfall and snow/ice melt from a watershed with an area of approximately 385 hectares.

2.2. History

The dam was originally designed and built by the Department of National Defence. According to the literature, the original construction took place circa 1958. Since that time, as the City has grown and water demands have risen, the dam has been raised three times to increase the storage capacity.

The first height increase of 0.3 m reportedly took place in 1979. This involved a concrete extension, which was dowelled into the existing structure.

The second construction took place in 1985, and increased the height of the spillway structure by approximately 1.15 m. The embankment portion was widened and heightened as well to accommodate the increased storage capacity. Again, the extension was constructed of concrete dowelled into the existing structure, and incorporated a steel formwork frame over the spillway section, which remains to this day.

The third extension was done in 1995, and increased the height of the gravity dam structure by a further 1.5 m of concrete, with a corresponding increase in berm geometry. Based on analysis done prior to the extension, it was determined that the gravity dam would not have an adequate factor of safety against overturning if the extension was simply "dowelled-in" as before. The 1995 alteration therefore included an extensive rock-anchoring program for the gravity dam portion to provide the required stability to the structure.

2.3. Description of Structure

A plan showing the various features of the dam has been included as Drawing No. 1. The concrete gravity dam comprises of a concrete spillway and concrete sections on either side of the spillway (i.e. north dam and south dam). The concrete sections on either side of the spillway have an elevation of 110.28 m, with the crest of the 15.7 m wide spillway section being at elevation of approximately 109.33 m, which represents the normal operating level of the lake. At this level, the dam has approximately 0.95 m of freeboard. The south dam extends

approximately 32.7 m to the south rock abutment. The north dam extends 13.3 m north of the spillway section, where it joins an extended, narrow (~200 mm wide) concrete cut-off wall, which is supported on both sides by a sand, gravel and rock fill embankment (central berm and north berm). The embankment cut-off wall extends approximately 80 m to the north rock abutment. The concrete dam and the concrete cut-off wall are reportedly founded on bedrock except for a portion of the cut-off wall as noted previously, which is founded in the overburden. The top of the concrete cut-off wall is reportedly at Elevation 110.30 m with the top of the embankment being at Elevation 110.50 m. It is therefore our understanding that the elevation of the top of the concrete cut-off wall in the embankment portion of the dam is at least equal to the elevation of the top of the concrete gravity dam portion of the dam.



3.0 Procedure

3.1. Drilling and Soil Sampling

The fieldwork for the geotechnical investigation was undertaken between October 13 and 21, 2004 with Hilti drill rig, winch and hammer. The fieldwork was supervised by a representative of Trow Associates Inc. (Trow) on a full time basis.

The fieldwork consisted of drilling 6 boreholes to depths varying between 3.2 m and 10.5 m. The locations of the boreholes are shown on Site Plan, Drawing 2.

Boreholes 1 to 3 inclusive advanced by casing and core drilling techniques. Boreholes 4 to 6 inclusive were initially advanced by performing continuous standard penetration tests and retrieving soil samples. However, the boreholes could only be advanced by this method in unfrozen soil to a depth of 1.0 m to 1.6 m below which frost was encountered. The boreholes were then cased and advanced by core drilling techniques with the Hilti drill rig using a Bx size core barrel. Water was used as the flushing medium.

Water level observations were made in the boreholes during the course of the fieldwork. Standpipes were installed in all the boreholes to establish the groundwater table at the site. All the soil samples were visually examined in the field for textural classification, preserved in plastic bags and identified. The bedrock core was also logged, placed in core boxes and identified. The boreholes were logged. On completion of drilling, all the soil samples and rock core were transported to the Trow laboratory in the City of Ottawa.

The locations and elevations of the boreholes were established by Trow Associates Inc. The elevations of the borehole refer to the Geodetic datum.

All the soil samples were visually examined in the laboratory by a geotechnical engineer and borehole logs prepared. The engineer also assigned the laboratory testing. The laboratory testing consisted of performing grain size analysis on selected soil samples. In addition, direct shear tests were performed on selected rock core samples to establish the peak angle of friction and residual angle of friction due to sliding along bedrock joints. Unconfined compressive strength tests were also performed on bedrock core from selected depths.



4.0 Site and Soil Description

Lake Geraldine is located in the northwest portion of Iqaluit, Nunavut. The ground surface elevation on the north and south side of the valley in which the dam is located is at Elevation 117.8 m to 117.9 m approximately. The bottom of the valley is at Elevation 102 m approximately. The sides of the valley comprise of bedrock. Bedrock is also present at a shallow depth in the bottom of the valley.

A detailed description of the geotechnical conditions encountered in the six boreholes drilled at the site is given on Drawings 3 to 8 inclusive. The borehole logs and related information depict subsurface conditions only at the specific locations and times indicated. Subsurface conditions and water levels at other locations may differ from conditions at the locations where sampling was conducted. The passage of time also may result in changes in the conditions interpreted to exist at the locations where sampling was conducted. Boreholes were drilled to provide representation of subsurface conditions as part of a geotechnical exploration program and are not intended to provide evidence of potential environmental conditions.

Boreholes 1 to 3 inclusive were drilled at the dam location and indicate that approximately 0.3 m to 0.9 m of fill is present in Boreholes 1 and 2 respectively (Elevation 101.1 m to 108.9 m).

In the three boreholes (Boreholes 4, 5 and 6) drilled in the valleys where a cut-off wall may be required, the surficial soil is silty sand which extends to a depth of 1.6 m to 1.9 m (Elevation 108.1 to 108.4). A grain size analysis performed on this stratum indicates that it contains 27 percent clay and silt, 55 percent sand and 18 percent gravel (Drawing 9).

The silty sand stratum in Borcholes 4 and 6 is underlain by a silty sand and gravel layer, which extends to 2.4 m to 2.8 m depth (Elevation 107.2 to 107.6 m). A grain size analysis performed on this stratum yielded a soil composition of 22 percent clay and silt, 43 percent sand and 35 percent gravel (Drawing 10).

The silty sand and gravel layer in Borehole 4 is underlain by sand and gravel till which extends to 3.8 m depth (Elevation 106.0 m).

Below the existing ground surface in Borehole 3, the fill in Boreholes 1 and 2, the till in Borehole 4, silty sand in Borehole 5 and silty sand and gravel in Borehole 6, gneiss bedrock was encountered. The boreholes were terminated in the bedrock at a depth of 3.2 m to 10.5 m. The gneiss bedrock is fine to coarse grained massive to foliated and contains some near vertical and inclined fractures. It is porphyritic to mica rich. It is grey to pink in colour. A Total Core Recovery and Rock Quality Designation of 37 to 100 percent and 0 to 100 percent respectively was encountered in these boreholes. On this basis, the bedrock quality may be defined as very poor to excellent. It is noted that weathered rock zones were encountered at various depths in the two boreholes drilled downstream of the dam (Boreholes 2 and 3).

The unconfined compressive strength of the bedrock was established on rock cores obtained from various depths. The test results are given on Table I. A review of Table I indicates that the unconfined compressive strength of the relatively south bedrock varies from 130 to 222 MPa.



One of the tests performed on relatively weathered bedrock yielded a compressive strength value of 78 MPa. An unconfined compressive strength of 26 MPa was established on one rock core sample where failure occurred along joint in the bedrock.

Table I Unconfined Compressive Strength of Bedrock

Borehole #	Depth (m)	h (m) Unconfined Compressive Remarks Strength (MPa)					
2	2.1	222	Intact relatively sound bedrock				
	3.1	130	Intact relatively sound bedrock				
	6.2	148	Intact relatively sound bedrock				
	7.2	151	Intact relatively sound bedrock				
3	0.5	139	Intact relatively sound bedrock				
	2.8	141	Intact relatively sound bedrock				
	5.8	26	Failure along a joint				
	8.1	78	Weathered bedrock				

Two direct shear tests were performed on joints in the bedrock cores from Borehole 2 to establish the peak angle of friction and the residual angle of friction of the bedrock due to sliding along the joints. The test results are given on Drawings 11 and 12 inclusive. A review of these drawings indicates that the gneiss bedrock has a peak angle of friction of 27 to 34 degrees and a residual angle of friction of 23 to 32 degrees for sliding along joints in the bedrock.

The peak angle of internal friction of the bedrock was estimated to be 40 degrees based on literature search.

Water level readings were recorded at a depth of 0 m to 1.6 m below the existing ground surface i.e. Elevation 101.6 m to 110.1 m. Close to the shores of Lake Geraldine, the groundwater was recorded at Elevation 109.5 m to Elevation 110.3 m. It was recorded at Elevation 101.8 m and Elevation 102.7 m in the two boreholes drilled downstream of the dam. It is possible that the groundwater table may not have stabilized in some of the boreholes during the relatively short time interval over which the readings were taken.



5.0 Proposed Dam Extension

The proposed dam extension would involve increasing the height of the concrete gravity dam and extending the dam to the south to abut the rock slope.

Increasing the height of the dam would result in an increase in the weight of the structure. However, the dam is understood to be founded on bedrock. The bedrock has an allowable bearing pressure in excess of 480 kPa. It is considered that this allowable bearing pressure would not be exceeded with the proposed addition. Extension of the dam structure on the south side would also be founded on bedrock as the bedrock is present at the existing ground surface in this area. The bedrock is considered capable of adequately supporting the proposed structure.

It is recommended that the south end of the dam structure should be keyed a distance of 0.5 m into the bedrock where it abuts the bedrock in the valley to prevent leakage at the interface of the concrete structure and the bedrock.

The peak angle of internal friction of the bedrock was estimated to be 40 degrees. Laboratory testing performed indicated that the bedrock has a peak angle of friction of 27 degrees to 34 and a residual angle of friction (\mathcal{O}_r) of 23 degrees to 32 due to sliding along joints or fissures in the bedrock. Based on this information, it is considered that the coefficient of friction between the bedrock and concrete may be taken as 0.80. A residual angle of friction of 23 degrees is recommended when checking the stability of the dam against sliding along joints or fissures in the bedrock.

It is noted that the bedrock at the site is jointed and fissured. Examination of the rock core revealed various joints in the bedrock that are inclined at an angle of 50 to 70 degrees. The dip of the joints could not be established from the cores. A review of the geological maps indicates that the joints in the bedrock in the vicinity of the dam dip towards the east at an inclination of 46 to 48 degrees. The dip and strike of the joints in the bedrock in the vicinity of the dam was established by a local geologist. A complete examination was not possible due to the snow cover. Information obtained from the field tends to confirm that the joints in the bedrock at the site are also inclined at an inclination of 40 to 60 degrees to the cast. On this basis, it would appear that the joints are inclined in a direction, which would not adversely affect the stability of the dam. However, it is recommended that a more detailed geological mapping of the site should be undertaken during spring or early summer of next year after the snow melt to confirm the preliminary information obtained.

It is understood that the weight of the dam was not sufficient to resist overturning moments and as a result rock anchors were used to provide lateral stability to the structure. They were designed for an allowable load of 630 kN. With the proposed increase in height of the structure, it is anticipated that additional rock anchors would be required.

The following criteria is recommended for the design of new rock anchors:

(1) The maximum working load in the rock anchors should be limited to 60 percent of the yield or 60 percent of the ultimate capacity of the anchor. Yield capacity should be used for anchors with steel grade not exceeding the ultimate stress of 825 MPa, and the ultimate capacity should be used for high strength steel anchors with steel grade exceeding the ultimate stress of 825 MPa.

- (2) The embedment of the anchors should be designed using the submerged weight of a cone of rock under the dam. The submerged weight of the cone of rock should not be less than the ultimate capacity of the anchor. The cone of rock should be assumed to have an apex angle of 90 degrees, and the apex of the cone should be assumed at the midpoint of the fixed anchor length (or bonded length) of the anchor. Where the embedment cones of adjacent anchors overlap, the combined embedment cones for a group of anchors should be used.
- (3) The maximum test load should be 80 percent of the ultimate capacity for anchors with steel grade exceeding the ultimate stress of 825 MPa and 90 percent of the yield capacity for anchors of steel grade not exceeding the ultimate stress of 825 MPa.
- (4) The maximum allowable bond stress at the interface of the anchor grout and the rock should be 1.0 MPa.
- (5) Neither the spacing nor stagger between anchors should be less than 0.5 times the fixed anchor length. If the spacing of less than 0.5 times the fixed anchor length is unavoidable, the fixed anchor length should be increased in proportion to the ratio of 0.5 times the fixed anchor length to the spacing or stagger of the anchors.

It is noted that the bedrock contains weathered zones at various depths. It is therefore possible that grouting of the bedrock may be required prior to installation of the rock anchors. It is noted that grouting of the bedrock was undertaken in some of the anchor holes prior to installation of the anchor during the last extension of the dam.

5.1. Central Berm

The central berm is located immediately north of the concrete gravity dam structure and is approximately 60 m long. The design crest width of the berm is 4 m and crest elevation is at Elevation 110.5 m. The berm has been designed with an upstream side slope of 1 to 1.5 Horizontal to 1 Vertical and a downstream slope of 2H:1V. A 200 mm thick reinforced concrete cut-off wall is located in the berm and has been founded on bedrock. The exception to this is a section of the wall, which is reported to have been founded in the overburden. The berm has been built with sand and gravel fill. A 600 mm thick layer of 100 mm to 200 mm riprap has been provided on the upstream face of the berm as erosion protection.

A review of the dam safety report indicates that the upstream slope immediately north of the dam is at an inclination of 1:25H:1V. It is reported that approximately 20 m length of the upstream slope just north of the concrete gravity dam terminus, extending approximately 1 m to 1.5 m into the crest has slumped by approximately 100 mm. This has been attributed to the overly steep slope in this area.



In order to raise the height of the dam, the existing concrete cut-off wall and the berm will be raised. It is recommended that the upstream slope of the berm should be raised with rock fill which should be placed at an inclination of 2H:1V from the toe of the existing slope. The rock fill berm placed at this inclination would result in a stable upstream slope. Rock fill is recommended for construction of the upstream slope as it would be stable at a steeper angle compared to the sand and gravel fill. In addition, the use of rock fill on the upstream side of the berm would result in less silting of the reservoir compared to the use of sand and gravel fill. The downstream slope of the berm may also be designed at an inclination of 2H:1V assuming that it would be built with sand and gravel fill. This slope should be protected from erosion by providing a layer of riprap at least 600 mm thick.

5.2. North Berm

The north berm is to be extended in the northerly direction so as to abut the bedrock surface in the valley. It is recommended that the upstream slope of the north berm should also be constructed with a slope of 2H:1V using rock fill to prevent siltation of the water reservoir. The downstream slope may be constructed with sand and gravel fill placed at an inclination of 2H:1V provided that a layer of riprap at least 0.6 m thick is provided one the surface of the slope to control erosion.

The concrete cut-off wall should be socketed at least 0.5 m into the bedrock at the base as well as where it abuts the wall of the valley.

It is noted that a portion of the concrete cut-off wall is founded in the sand and gravel overburden. Consequently, the potential for scepage to take place beneath the concrete cut-off wall exists in this area. It is reported that periodic examination of the area to date has not revealed any signs of under seepage. However, the proposed increase in the height of water to be retained would result in increased seepage forces. It is therefore recommended that the portion of the concrete cut-off wall that is not founded on the bedrock should be grouted to achieve an effective cut-off. The grouting should extend from the founding level of the concrete cut-off wall to the underlying bedrock to provide a positive cut-off.

5.3. South Berm

Because of the increase in water level in the reservoir it would be necessary to construct a concrete cut-off wall and berm across the valley in the vicinity of Borehole 4. This borehole has revealed that the overburden in this area comprises of silty sand and sand and gravel underlain by silty sand till. The berm may be constructed with upstream slope of 2H:1V if rock fill is used to construct the berm. The downstream slope of the berm may also be constructed at a slope of 2H:1V with sand and gravel fill provided 600 mm thick layer of riprap is provided as protection against erosion.

The concrete cut-off wall should be socketed at least 0.5 m into the bedrock to prevent seepage at the bedrock/concrete interface. The wall should also be socketed at least 0.5 m into the bedrock at the two ends where it abuts the bedrock face in the valley.



6.0 Granular Materials Search

As part of the geotechnical investigation, an attempt was made to usually locate any potential sources of granular material present in the vicinity of the site. For this purpose, the site was visited by a geotechnical engineer. Visual examination of the area revealed that the majority of the area comprises of bedrock outcrop with minimal overburden deposit. The areas where limited overburden was encountered is in the existing valleys adjacent to the reservoir. However, removal of the overburden material from the valleys is not recommended since this may result in an increase in seepage of water out of the reservoir.

Information received locally indicates that the granular materials used for the last extension of the dam were imported from the local gravel pit. It is anticipated that the material required for construction of the new berms would also have to be imported from the local gravel pit.



7.0 General Comments

The comments given in this report are intended only for the guidance of design engineers. The number of boreholes required to determine the localized underground conditions between boreholes affecting construction costs, techniques, sequencing, equipment, scheduling, etc., would be much greater than has been carried out for the design purposes. Contractors bidding on or undertaking the works should, in this light, decide on their own investigations, as well as their own interpretations of the factual borehole results, so that they may draw their own conclusions as to how the subsurface conditions may affect them.

The information contained in this report is not intended to reflect on environmental aspects of the soils. Should specific information be required, including for example, the presence of pollutants, contaminants or other hazards in the soil, additional testing may be required.

We trust this report is satisfactory for your purposes. If you have any questions regarding our submission, please do not hesitate to contact this office.

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Drawings