under artesian conditions, we conclude that it is very probable that short term pumping at rates of 16 L/s would be possible from either well.

The drilling of a new water well in the community would require truck access by an ice road, or transport of a drill by means of a transport (e.g., Hercules) aircraft. A class D estimate of the drilling and testing of a new well would be approximately $150,000 (not including air transportation costs).

The most cost effective back-up water supply would come from well WW2. This well however would have to be thawed/rehabilitated, and the flows and water quality confirmed prior to use.

In order to meet the 16 L/s peak demand, a new pump would have to be installed in WW1, and a similar pump installed in WW2. Pre-design recommendations with respect to the wellhead completion and pump installation are provided in the following section.

5.0 CONCLUSIONS AND RECOMMENDATIONS

We conclude the following with respect to the water supply wells and back-up supply for Old Crow:

- Based on the information available at this time, the deep confined bedrock aquifer in which WW1 and WW2 are completed is the optimum water source for the primary and back-up water supply for Old Crow for the following reasons:
    - the groundwater source offers a supply of consistent year round quality that meets all existing health-based GCDWQ,
    - the aquifer is well protected from surface sources of contamination by the fine grained soils, upward gradient, and permafrost; and,
    - based on the available well testing and performance information the aquifer can provide sufficient quantities of water to support the bulk water delivery and fire protection.
- We consider that wells WW1 and WW2 should be sufficiently protected from surface sources of contamination due to the unique subsurface conditions at the wells (thick confining unit, sub-permafrost aquifer, upward gradient) and the well construction with deep casing. Although they do not have surface sanitary seals, and are within a flood plain, we consider the above features would offer sufficient protection of water quality at these wells.
- A back-up well completed in the same aquifer would presumably supply water of similar quality as from well WW1, and would provide redundancy in the event that one well is not available for any reason (e.g., due to freeze-up, mechanical problems, or being taken off-line for rehabilitation). If possible, thawing and rehabilitation of WW2 would be the most economical option for a back-up water supply.
- Thawing/rehabilitation of WW2 would consist of thawing with a portable with a portable water heater thawing device, flushing, and testing to confirm that the well yield and water quality are

similar to that at the time of drilling. We consider the probability of success of thawing and rehabilitating to be high.

- If WW2 cannot be thawed/rehabilitated, or is found to be unsuitable as a back-up water supply for some reason, then a new back-up well could be drilled in close proximity to well WW1.

Pre-design recommendations that result from the study include:

- We recommend that the existing groundwater resource be used for the primary and back-up water supply.
- Yukon Government – Environmental Health Services should be consulted regarding the proposed water source and water system improvements in advance of proceeding to detailed design to ensure that they are in agreement that this groundwater source is the best option for Old Crow, and in advance of expending more effort on design and construction prior to permitting,
- If it is determined by the Owner, in consultation with Environmental Health, that further development of the groundwater supply is indeed the most logical approach, then the following should be completed prior to the detailed design:
    - Attempt to thaw and rehabilitate well;
    - If WW2 is found to be not suitable for a back-up well, a new well should be drilled in close proximity to WW1; and,
    - Complete pumping trials at WW1 and WW2 (or potential ne back-up well) to compare with previous test results and confirm ability to meet the short term and long term pumping demands.
- If it is determined by the Owner, in consultation with Environmental Health that further development of the groundwater supply is indeed the most logical approach, then the following should be considered for detailed design:
    - Each well should have a submersible pump installed that is capable of pumping at approximately 16 L/s
    - The pump and intake should be installed at least 65 m below grade to ensure it is below the permafrost level, so that in the event of a well freeze-up, the pump would not be damaged.
    - The wells should be completed with suitably designed and thermostatically controlled heat trace to at least 65 m bg to provide freeze protection.
    - We do not recommend that the wells be retrofitted with pitless adaptors as this would be very difficult to install under artesian conditions and presence of permafrost. Instead of a pitless adaptor, a heated well house (similar to that at well WW1) should be installed around the second well. The wells casings should be

terminated in vermin proof heated enclosures that can be accessed for monitoring, maintenance and cleaning.

- The well pumping schedule should be such that each well is used frequently to reduce the potential for freeze-up and well fouling.

6.0 LIMITATIONS OF REPORT

This report and its contents are intended for the sole use of FSC Architects and Engineers and their agents. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any Party other than FSC Architects and Engineers, or for any Project other than the proposed development at the subject site. Any such unauthorized use of this report is at the sole risk of the user. Use of this report is subject to the terms and conditions stated in EBA's Services Agreement and in the General Conditions provided in Appendix C of this report.

7.0 CLOSURE

We trust this report meets your present requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Respectfully submitted,
EBA Engineering Consultants Ltd.

Ryan Martin, M.Eng., P.Eng.
Project Director, Hydrogeologist
Whitehorse Environment Group
Direct Line: (867) 668-2071 ext.243
Email : rmarshall@eba.ca

Scott Schillereff, P.Geo.
Principal Consultant
Environment Practice
Direct Line: (250) 862-4832
Email: sschillereff@eba.ca

Attachments:

Table 1: Water Quality Results

Appendix A - Old Crow Groundwater Supply – July, 1982

Appendix B – Laboratory Reports

Appendix C – EBA's General Conditions

TABLES

TABLE 1: LABORATORY ANALYTICAL RESULTS FOR OLD CROW WATER WELL ASSESSMENT

Analyte		Sample ID	Mar2010 Old Crow Raw	Guidelines for Canadian Drinking Water Quality [1]	
		Description	Raw Water - WW1		
		Exova Report	730789-1		
		Date Sampled	3-Mar-10		
		Sampled by	EBA	MAC [2]	AO [3]
		Unit	Results		
Physical and Field Parameters					
Temperature	T	°C	2.0	-	15
Colour		CU	<5	-	15
Electrical Conductivity (field)	EC	uS/cm	624	-	-
Electrical Conductivity (lab)	EC	uS/cm	479	-	-
Total Dissolved Solids (field)	TDS	mg/L	436	-	500
Total Dissolved Solids (lab)	TDS	mg/L	250	-	500
Hardness (CaCO3)		mg/L	207	-	-
pH (field)	pH	pH units	7.78	-	6.5-8.5
pH (lab)	pH	pH units	7.85	-	6.5-8.5
Turbidity (field)		NTU	0.84		1 [4]
Turbidity (lab)		NTU	1.6	-	-
Anions					
T-Alkalinity	CaCO3	mg/L	150	-	-
Chloride	Cl	mg/L	50.2	-	250
Sulphate	SO4	mg/L	22	-	500
Nutrients					
Nitrate-N	NO3	mg/L	0.01	10	-
Nitrite-N	NO2	mg/L	<0.005	1	-
Dissolved Metals					
Sodium	Na	mg/L	13.7	-	200
Total Metals					
Aluminum	Al	mg/L	<0.002		
Antimony	Sb	mg/L	<0.0002	0.006	-
Arsenic	As	mg/L	0.0084	0.010	-
Barium	Ba	mg/L	0.043	1	-
Boron	B	mg/L	0.074	5	-
Cadmium	Cd	mg/L	<0.00001	0.005	-
Chromium	Cr	mg/L	<0.0005	0.05	-
Copper	Cu	mg/L	0.002	-	1
Iron	Fe	mg/L	0.17	-	0.3
Lead	Pb	mg/L	0.0003	0.01	-
Manganese	Mn	mg/L	**0.162**	-	0.05
Selenium	Se	mg/L	<0.0002	0.01	-
Sodium	Na	mg/L	13.70	-	200
Uranium	U	mg/L	<0.0005	0.02	-
Zinc	Zn	mg/L	0.013	-	5
Trihalomethanes THM Formation Potential Results					
Bromodichloromethane	BDCM	mg/L	0.003	0.016	-
Bromoform		mg/L	<0.001	-	-
Chloroform		mg/L	0.002	-	-
Dibromochloromethane		mg/L	0.002	-	-
Total Trihalomethanes		mg/L	0.007	0.100	-

Notes:

bold indicates that a value exceeds an asthetic objective

"<" indicates less than detection limit.

"-" indicates not analyzed / no guideline established

[1] GCDWQ criteria are taken from the "Guidelines for Canadian Drinking Water Quality, May 2008"

[2] MAC refers to the Maximum Acceptable Concentration according to the GCDWQ criteria.

[3] AO refers to the Aesthetic Objective according to the GCDWQ criteria.

[4] Depends on water source (surface water or GUDI vs. secure groundwater/non-GUDI), and water treatment type. The health-based turbidity guideline does not apply to secure groundwater sources, i.e., those not under the direct influence of surface water. Turbidity in these cases is non-organic, should pose no health threat and should not hinder disinfection. However, for effective operation of the distribution system, it is good practice to ensure that water entering the distribution system has low turbidity levels of around 1.0 NTU.

APPENDIX

APPENDIX B LABORATORY REPORTS *

Exova
#104, 19575-55 A Ave.
Surrey, British Columbia
V3S 8P8, Canada

T: +1 (604) 514-3322
F: +1 (604) 514-3323
E: Surrey@exova.com
W: www.exova.com

Report Transmission Cover Page

Bill To:	EBA Engineering Consulting Lt	Project:		Lot ID:	**730789**
Report To:	EBA Engineering Consulting Lt	ID:	W23101323	Control Number:	
	Unit 6, 151 Industrial Road	Name:	Old Crow Water Well Assesment	Date Received:	Mar 10, 2010
	Whitehorse, YT, Canada	Location:	Old Crow,YT	Date Reported:	Mar 22, 2010
	Y1A 2V3	LSD:		Report Number:	1303838
Attn:	Ryan Martin	P.O.:			
Sampled By:	RMM	Acct code:			
Company:	EBA				

Contact & Affiliation	Address	Delivery Commitments
Ryan Martin EBA Engineering - Edmonton	Unit 6, 151 Industrial Road Whitehorse, Yukon Territory Y1A 2V3 Phone: (867) 668-3068 Fax: (867) 668-4349 Email: rmartin@eba.ca	On [Lot Verification] send (COA) by Email - Single Report On [Report Approval] send (COC, Test Report) by Email - Merge Reports
Kim Greenman EBA Engineering - Edmonton	Unit 6, 151 Industrial Road, Calcite Business Whitehorse, Yukon Territory Y1A 2V3 Phone: (867) 668-2071 Fax: (867) 668-4349 Email: kgreenman@eba.ca	On [Lot Approval and Final Test Report Approval] send (Invoice) by Email - Single Report

Notes To Clients:

- Analysis was performed on sample 1 that exceeded the recommended holding time for pH analysis.

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Surrey, British Columbia
V3S 8P8, Canada

T: +1 (604) 514-3322
F: +1 (604) 514-3323
E: Surrey@exova.com
W: www.exova.com

Exova

Analytical Report

Bill To:	EBA Engineering Consulting Lt	Project:		Lot ID:	**730789**
Report To:	EBA Engineering Consulting Lt	ID:	W23101323	Control Number:	
	Unit 6, 151 Industrial Road	Name:	Old Crow Water Well Assesment	Date Received:	Mar 10, 2010
	Whitehorse, YT, Canada	Location:	Old Crow,YT	Date Reported:	Mar 22, 2010
	Y1A 2V3	LSD:		Report Number:	1303838
Attn:	Ryan Martin	P.O.:			
Sampled By:	RMM	Acct code:			
Company:	EBA				

Reference Number	730789-1
Sample Date	March 03, 2010
Sample Time	NA
Sample Location	
Sample Description	Mar2010-Old Crow Raw
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Metals Extractable						
Aluminum	Extractable	mg/L	<0.002	0.002	0.1	Below OG
Antimony	Extractable	mg/L	<0.0002	0.0002	0.006	Below MAC
Arsenic	Extractable	mg/L	0.0084	0.0002	0.01	Below MAC
Barium	Extractable	mg/L	0.043	0.001	1	Below MAC
Boron	Extractable	mg/L	0.074	0.002	5	Below MAC
Cadmium	Extractable	mg/L	<0.00001	0.00001	0.005	Below MAC
Chromium	Extractable	mg/L	<0.0005	0.0005	0.05	Below MAC
Copper	Extractable	mg/L	0.002	0.001	1	Below AO
Lead	Extractable	mg/L	0.0003	0.0001	0.01	Below MAC
Selenium	Extractable	mg/L	<0.0002	0.0002	0.01	Below MAC
Uranium	Extractable	mg/L	<0.0005	0.0005	0.02	Below MAC
Zinc	Extractable	mg/L	0.013	0.001	5	Below AO
Physical and Aggregate Properties						
Colour	Apparent, Potable	Colour units	<5	5	15	Below AO
Turbidity		NTU	1.6	0.1	0.1	Above OG
Routine Water						
pH	@ 25 °C	pH	7.85		6.5-8.5	Within AO
pH			8.00		6.5 - 8.5	Within AO
Electrical Conductivity		µS/cm at 25 C	479	1		
Sodium	Extractable	mg/L	13.7	0.4	200	Below AO
Iron	Extractable	mg/L	0.17	0.01	0.3	Below AO
Manganese	Extractable	mg/L	0.162	0.005	0.05	Above AO
Chloride	Dissolved	mg/L	50.2	0.4	250	Below AO
Fluoride		mg/L	0.21	0.05	1.5	Below MAC
Nitrate - N		mg/L	0.01	0.01	10	Below MAC
Nitrite - N		mg/L	<0.005	0.005	1	Below MAC
Sulfate (SO4)		mg/L	22	0.9	500	Below AO
T-Alkalinity	as CaCO3	mg/L	150	5		
Total Dissolved Solids		mg/L	250	1	500	Below AO
Hardness	as CaCO3	mg/L	207			
Trihalomethanes - Surrogate Recovery						
Dibromofluoromethane	EPA Surrogate	%	98	86-118		
Toluene-d8	EPA Surrogate	%	102	88-110		
Bromofluorobenzene	EPA Surrogate	%	98	86-115		
Trihalomethane Formation Potential						
pH adjustment	required prior to		No			

Exova
#104, 19575-55 A Ave.
Surrey, British Columbia
V3S 8P8, Canada

T: +1 (604) 514-3322
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Analytical Report

Bill To:	EBA Engineering Consulting Lt	Project:		Lot ID:	**730789**
Report To:	EBA Engineering Consulting Lt	ID:	W23101323	Control Number:	
	Unit 6, 151 Industrial Road	Name:	Old Crow Water Well Assesment	Date Received:	Mar 10, 2010
	Whitehorse, YT, Canada	Location:	Old Crow,YT	Date Reported:	Mar 22, 2010
	Y1A 2V3	LSD:		Report Number:	1303838
Attn:	Ryan Martin	P.O.:			
Sampled By:	RMM	Acct code:			
Company:	EBA				

Reference Number	730789-1
Sample Date	March 03, 2010
Sample Time	NA
Sample Location	
Sample Description	Mar2010-Old Crow Raw
Sample Matrix	Water

Analyte		Units	Result	Nominal Detection Limit	Guideline Limit	Guideline Comments
Trihalomethane Formation Potential - Continued						
	THMFP					
Chlorine	spike concentration	mg/L	5.0	0.1		
Incubation Time		Days	7	1		
Chlorine	final after incubation	mg/L	3.6	0.1		
Bromodichloromethane		mg/L	0.003	0.001		
Bromoform		mg/L	<0.001	0.001		
Chloroform		mg/L	0.002	0.001		
Dibromochloromethane		mg/L	0.002	0.001		
Total Trihalomethanes		mg/L	0.007	0.001		

Approved by:

Andrew Garrard, BSc
General Manager

Exova
#104, 19575-55 A Ave.
Surrey, British Columbia
V3S 8P8, Canada

T: +1 (604) 514-3322
F: +1 (604) 514-3323
E: Surrey@exova.com
W: www.exova.com

Methodology and Notes

Bill To:	EBA Engineering Consulting Lt	Project:	
Report To:	EBA Engineering Consulting Lt	ID:	W23101323
	Unit 6, 151 Industrial Road	Name:	Old Crow Water Well Assesment
	Whitehorse, YT, Canada	Location:	Old Crow,YT
	Y1A 2V3	LSD:	
Attn:	Ryan Martin	P.O.:	
Sampled By:	RMM	Acct code:	
Company:	EBA		

Lot ID:	**730789**
Control Number:	
Date Received:	Mar 10, 2010
Date Reported:	Mar 22, 2010
Report Number:	1303838

Method of Analysis

Method Name	Reference		Method	Date Analysis Started	Location
Alkalinity, pH, and EC in water	APHA	*	Alkalinity - Titration Method, 2320 B	12-Mar-10	Exova Edmonton
Alkalinity, pH, and EC in water	APHA	*	Conductivity, 2510	12-Mar-10	Exova Edmonton
Alkalinity, pH, and EC in water	APHA	*	pH - Electrometric Method, 4500-H+ B	12-Mar-10	Exova Edmonton
Anions (Routine) by Ion Chromatography	APHA	*	Ion Chromatography with Chemical Suppression of Eluent Cond., 4110 B	12-Mar-10	Exova Edmonton
Chloride in Water	APHA	*	Automated Ferricyanide Method, 4500-Cl- E	12-Mar-10	Exova Edmonton
Colour (Apparent) in water	APHA	*	Visual Comparison Method, 2120 B	15-Mar-10	Exova Edmonton
Metals ICP-MS (Extractable) in water	US EPA	*	Determination of Trace Elements in Waters and Wastes by ICP-MS, 200.8	15-Mar-10	Exova Edmonton
Metals Trace (Extractable) in water	APHA		Hardness by Calculation, 2340 B	12-Mar-10	Exova Edmonton
Metals Trace (Extractable) in water	APHA	*	Inductively Coupled Plasma (ICP) Method, 3120 B	12-Mar-10	Exova Edmonton
pH in water (Surrey)	APHA	*	pH - Electrometric Method, 4500-H+ B	11-Mar-10	Exova Surrey
Preparation - THM Formation Potential	APHA	*	THM Potential, 5710 B	11-Mar-10	Exova Surrey
THM - PrepWater	US EPA	*	US EPA method, 524	22-Mar-10	Exova Calgary
Turbidity in Water	APHA	*	Turbidity - Nephelometric Method, 2130 B	15-Mar-10	Exova Edmonton

** Reference Method Modified*

References

US EPA	US Environmental Protection Agency Test Methods
APHA	Standard Methods for the Examination of Water and Wastewater

Guidelines

Guideline Description	Health Canada GCDWQ
Guideline Source	Guidelines for Canadian Drinking Water Quality, Health Canada, May 2008
Guideline Comments	MAC = Maximum Acceptable Concentration AO = Aesthetic Objective OG = Operational Guideline for Water Treatment Plants Refer to Health Canada GCDWQ for complete guidelines and additional drinking water information at www.hc-sc.gc.ca

Comments:

- Analysis was performed on sample 1 that exceeded the recommended holding time for pH analysis.

Exova
#104, 19575-55 A Ave.
Surrey, British Columbia
V3S 8P8, Canada

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F: +1 (604) 514-3323
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Methodology and Notes

Bill To:	EBA Engineering Consulting Lt	Project:	
Report To:	EBA Engineering Consulting Lt	ID:	W23101323
	Unit 6, 151 Industrial Road	Name:	Old Crow Water Well Assesment
	Whitehorse, YT, Canada	Location:	Old Crow,YT
	Y1A 2V3	LSD:	
Attn:	Ryan Martin	P.O.:	
Sampled By:	RMM	Acct code:	
Company:	EBA		

Lot ID:	**730789**
Control Number:	
Date Received:	Mar 10, 2010
Date Reported:	Mar 22, 2010
Report Number:	1303838

The comparison of test results to guideline limits is provided for information purposes only. This is not to be taken as a statement of conformance / nonconformance to any guideline, regulation or limit. The data user is responsible for all conclusions drawn with respect to the data and is advised to consult official regulatory references when evaluating compliance.

Please direct any inquiries regarding this report to our Client Services group.
Results relate only to samples as submitted.
The test report shall not be reproduced except in full, without the written approval of the laboratory.

Bodycote TESTING GROUP

LOT: _____ Control Number _____

Environmental Sample Information Sheet

Note: Proper completion of this form is required in order to proceed with analysis

See reverse for your nearest Bodycote location and proper sampling protocol

Billing Address:			**Copy of Report To:**			Copy of invoice:
Company:	EBA Engineering Consulting Ltd.		Company:	EBA Engineering Consulting Ltd.	Mail invoice to this address for approval	☐
Address:	Unit 6, 151 Industrial Rd Whitehorse, YT Y1A 2V3	QA/QC Report ☐	Address:	Unit 6, 151 Industrial Rd Whitehorse, YT Y1A 2V3		
		Report Result:				Report Result:
Attention:		Fax ☒	Attention:			Fax ☒
Phone:	867-668-3068	Mail ☐	Phone:	867-668-3068		Mail ☐
Fax:	867-668-4349	Courier ☐	Fax:	867-668-4349		Courier ☐
Cell:		e-mail ☒	Cell:			e-mail ☒
e-mail:	rmartin@eba.ca	e-Service ☐	e-mail:	rmartin@eba.ca		e-Service ☐

Information to be included on Report and Invoice

Project ID: W23101323
Project Name: Old Crow Water Well Assesment
Project Location: Old Crow, YT
Legal Location:
PO#:
Proj. Acct. Code:
Agreement ID:

RUSH **Please contact the laboratory to confirm rush dates and times before submitting samples.**

Upon filling out this section, client accepts that surcharges will be attached to this analysis

RUSH required on: All Analysis ☐ or As indicated ☐

Date Required: _____

Signature: _____

Bodycote Authorization: _____

Sample Custody (Please Print)

Sampled by: RMM

Company EBA Signature

I authorize Bodycote to proceed with the work indicated on this form:

Date: _____

Received by: _____ Sample Temp. _____

Waybill #: _____ Date _____

Company _____ Time _____

RECEIVED MAR 10 2010

Special Instructions / Comments

FOR LAB USE ONLY

Condiftion of containers/coolers upon arrival at lab

☐ Check here if Bodycote is required to report results directly to a regulatory body (Please include contact information)

☐ Check here if you are testing POTABLE WATER for **HUMAN CONSUMPTION**

Please indicate which regulations you are required to meet:

	Sample Identification	Location	Depth IN	Depth CM	Depth M	Date/Time Sampled	Matrix	Sampling Method	Number of Containers	W99	THM Prep	THMP	Enter tests above (✓ relevant samples below)
1	Mar 2010 - Old Crow Raw	OC Well				03-Mar-10	Water	Raw	4	☒	☒	☒	
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													

NOTE: All hazardous samples must be labelled according to WHIMIS guidelines.

APPENDIX

APPENDIX C EBA'S GENERAL CONDITIONS *

GEO-ENVIRONMENTAL REPORT – GENERAL CONDITIONS

This report incorporates and is subject to these "General Conditions".

1.0 USE OF REPORT AND OWNERSHIP

This report pertains to a specific site, a specific development, and a specific scope of work. It is not applicable to any other sites, nor should it be relied upon for types of development other than those to which it refers. Any variation from the site or proposed development would necessitate a supplementary investigation and assessment.

This report and the assessments and recommendations contained in it are intended for the sole use of EBA's client. EBA does not accept any responsibility for the accuracy of any of the data, the analysis or the recommendations contained or referenced in the report when the report is used or relied upon by any party other than EBA's Client unless otherwise authorized in writing by EBA. Any unauthorized use of the report is at the sole risk of the user.

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Where EBA submits both electronic file and hard copy versions of reports, drawings and other project-related documents and deliverables (collectively termed EBA's instruments of professional service), only the signed and/or sealed versions shall be considered final and legally binding. The original signed and/or sealed version archived by EBA shall be deemed to be the original for the Project.

Both electronic file and hard copy versions of EBA's instruments of professional service shall not, under any circumstances, no matter who owns or uses them, be altered by any party except EBA. The Client warrants that EBA's instruments of professional service will be used only and exactly as submitted by EBA.

Electronic files submitted by EBA have been prepared and submitted using specific software and hardware systems. EBA makes no representation about the compatibility of these files with the Client's current or future software and hardware systems.

3.0 NOTIFICATION OF AUTHORITIES

In certain instances, the discovery of hazardous substances or conditions and materials may require that regulatory agencies and other persons be informed and the client agrees that notification to such bodies or persons as required may be done by EBA in its reasonably exercised discretion.

4.0 INFORMATION PROVIDED TO EBA BY OTHERS

During the performance of the work and the preparation of the report, EBA may rely on information provided by persons other than the Client. While EBA endeavours to verify the accuracy of such information when instructed to do so by the Client, EBA accepts no responsibility for the accuracy or the reliability of such information which may affect the report.

Appendix C

Old Crow Groundwater Study - 1982

EBA Engineering Consultants Ltd.

EARTH-SCIENCES ENGINEERING

E. W. Brooker, President
D. W. Hayley, Vice President
L. A. Balanko
C. B. Dawley
C. T. Hwang
A. B. MacDonald
D. H. Seibt

1982 09 10

Government of Yukon
Department of Highways and Public Works
P.O. Box 2703
Whitehorse, Yukon
Y1A 2C6

ATTENTION: Mr. J.M. Grainger, P.Eng.
Municipal Engineering

Dear John:

Subject: Water Supply Study
Old Crow, Yukon
EBA Project No. 209-3546

We are pleased to submit 30 copies of our formal report on the Old Crow Water Supply Study. It is hoped that our numerous meetings and discussions have resulted in a final report which satisfies your requirements. Although not specifically noted in the report, some recognition is due to Mr. P.K. Glen, P.Eng., from EBA's Calgary Office. Paul collected the field data, and also assisted in the preparation of the hydrological section of the report.

Please contact our Whitehorse office if we can provide assistance with future phases of the water supply system.

Yours truly,

EBA Engineering Consultants Ltd.

J. Richard Trimble

J.R. Trimble, P.Eng.
SENIOR PROJECT ENGINEER
WHITEHORSE MANAGER

JRT/nlh

Encl.

OLD CROW GROUNDWATER SUPPLY

A GEOTECHNICAL, HYDROLOGICAL AND THERMAL STUDY

OLD CROW, YUKON

Submitted to:

GOVERNMENT OF YUKON

Prepared by:

EBA ENGINEERING CONSULTANTS LTD.

JULY, 1982

ABSTRACT

Old Crow, Yukon, is situated approximately 120 km north of the Arctic Circle, at 67° 33' N and 139° 52' W, on a floodplain of the Porcupine River. Up until the present time, drinking water has been obtained from the Porcupine River, which is subject to occasional periods of unsuitable water quality and the inconvenience of maintaining an ice-free hole during the long winter at this latitude. In addition, perennially frozen ground is continuous in this area which further complicates the problem of an alternate water source. The present study arose after the burning of the Old Crow School in December, 1981. The Government of Yukon constructed a winter road to the community in early 1982 over which a new pre-fabricated school was transported. The road also allowed access of truck-mounted drilling equipment to conduct geotechnical soil testing and water well drilling. Drilling was completed in March 1982, during which temperatures ranged down to and below -30° C.

The first deep water well drilled encountered potable water under artesian pressure from beneath the permafrost, at approximately 79 m depth. This report outlines the preliminary analyses, field work, and the resulting engineering recommendations pertaining to the use of the well as a permanent potable water supply. Aquifer characteristics and safe yields have been determined, and the results of detailed geotechnical, thermal and structural considerations for the well casing are presented.

To the knowledge of EBA Engineering Consultants Ltd., and the Government of Yukon, this is the first complete geotechnical investigation of this extent to be conducted in Old Crow. This water source is believed to be unique as it is the most northerly sub-permafrost artesian aquifer in North America to be used as a community water supply.

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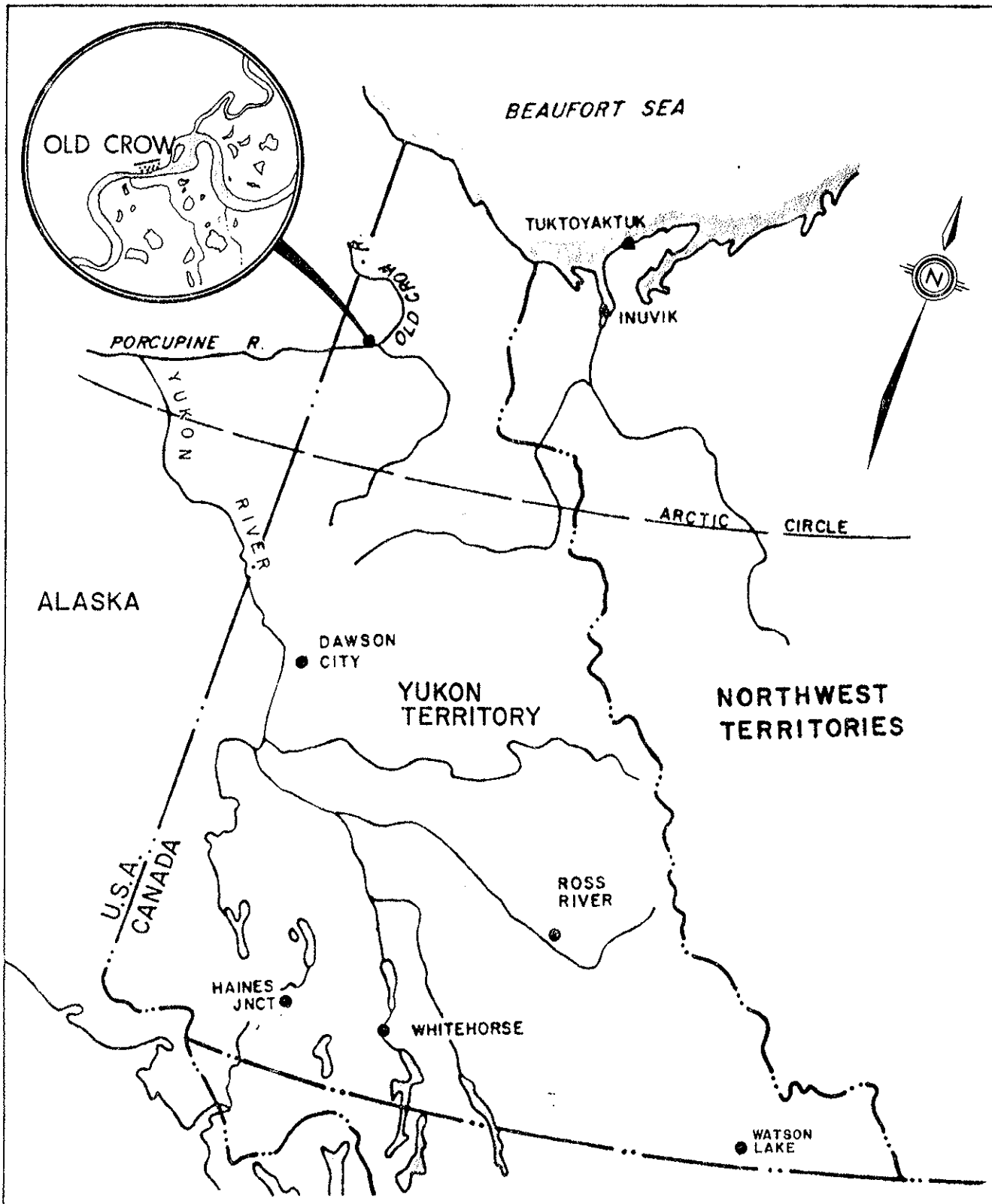
1.0 INTRODUCTION

1.1 Background

Since the mid-1970's, several reports have been prepared, by various consultants, to address the problem of a permanent potable water supply for the community of Old Crow, Yukon. The community, located as shown in Figure 1, has a population of approximately 250 (verbal communication, Old Crow band council, 1982), and up until now has relied on drinking water obtained from the Porcupine River. This source; however, is subject to natural disruptions and occasional periods of unsuitable water quality (due to high turbidity) particularly during the spring snowmelt period. There is also the problem of maintaining an ice-free hole in the river ice during the long winter at this latitude.

Until the present time, consultants have had little or no geological and/or physical data upon which to base their recommendations, primarily due to the high cost of sending personnel and equipment to the area. The present study arose as a result of the fire that claimed the Old Crow School in December, 1981. To facilitate the construction of a new school, the Government of Yukon constructed a winter road to the community, over which a pre-fabricated school was transported. This road also allowed the access of truck-mounted drilling



LOCATION PLAN — FIGURE 1

EBA Engineering Consultants Ltd.	
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equipment to conduct geotechnical soil testing and water well drilling; thus forming the basis for this report.

1.2 Site Description

Old Crow is located approximately 120 km north of the Arctic Circle, and 50 km east of the Alaska/Yukon border, at 67° 33' N and 139° 52' W. The settlement is situated on a floodplain of the Porcupine River, immediately downstream of the junction of the Porcupine and Old Crow Rivers. Geodetic elevation is approximately 251 m above sea level. A general location map is shown in Figure 1.

1.2.1 Bedrock Geology

Old Crow lies within a broad physiographic area known as the Yukon Plateau; the local area is referred to as the Porcupine Plateau. The area is believed to be an erosional surface cut into the bedrock, mantled with a thin veneer of recent sediments (Douglas, 1976). Bedrock consists mainly of marine siltstones, sandstones and shales, interspersed with marine limestones and dolomites. Fine-grained quartzites of either fluviatile or marine origin have also been noted (Norris, 1976). These stratified rocks range in age from Upper Cretaceous to Precambrian, and are observed to be both folded and faulted. The site of the community is bounded by several southwest-northeast trending faults

(Norris, 1976) which cut only the rocks older than Lower Cretaceous, not affecting the younger, near-surface rocks.

1.2.2 Pleistocene Geology

The Porcupine Plateau is almost entirely unglaciated. The Northern-most part, Old Crow Plain, is underlain by relatively thin deposits of lacustrine silts and clays, capped with peat. Closely spaced lakes and ponds have an oriented rectangular pattern apparently produced by the prevailing winds (Douglas, 1976). These lakes are generally clustered in distinct flat basins, formed by fine grained deposits in the bottoms of large ancient lakes. The community of Old Crow is located on the northern edge of the Bluefish Basin, which is located immediately south of the larger Old Crow Basin. These basins are dissected primarily by the Porcupine and Old Crow Rivers (and their tributaries) which flow through youthful valleys in the area, and meander elaborately. Plate 1 shows a general view of the Bluefish Basin.

The community is located on the Porcupine River, immediately downstream of the junction of the Old Crow and Porcupine Rivers. The site is an active river floodplain which is slowly eroding at the upstream edge of the community. The Porcupine River at this location is essentially erosional, slowly downcutting through the ancient lacustrine deposits.

PLATE 1 Bluefish Basin, looking South over Old Crow (not visible) from Old Crow Mountain.

1.2.3 Permafrost

Old Crow is situated immediately north of the southern limit of continuous permafrost, and thus perennially frozen ground should be expected throughout the area. Holes drilled previously by others (Geological Survey of Canada, 1973; EPEC, 1980) confirm that the community is entirely underlain by permafrost, of undetermined thickness. The maximum depth of these previously drilled holes was approximately six metres. Details of deeper subsurface stratigraphy and permafrost ice classification were not determined; however, an analysis of the shallow hole soil lithology and limited laboratory test results indicates that excess ground ice will likely be encountered. Details of permafrost conditions available from other locations (Smith and Hwang, 1973) at an equivalent latitude and freezing index suggest that permafrost at Old Crow could extend as deep as 90 metres.

1.3 Scope of Work

The initial scope of work for this project was outlined in an EBA proposal letter dated 1982 02 18. This was updated during several meetings with Mr. J. Cormie, P. Eng. and Mr. J. Grainger, P. Eng. of Government of Yukon, Department of Highways and Public Works. The scope of work is summarized as follows:

1. Drill soil test holes and obtain geotechnical information to delineate the extent of unfrozen soils adjacent to the Porcupine River

and evaluate the feasibility of constructing a permanent infiltration gallery [1] for a potable water supply;

2. Drill one or two deep water well holes to explore for a potable water source by intersecting a possible "thaw bulb" of the Porcupine River, directly beneath the community site.

3. If time permits, drill an additional test hole near the lake on the opposite side of the airstrip, to evaluate the lake as a potential source of drinking water, or to intersect subsurface drainage courses.

   Note: If water was encountered in either Items 2 or 3, the geotechnical investigation in Item 1 was still to be carried out.

4. Conduct general geotechnical drilling and sampling to provide engineering and foundation recommendations for the construction of a water supply point.

All work was to be directed towards obtaining a piped water supply to the new school, and a well-head water source for use by the remainder of the community, which would take the form of a pumphouse/truck fill point.

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(1) Old Crow Water Supply Study (1979) prepared by Stanley Associates Engineering Ltd. for Government of Yukon, November, 1979.

2.0 PRE-FIELD ENGINEERING

Prior to site drilling, the feasibility of obtaining potable water by several different schemes was considered in preparation for the field program. Initially, all available topographical and geological maps were gathered, and examined in conjunction with high level air photographs of the area. Hydrological and/or groundwater maps have never been prepared for this area. It was noted that several ancient channels of the Porcupine River were visible between the community and the north edge of the Bluefish Basin, towards Old Crow Mountain, It was anticipated that there was the potential for a groundwater aquifer in alluvial deposits present in these channels. Also, depending upon the river history of the main channel, permafrost could be thin in these areas. It was proposed to drill a shallow (30 m) hole directly beneath the community to try and intersect any water within the alluvial gravels in these ancient river channels. The original borehole location chosen by the Government of Yukon was to be near the school (the prime water user) and also as close to the existing Porcupine River channel as possible, to try and intersect the "thaw bulb" of the active river channel. A further examination of previously published data from the Lower Mackenzie Valley (Smith and Hwang, 1973) plus an examination of the seasonal water level fluctuations in the Porcupine River resulted in the recommendation that a shallow hole drilled at the proposed location would likely not penetrate the permafrost and would not intersect the "thaw bulb" of

the Porcupine River. This conclusion was further substantiated by estimating ground temperature isotherms by graphical analogy using the maximum flood level in the Porcupine River and assumed ground and water temperatures. The results of this calculation are illustrated in Figure 2. On the basis of this information, it was recommended that the borehole at the preferred location be drilled to at least 100 m, to penetrate the permafrost. At this depth, there might be a hydraulic link with alluvial deposits on the bottom of the Porcupine River, or possibly a deeper groundwater aquifer, a rare occurrence at this latitude.

3.0 FIELD WORK

The field work was completed between March 17 and 30, 1982, and consisted of four main phases. These are listed below, in chronological order of completion:

1. Deep water well drilling, including some overburden and bedrock sampling.

2. Geotechnical drilling and delineation of the Porcupine River thaw bulb. This included permafrost coring and sampling at the water well site, for foundation design of structures required for well development.

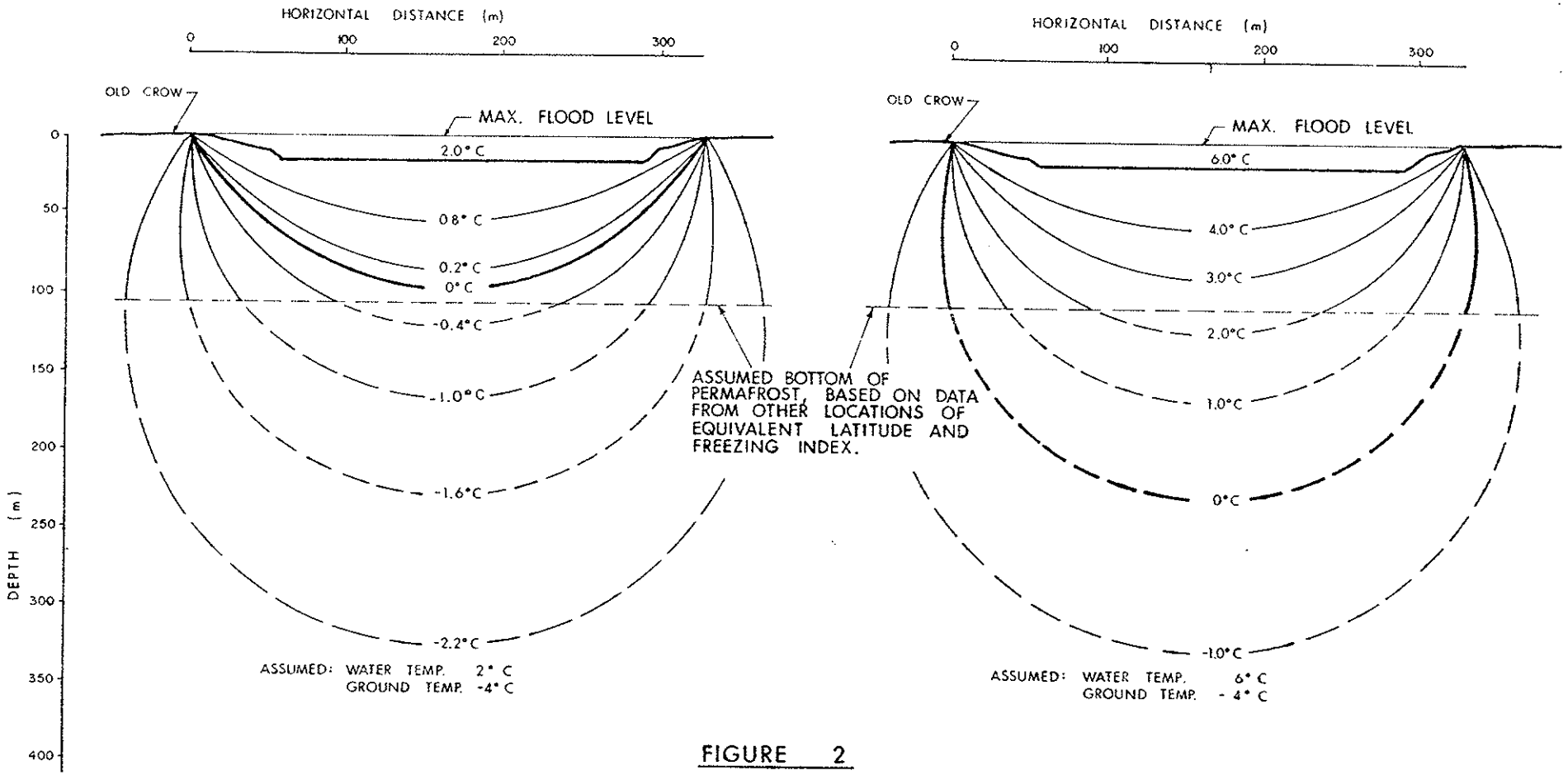

FIGURE 2

GROUND TEMPERATURE ISOTHERM/THAW BULB PREDICTIONS*
PORCUPINE RIVER AT OLD CROW, YUKON

* As determined using:
Brown W.G., 1963,
"Graphical Determination of Temperature Under Heated or Cooled Areas on the Ground Surface."
Technical Paper No. 163, DBR/NRC, Ottawa

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3. Ground temperature (thermistor) cable installation near the water well site, to monitor the thermal regime.

Details of each phase are presented in the following sections. The scope of the field program was modified because potable water was encountered in the first deep water well. As a result, the majority of the remaining field time was spent on ensuring proper well development and obtaining geotechnical data to design a suitable water supply point. The holes proposed for the far side of the airport were deleted (due to time constraints) and the Porcupine River "thaw bulb" delineation was allowed minimal time.

The Site Plan showing the borehole locations is presented in Appendix A, Drawing No. 3546-A-1, as are the borehole logs. All holes were drilled using a Schramm T66H Rotary Drill, contracted from Midnight Sun Drilling Co. Ltd. of Whitehorse, Yukon. Compressed air was used as the circulating medium to return cuttings to the surface. Borehole logging was completed by obtaining samples from the cuttings exhaust hose, by using a 75 mm diameter split-spoon drive sampler, and by using a 100 mm diameter CRREL auger core barrel (TH 3 only). All soil and rock samples were returned to EBA's Whitehorse laboratory for detailed classification and strength testing.

3.1 Water Well Drilling and Well Construction

Plate 2 shows an aerial view of the water well site. Drilling for the initial deep water well (WW 1) was completed on March 17 and 18, 1982, at the location shown on the Site Plan in Appendix A. Detailed sampling was carried out at selected intervals down to approximately 24 m depth, using the split spoon sampler. The remainder of the hole was logged by examining cuttings. The well was terminated at 79.3 m, when water under artesian pressure was encountered. Artesian flow from the top of the casing was estimated at 6.1 L/s (80 Igpm). Plate 3 shows the flow from the top of the casing. The artesian flow prevented proper well completion at this time, therefore, the well was partially sealed and the drilling of a second deep water well (WW 2) requested by the Government of Yukon, proceeded. At this time, the well casing was only set to approximately 41 m, but was re-set to 79 m on March 24, 1982.

Well No. 2 was drilled approximately 17 m east of Well No. 1 (see Site Plan) and was completed between March 18 and 20, 1982. Water was again detected at approximately 79 m depth. Significant flows of water; however, were not encountered until approximately 97 m depth, when artesian flow from the top of the casing was noted to be approximately 2.3 L/s (30 Igpm). The hole was terminated at 122 m, utilizing all of the available well casing.

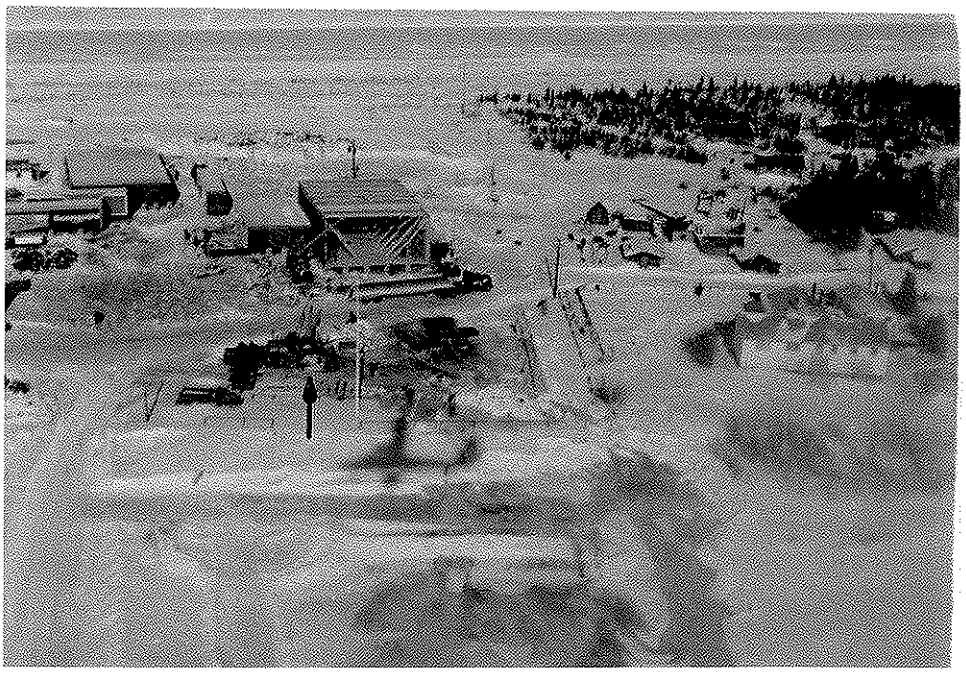

PLATE 2 Aerial view of water well site showing Midnight Sun's pump truck over Well No. 1.

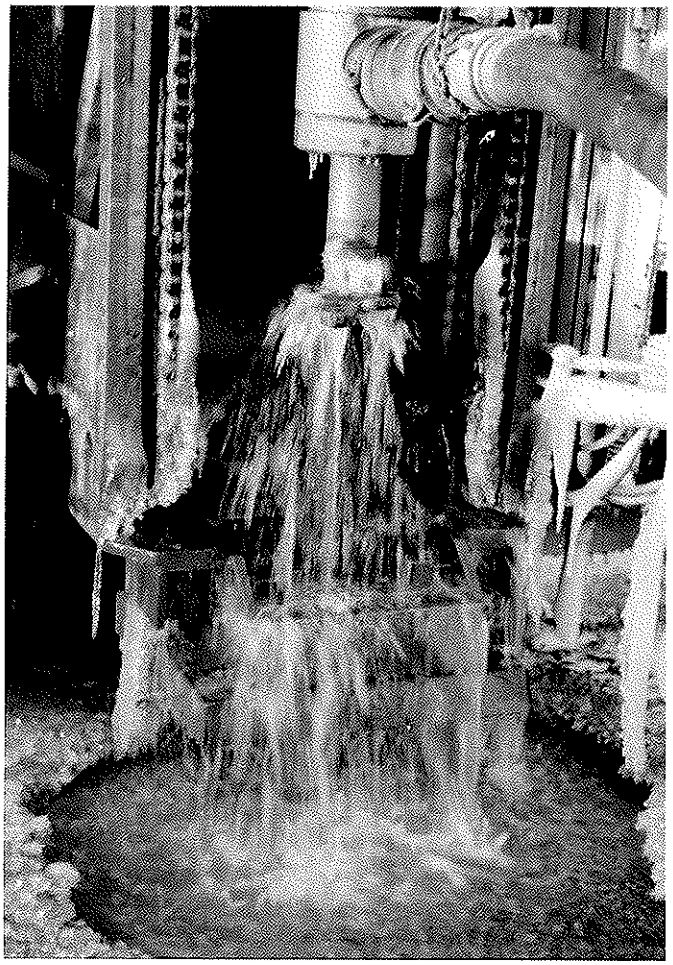

PLATE 3 Artesian flow from top of casing during drilling of Water Well No. 1.

Well screens could not be placed in the bottom of either well, due to the artesian flow. A pump was installed in WW 2 on March 21, 1982 and the well was pumped for approximately 48 hours at rates varying from 13.1 L/s to 18.9 L/s (175 lgpm to 250 lgpm). Pumping in WW 2 ceased when WW 1 was drawn down enough to allow its completion. This indicates that both wells are within the same aquifer, at different depths. Plate 4 shows the drill rig completing Well No. 1, while No. 2 was being pumped (see also cover photo).
WW 1 was developed on March 25, 1982 followed by a 72 hour pump test which was initiated on March 26, 1982. Details regarding the pump test are discussed in a later section of this report. WW 2 served as an observation well during this test.

Subsequent to the completion of the pump test, approximately 76 m of heat trace cable was installed in Well No. 1. The well was then fitted with a valve and allowed to flow through a discharge pipe to the river.

3.2 Geotechnical Drilling

Five geotechnical test holes and stratigraphic probe holes (TH 3 to TH 7, inclusive) were drilled at the site between March 21 and 23, 1982. The locations are shown on the Site Plan, Drawing No. 3546-A-1, Appendix A. The borehole logs are also presented in Appendix A.

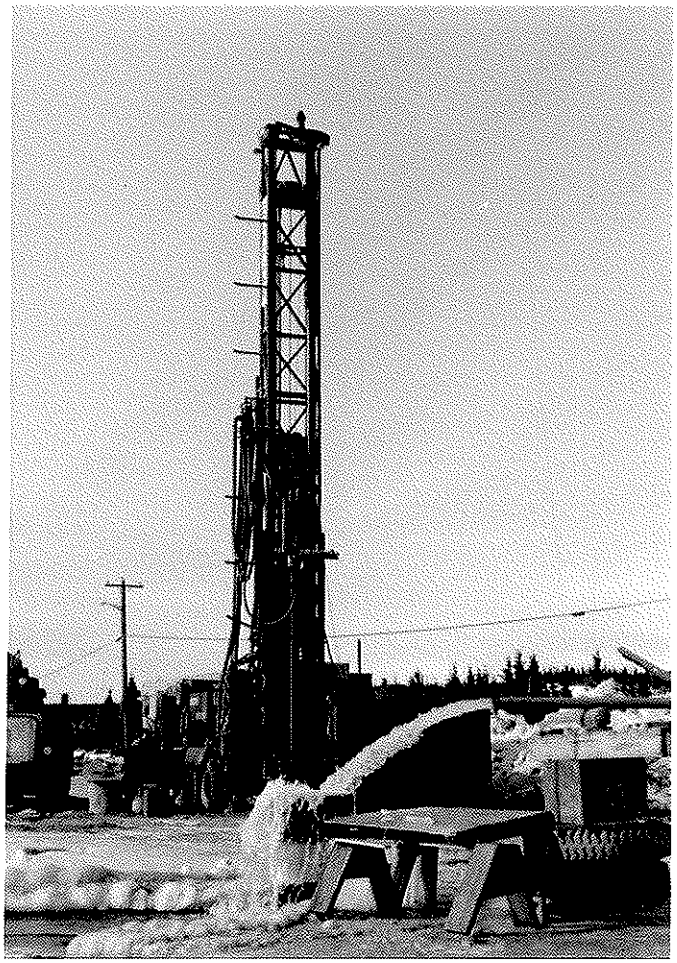

PLATE 4 General View of Schramm T66H Rotary Drill positioned over Water Well No. 1. Water Well No. 2 is being pumped to allow re-set of casing in No. 1.

TH 3 was drilled approximately between the two water wells, and was sampled in detail to provide geotechnical data on the permafrost for the well casing and future ancillary surface structures. A permafrost CRREL core barrel was used to obtain undisturbed core samples for detailed classification and strength testing.

TH 4 to TH 7 were drilled on a line extending from the riverbank across the ice to the middle of the Porcupine River. The intent of these holes was to determine the thickness and extent of alluvial deposits on the river bottom, and to ascertain the position of the Porcupine River "thaw bulb", if any. This information would be required to evaluate the feasibility of constructing an "infiltration gallery" in the channel bottom to provide potable water for the community. As noted in the "scope of work" this drilling was to be completed irrespective of the success in the deep water wells.

3.3 Ground Temperature Cable Installation

On March 23, 1982, a ground temperature cable supplied by Energy Mines and Resources Canada, Earth Physics Branch, Ottawa, was installed at the approximate location shown on the Site Plan in Appendix A. The cable was "folded back" so that it would fit inside the 66 m deep hole. Positions of the thermistors on the cable, and details of the installation are shown on Figure 3.

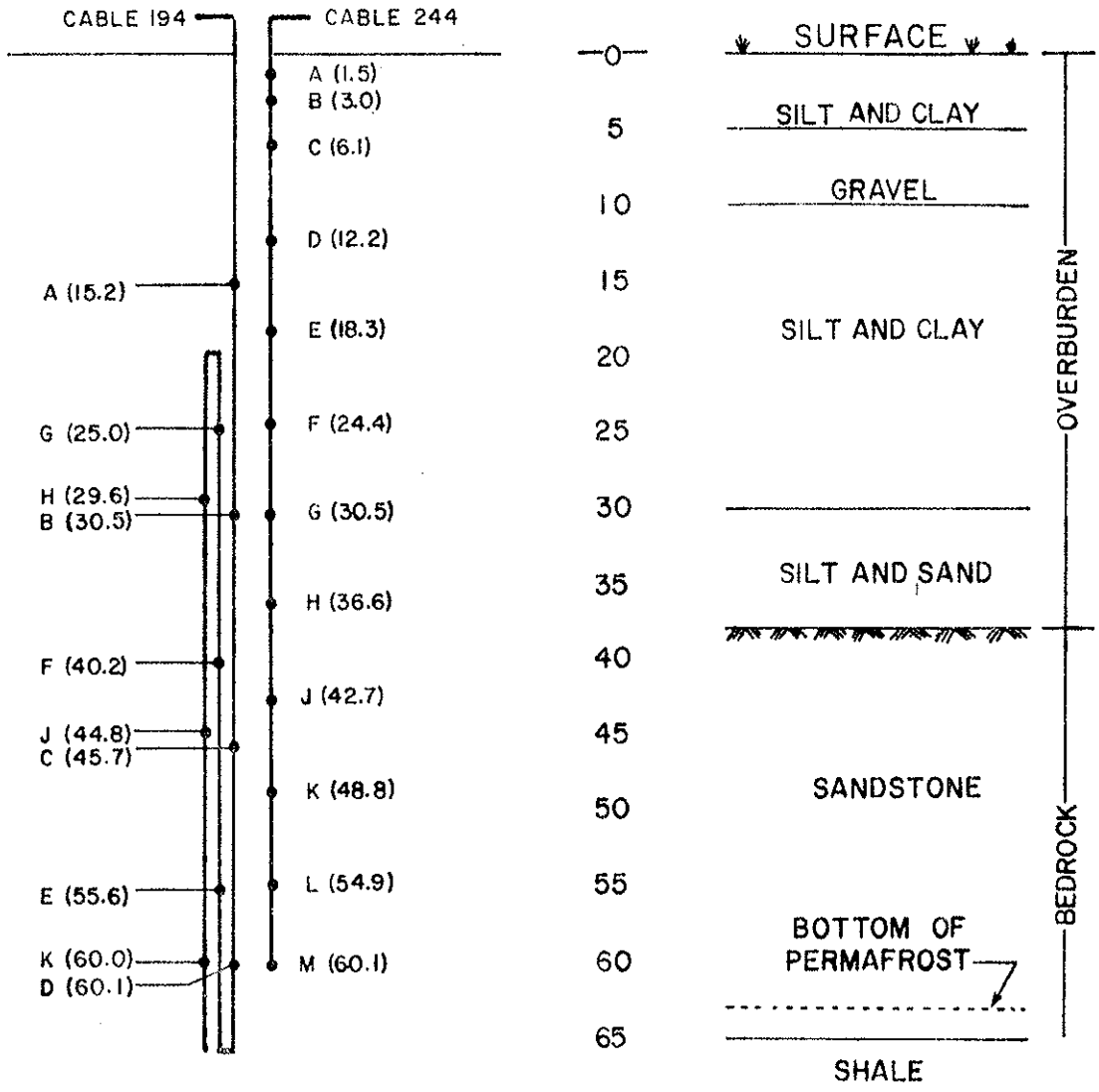

FIGURE 3

DETAILS OF GROUND TEMPERATURE CABLE INSTALLATION

OLD CROW, YUKON

(see SITE PLAN for location)

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3.4 Protective Piling Installation

After the drilling was completed, both water wells were provided with protective surface piling. These were required to provide some protection against ice floe scour during spring snowmelt/flood periods, and also to provide protection for the well heads against vehicles that may be operated in the vicinity of the well. The protective piling around each well consists of four 143 mm diameter piles installed to 5.2 m depth, and four 168 mm diameter piles installed to 7.9 m depth. The 143 mm diameter piles support a single layer framework of steel angle-iron. Details of the protective piling installation are described in Appendix C, as Drawing No. 3546-C-5. Plate 5 shows a view of the completed water wells and the protective piling.

4.0 SUBSURFACE CONDITIONS

4.1 Water Well Site

Detailed borehole logs are presented in Appendix A. The results of the laboratory testing program are shown on the borehole logs, where applicable, and on the summary of laboratory test results in Appendix B.

PLATE 5 View of completed water wells and protective piling installation.

Generalized subsurface conditions for the water well site are illustrated on the cross section, presented as Drawing No. 3546-A-2, Appendix A (after the borehole logs). Subsurface conditions are generally consistent between the two wells, and bedrock was encountered at an average depth of 37 m below existing grade. Overburden consists of fine-grained lacustrine silt and clay, becoming relatively coarser grained closer to the bedrock surface. The bedrock is composed of sandstone overlying limestone and dolomite. On the basis of the borehole information, the aquifer is confined to the limestones and dolomites, which appear to be fractured.

4.1.1 Permafrost

At the time of the drilling program in mid-March, frozen ground was encountered from the surface down to approximately 63 m. This depth is believed to be the bottom of permafrost in this area. The exact depth will be confirmed at a later date, after several sets of thermistor readings have been taken. A gravel layer, which appeared to be unfrozen, was encountered in both holes between approximately 5 and 10 m depth. It was very difficult to obtain undisturbed samples of this layer; however, it is possible that there is a slow movement of water from the ponds and marshy areas to the north of the airstrip, through this gravel and into the river. It would be trapped by seasonal frost at the riverbank during the winter.

The permafrost at the borehole locations ranges from non-visible ground ice (Nbn) to stratified ice lenses (Vs) up to 15% by volume. The natural moisture contents and bulk densities of the cores from the higher ice content areas indicate that these soils would be very unstable when thawed. To further evaluate the engineering properties of the overburden, two thaw-strain (consolidation) tests were completed on two permafrost cores with non-visible (Nbn) ice contents. These results are included in Appendix B. The data shows that if the soil thaws, approximately 4% vertical strain could be expected under overburden pressure (at a depth of approximately five metres). This; however, should be considered as a "best case" situation, because soil containing visible ice will experience significantly greater vertical deformation.

4.2 Porcupine River

The borehole logs from TH 4 to TH 7 are also included in Appendix A. Generalized subsurface conditions along the line of boreholes are illustrated on the cross-section, Drawing No. 3546-A-3, Appendix A. The borehole data shows that there is only a thin veneer of alluvial gravels within the river channel at this location. This confirms the degradational river regime, as these gravels are probably scoured away and re-deposited annually. An "infiltration gallery" water supply system is not suitable for this site due to the relatively thin layer of gravel on the river bed and the unpredictability of the annual scour depth.

Relatively impervious silts and clays were noted beneath the veneer of alluvium. Although undisturbed samples were not taken, these fine grained soils below the gravel appeared relatively "dry" and it was difficult to determine if they were frozen or unfrozen. They are shown as unfrozen on the borehole logs, which is probably accurate for the soils beneath the active channel, but may not accurately reflect conditions closer to the river bank. It was not possible to determine the exact limit of the thaw bulb, due to time constraints and other difficulties encountered at the site.

5.0 WELL TESTS

5.1 General

Following the completion of WW 1 and WW 2, the hydraulic properties of the aquifer and the hydraulic efficiency of the wells were examined. Measured aquifer characteristics included transmissibility, coefficient of storage, as well as the efficiency of the production well (WW 1) which was assessed by measuring head loss in the adjacent observation well (WW 2). The following subsection provides a brief discussion of the pump test carried out in WW 1.

5.2 Pump Test

On March 27, 1982, a 72 hour step-drawdown pump test was initiated on WW 1. Water level readings were taken at specific time intervals throughout the test.

WW 2 was used as an observation well during the test in order to assess the drawdown characteristics of the aquifer. Readings were taken simultaneously in both WW 1 and WW 2. The times and corresponding water levels for WW 1 and WW 2 are included in Tables C-1 and C-2 respectively, in Appendix C. Drawdown curves corresponding to these Tables are presented in Appendix C following the corresponding Tables. The step-drawdown test was conducted on WW 1 as a means of providing more data with regard to the potential of the well. The well was pumped at a rate of 15 L/s (200 Igpm) for 6 minutes following which the pumping rate was increased to 17 L/s (225 Igpm). This rate was maintained for the remainder of the 72 hour (4320 minute) test. Readings were taken throughout the entire test; however, no data is available for WW 2 beyond 62 hours as the well froze up and ice completely blocked the casing.

5.3 Recovery Test

Following 72 hours of continuous pumping the pump was stopped and the well was allowed to recover. Water level measurements were again taken at specific times in WW 1. No recovery data is available for WW 2 due to the freezing problem encountered during the pump test. The recovery of the well was monitored for a period of 20 hours following which problems were encountered in removing the pump (due to ice buildup in the casing) and no further readings were available. The recovery data for WW 1 is presented on Table C-3 in Appendix C, and the corresponding graph follows the Table.

The analysis of the test data is discussed in the following section of this report.

6.0 WELL HYDRAULICS

6.1 General

The analysis of the pump test data was carried out using both the Theis non-equilibrium well formula and the straight line approximation method from Jacob's modification of the Theis non-equilibrium formula. The Theis method was employed because of the limited amount of information available regarding the nature of the aquifer, in particular, its distance-drawdown behaviour. The modified Jacob's method was used as a means of supplementing the information obtained from the Theis analysis and because of its simplified nature, theoretical time-drawdown predictions could be made. Both methods used are based on a common set of assumptions regarding the nature of the aquifer. The major assumptions are as follows:

a. The water bearing formation is homogenous in character and permeability.
b. The formation is of uniform thickness.
c. The formation is infinite in area.
d. The formation receives no recharge from any source.
e. The pumped well penetrates and receives water from the full thickness of the water bearing formation.

The following subsections contain a brief discussion of the analyses and the conclusions derived from each of them.

6.2 Theis Analysis

The Theis formula was primarly developed for the analysis of well flow for the case of a homogenous and isotropic aquifer. The formula takes into account the effect of time and the storage characteristics of the aquifer. In its simplest form the formula is:

$$S = \frac{114.6\ Q}{T}\ W(u)$$

where:

$$u = \frac{1.87\ R^2\ S_c}{Tt}$$

S = drawdown (ft)

Q = discharge (Igpm)

T = coefficient of transmissibility (Igpd/ft)

r = distance from pumped well to obervation point (ft)

S_c = storage coefficient (dimensionless)

t = time after pumping started (days)

W(u) = is commonly referred to as the "well function", representing an integral of "u".

The direct calculation of precise aquifer coefficients from the "well function" integration is only possible using an iterative computer solution. However, an approximate graphical solution is also commonly used. The solution involves matching a curve plotted from the pump test data against a "type curve" prepared by plotting values of 'u' against values of 'W(u)'.

The Theis analysis was carried out using the data from the observation well. The observation well is used in this case because the formula takes into consideration drawdown vs. radius from the centre of the pump well. In using the observation well data, a constant radius is known and readings not influenced by pump vibration are available. The results of the analysis show the aquifer has an apparent transmissibility of 42.2 m^3/day/m (2840 Igpd/ft). The storage coefficient for the aquifer has been calculated to be 1.52×10^{-3} while the 20 year safe yield is 18.9 L/s (250 Igpm) based on the formula developed by Farvolden in 1961 and outlined in Ozoray, 1977.

Well recovery data which is only available for the pump well was also analyzed using the Theis recovery method. The results of this analysis show that the aquifer has an apparent transmissibility of 122 m^3/day/m (8220 Igpd/ft).

6.3 Modified Jacob's Method

An analysis of the drawdown data from the pump well and the observation well was carried out using the straight line approximation method of Jacob's modification to the Theis non-equilibrium formula. The transmissibility of the aquifer is calculated from the pumping rate and the slope of the time drawdown curve using the following formula.

$$T = 264\ Q/\Delta S$$

where:

T = coefficient of Transmissibility in Igpd per foot

Q = pumping rate in Igpm

ΔS = slope of the time-drawdown graph, per log cycle

The apparent transmissibility of the aquifer based on the drawdown data obtained from the pumpwell is 17.1 m^3/day/m (1150 Igpd/ft). The apparent transmissibility of the aquifer based on the drawdown data obtained from the observation well is 34.4 m^3/day/m (2315 Igpd/ft). The 20 year safe yield using a transmissibility of 17.1 m^3/day/m is 8.0 L/s (105 Igpm). The storage coefficient calculated using the observation well data is 3.62×10^{-3}.

6.4 Discussion

Simplified aquifer conditions were assumed for these analyses. A computer-aided, finite element mode of analysis would be required to more precisely model actual aquifer characteristics. The added expense of such an analysis was not considered justified in view of the intended well use as a relatively low demand water supply source. The analytical methods employed for this study, however, are considered to yield conservative, or lower than actual aquifer parameters. In this regard, calculated values can be taken as minimums for this well and aquifer.

A summary of all these results is presented in Table 1. Significant variations in apparent transmissibilities were noted between the drawdown data for the pump well and the observation well. These differences are generally attributed to reduced transmissibilities resulting from the hydraulic characteristics of the fractures occurring in the formation and because of restrictions on transmissibility due to casing size. In addition to this, the observation well also penetrated the water bearing formation to a greater depth than did the pump well. Therefore, more fractures were exposed thus allowing greater flow. The results obtained from the analysis of the observation well data are considered to be somewhat more representative of the aquifer as it is not influenced by well losses to the same degree as the pump well and because there are no influences on water level readings resulting from pump vibration.

TABLE 1

Summary of Aquifer Characteristics

Parameter	Theis	Modified Jacob's	
		(observation well) WW 2	(pump well) WW 1
Transmissibility (T) (m^3/day/m) (igpd/ft)	(42.2) (2840)	(34.4) (2315)	(17.1) (1150)
Storage Coefficient (S_c)	1.52×10^{-3}	3.62×10^{-3}	--
20 year safe yield (L/s) (Igpm)	(18.9) (250)	(16.0) (211)	(8.0) (105)

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A very significant difference was also observed between the apparent transmissibilities calculated using the pump well drawdown data and the recovery data. The apparent transmissibility calculated from the recovery data is considerably higher than that calculated from the drawdown data. This difference is considered to be a result of an inappropriate set of assumptions regarding the hydraulic characteristics of the aquifer, suggesting that the aquifer is outside the set of assumptions upon which the recovery formula is based. As mentioned, a more precise analysis of aquifer characteristics would require computer modeling of the fractures within the water bearing formation. However, in light of the relatively low water volume requirements the basic conservative analysis which was carried out is considered to be sufficient.

A table containing temperatures and barometric pressures for the Old Crow area covering the period during which the pump test took place is presented in Appendix C. A correction for barometric pressure is required in a sensitive, detailed analysis of the wells; however, considering the type of analysis which was carried out on this data, variations in barometric pressure would result in relatively insignificant changes.

The 20 year safe yield of the well is considered to be at least 8.0 L/s (105 Igpm). Therefore, anticipated volume requirements can be met without significantly taxing the aquifer. Table 2 provides a summary of the expected range of theoretical drawdowns using a maximum and minimum transmissibility for three

TABLE 2

Theoretical Drawdown vs. Time

TIME SINCE PUMPING STARTED	PUMPING RATE	EXPECTED RANGE OF THEORETICAL DRAWDOWN
1 year	3.8 L/s (50 Igpm)	2.7 - 19.5 m
1 year	7.6 L/s (100 Igpm)	5.5 - 38.7 m
1 year	11.4 L/s (150 Igpm)	8.2 - 57.9 m
10 years	3.8 L/s (50 Igpm)	3.1 - 22.9 m
10 years	7.6 L/s (100 Igpm)	6.4 - 45.7 m
10 years	11.4 L/s (150 Igpm)	9.4 - 68.6 m
20 years	3.8 L/s (50 Igpm)	3.2 - 24.7 m
20 years	7.6 L/s (100 Igpm)	6.7 - 49.1 m
20 years	11.4 L/s (150 Igpm)	10.5 - 73.5 m
30 years	3.8 L/s (50 Igpm)	3.4 - 25.0 m
30 years	7.6 L/s (100 Igpm)	7.0 - 49.4 m
30 years	11.4 L/s (150 Igpm)	10.5 - 73.8 m

pumping rates for periods of 1, 10, 20 and 30 years of continuous pumping. A regular monitoring program of temperature and flow rate should be established so that problems with the well can be noted at an early stage, thus ensuring a continual supply of water.

7.0 WATER QUALITY

Three water samples taken from both the pump well (WW 1) and the observation well (WW 2), at different dates, were submitted to Chemex Laboratories in Edmonton for analysis. The results of this analysis are summarized in Table 3 while data sheets are included in Appendix D. From conversations with representatives of Chemex Laboratories, it should be noted that the first sample from WW 1 (sampled 82/03/18) was insufficient in volume to provide completely reliable results for some parameters. The results of the analysis on the WW 1 sample from 82/04/15 are presented with greater confidence.

Table 3 also shows a comparison of the chemistry of the water obtained from the test site with maximum acceptable concentrations and objective concentrations according to the Canadian Drinking Water Standards. In general, those parameters tested comply with the maximum acceptable concentration according to the Canadian Drinking Water Standards, with the exceptions of iron and lead concentrations in the sample obtained from WW 1 on 82/03/81, iron concentrations in the sample obtained from WW 2 on 82/03/22 and manganese concentrations

TABLE 3

Summary of Water Chemistry Data

PARAMETER	WW 1 SAMPLED 82/04/15	WW 1 SAMPLED 82/03/18	WW 2 SAMPLED 82/03/22	MAXIMUM ACCEPTABLE CONCENTRATIONS	OBJECTIVE CONCENTRATIONS
ALKALINITY (ppm as $CaCO_3$)	147	151.0	143.43	--	--
ANTIMONY (ppm)	0.0002	*	<0.0002	--	<0.0002
ARSENIC (ppm)	0.0090	0.044	0.006	0.05	<0.005
BARIUM (ppm)	<0.1	0.3	<0.1	1.0	<0.1
BORON (ppm)	<0.05	*	0.07	5.0	<0.01
CADMIUM (ppm)	<0.001	0.001	0.001	0.005	<0.001
CALCIUM (ppm)	44.4	34	33	--	--
CARBONATE (ppm)	<1	<1	<1	--	--
BICARBONATE (ppm)	179	176	176	--	--
CHLORIDE (ppm)	55.2	78	54	750	<250
COPPER (ppm)	<0.001	0.005	0.001	1.0	<1.0
FLUORIDE (ppm)	0.19	0.36	0.33	1.5	1.0
TOTAL HARDNESS (as $CaCO_3$)	209	176	177	--	--
IRON (ppm)	<0.01	1	1	0.3	0.05
LEAD (ppm)	<0.002	0.058	0.009	0.05	<0.001
MAGNESIUM (ppm)	23.7	22	23	--	--
MANGANESE (ppm)	0.18	0.20	0.14	0.05	<0.01
MERCURY (ppm)	0.00018	*	0.00010	0.001	<0.0002
NITRATE (ppm as N)	0.005	0.12	<0.01	10.0	<0.001
NITRITE (ppm as N)	<0.003	0.12	<0.01	1.0	<0.001
POTASSIUM (ppm)	2.95	5	4	--	--
pH (units)	7.85	7.7	7.7	6.5 - 8.5	--
SELENIUM (ppm)	<0.0002	*	<0.0002	0.01	<0.002
SILVER (ppm)	<0.001	*	<0.001	0.05	0.005
SODIUM (ppm)	14.3	18	16	--	--
SULPHATE (ppm)	25.8	22	24	500	<150
SULPHIDE (ppm)	<0.01	--	--	--	--
ZINC (ppm)	0.002	0.015	0.11	5.0	<5.0
CONDUCTIVITY (µmhos/cm)	475	517	488	--	--
TURBIDITY (JTU)	0.47	*	12.0	5	<15
COLOUR (Pt-CO units)	<5	*	5	15	<15
TOTAL DISSOLVED SOLIDS (mg/L)	280	356	338	500	--
% VOLATILE SOLIDS (mg/L)	1.2	--	--	--	--
FECAL COLIFORM (counts/100 mL)	0	0	0	0	0
TOTAL COLIFORM (counts/100 mL)	0	0	10	0	0
TOTAL SUSPENDED SOLIDS (mg/L)	1.6	--	--	--	--
NON FILTERABLE FIXED RESIDUE (mg/L)	--	1480	168	--	--

* Insufficient Sample to Complete Test

NOTE: It is questionable as to whether there was sufficient sample from WW 1 (82/03/18) for a reliable analysis of some parameters. The results from the WW 1 sample of 82/04/15 are presented with greater confidence.

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in all three samples. Several of the parameters have concentrations which are somewhat higher than the objective concentrations. However, there is apparently no serious problem with the quality of the water at present.

The higher than acceptable concentrations of iron and manganese are not expected to cause any health problem, and are viewed as aesthetic concerns only. Some staining may be caused as a result of their presence. Iron concentrations may be significantly reduced by installing a filter. It is also recommended that additional water quality analyses be carried out and that the results of these be submitted for review.

8.0 GEOTECHNICAL, THERMAL AND STRUCTURAL CONSIDERATIONS

8.1 General

The long term performance of a water well through permafrost presents unique geotechnical, thermal and structural problems. Consideration must be given to thaw induced by the "warm" water travelling upwards through the permafrost as there is a potential for negative skin friction forces to be transferred to the well casing. This could overstress the casing, possibly resulting in bending or buckling. A further examination of these topics is presented in the following sections.

8.2 Thermal Considerations

Preliminary data from one set of thermistor readings in the installed cable indicate that ground temperatures vary from a low of approximately -3.5° C in the top section of the well to 0° C (bottom of permafrost) at approximately 65 m depth. The water temperature in the well has been noted to vary from approximately 0.5° C to 2.5° C, but most recently (May 26, 1982) was measured at 0.8° C.

Detailed quasi-static and finite element computer methods have been used to predict the thermal regime around the well casing. During the analyses, different combinations of ground temperatures and pipe (water) temeperatures were assumed, so that all possible configurations along the pipe would be analyzed.

8.2.1 Quasi-Static Analysis

The EBA computer was used to analyze thaw around the well casing using the quasi-static approach outlined by Hwang, 1977. The solution assumes that the temperature distribution in the thawed zone around the pipe is of the steady-state type, and the movement of the thaw interface is determined by heat flux balance at the interface. These results are presented in Table 4, and are illustrated graphically in Appendix E, as Drawing Nos. 3546-E-1 to E-3, in-

TABLE 4

Results of Quasi-Static Analysis
of Thaw Around Well Casing

WATER TEMPERATURE	GROUND TEMPERATURE	THAW RADIUS FROM EDGE OF CASING (metres)		
		0.5 yrs	2 yrs	10 yrs
0.5	-1.0	0.25	0.41	0.68
	-3.0	0.14	0.16 (steady state @ 1.2 yrs)	0.16
	-5.0	0.08 (steady state @ 54 days)	0.08	0.08
1.0	-3.5	0.09 (steady state @ 31 days)	0.09	0.09
1.5	-1.0	0.45	0.79	1.50
	-2.0	0.32	0.51	0.81
	-3.0	0.37	0.58	0.88
	-5.0	0.29	0.38	0.40 (steady state @ 4 yrs)
2.0	-3.5	0.26 (steady state @ 236 days)	0.26	0.26
2.2	-2.0	0.51	0.88	1.63
	-5.0	0.40	0.60	0.80
2.5	-1.0	0.57	1.02	2.00
	-3.0	0.51	0.85	1.49
	-5.0	0.44	0.68	0.96

clusive. The data indicates that with "cold" water temperatures and cold ground temperature, some thaw around the casing can be expected, if flow is maintained through the well casing.

8.2.2 Finite Element Analysis

A more precise analysis of the ground thermal regime adjacent to the casing was undertaken with the aid of EBA's Geothermal Model, using finite element techniques. Thermal conditions were modelled using a pipe (water) temperature of $+1.0^{\circ}$ C and a ground temperature of -3.5° C. A steady-state condition was achieved in approximately 2.3 years, at a thaw radius of 0.07 m from the edge of the casing. After steady state conditions were reached, the geothermal model was then used to simulate conditions assuming the well stopped flowing. The results indicate that the ground would completely freeze back to the casing within 1.5 days. This data and other information pertaining to the use of the model is summarized in a letter included in Appendix E.

8.2.3 Well Freezeback

Theoretical heat balance calculations indicate that the water in the well will start to freeze back when the flow drops below 0.5 L/s (6 lgpm). This calculation, combined with the results of the finite element analysis (see Appendix E) illustrate the need for the heat trace cable, which was installed in Well No. 1 at the conclusion of the field program. Freeze-up of the wells should

be avoided if at all possible, as internal ice forces may split the casing. The heat trace cable should only be used sparingly, in the event of a freezeup. Continued use of the cable may generate undesirable permafrost thaw.

8.2.4 Discussion

The finite element and the quasi-static techniques have arrived at slightly different predictions of permafrost thaw. This is primarily due to the fact that the quasi-static method considers phase change (latent heat) only, whereas the finite element method considers both the latent heat and specific heat of the soils. Thus, the finite element method should yield the more accurate result. The primary factor influencing the thaw prediction; however, is the ground temperature. A realistic refined prediction of thaw around the casing can not be made until several more sets of thermistor readings have been taken, and are stabilized. For the purposes of the present study, an estimate of 0.1 m (radius) thaw around the casing is considered to be appropriate, reaching steady state in approximately 2.2 years.

8.3 Negative Skin Friction On Casing

The thawed zone around the casing will be conical in shape -- larger in diameter near the bottom of the permafrost, as the ground temperature increases. Thawing of ice-rich soils adjacent to the casing, and the subsequent volume change due to melting of ground ice creates a downward drag on the casing referred to as negative skin friction. Both water wells penetrate approxi-

mately 38 m of ice-rich soil, which when melted would exert a negative skin friction stress of approximately 44 kPa. However, both casings are seated in bedrock for approximately an equivalent length, which would help to resist these downward forces.

Also, due to the relatively small annulus of thawed soil adjacent to the casing, bending or buckling movements would likely not be significant. Some minor lateral movements of the casing; however, should be expected. These will be accompanied by a minor surface depression around the top of the casing, and possibly by a minor downward movement of the top of the casing. It is not possible to predict the magnitude of these movements at the present time; however, the yield stress of the steel (276 MPa) should be sufficient to resist failure. The majority of the casing movements should be complete within approximately two years, as steady state thermal conditions will have been reached. It is thus believed that surface support is not required for the casing. However, it is recommended that a gravel blanket, as thick as practical, be placed around the top of each well to compensate for minor surface depressions around the casing.

8.4 Foundations for Ancillary Structures

Foundations for ancillary structures such as pumphouses, protective sheds around the well heads, etc., may be constructed in either of two ways:

1. Structurally attach the buildings to the protective pilings around each of the wells. This will involve leaving a ventilation space beneath the building to minimize heat transfer into the ground.

2. Found the buildings on a gravel pad at least 1.5 m thick, placed directly on the permafrost. The pad should ideally be constructed in late fall to minimize thermal disturbance to the ground. The pad should be constructed of gravels excavated from the Porcupine River, placed in 150 mm thick lifts, each lift compacted to 100 percent of Standard Proctor maximum dry density (ASTM D698). In addition, a minimum 1.0 m of breezeway should be maintained between the base of the building and the gravel pad. Bearing points for the building should be provided with screw-jacks or teleposts, so that they may be periodically adjusted.

In both cases, a flexible connection should be provided between the well casing and the service building.

8.5 Service Lines to School

Thermal calculations indicate that shallow buried service lines to the new school must be provided with at least a 150 mm thickness of insulation. Moisture resistant insulation, suitable for burial, should be used. The analysis assumes a 75 mm (3 inch) diameter pipe covered in Styrofoam insulation, with an air temperature of -40° C and a water temperature of $+1^{\circ}$ C. Under these conditions, immobile water will freeze up in approximately three days. In

addition, in the event of a freeze-up, all service lines should be heat traced. All buried lines should be provided with at least 0.6 m of natural soil cover.

8.6 Recirculating Water Between the Wells

It is not known how much longer artesian conditions in the aquifer will persist. Also, bleeding of water from the wells to prevent feeze-up in the permafrost may cause massive surface ice problems in the winter. Recirculating water between the wells appears to be a feasible method of avoiding continuous bleeding; however, the following precautions should be noted:

1. On the basis of existing flow rate information, water should be circulated from Well No. 1 to Well No. 2. Initial artesian flows; however, may not be indicative of artesian pressures which will be the controlling factor in flow direction. Pressure gauges should be installed on both wells to determine the preferable flow direction.

2. After recirculation begins, the water quality should be carefully monitored. In particular, sediment loads should be noted so that any potential "wash-outs" at the base of the casing can be identified.

3. The hydraulic characteristics of the aquifer may be temporarily altered. Well development was more or less complete for Well No. 2,

and a reverse flow may dislodge particles, possibly affecting the hydraulic conductivity and the well efficiency. There is also the possibility that the "injection" well may not have the capacity to handle reverse flows.

4. Water temperatures should be recorded on a regular basis. This will assist in updating predictions of permafrost thaw around the casings.

9.0 CONCLUSIONS

The major conclusions and recommendations arising from this study are summarized as follows:

1. The 20 year safe yield for Well No. 1 can be considered to be at least 8.0 L/s (105 Igpm).

2. Water quality conforms to the majority of the specifications noted in the Canadian Drinking Water Standards, and is thus considered to be potable.

3. Permafrost will thaw around the well casing to a radius of approximately 0.1 m, and will reach a steady state condition after approximately 2.2 years.

4. A continuous flow of at least 0.5 L/s (6 Igpm) is required to prevent freezeback of the water.

5. Both water wells should be provided with heat tracing to the bottom of the permafrost (63 m), to reduce the potential for freezeback, should the water in the wells stop flowing. The heat trace should only be turned on long enough to start the flow of water, should it freeze. Energy from the heat trace has not been incorporated in the thermal analyses.

6. Recirculating water between the wells is a feasible method of eliminating bleeding, subject to the conditions presented in the preceding section.

7. A minimum thickness of 150 mm of appropriate insulation is required on all exposed and shallow buried service lines. The lines should also be heat traced.

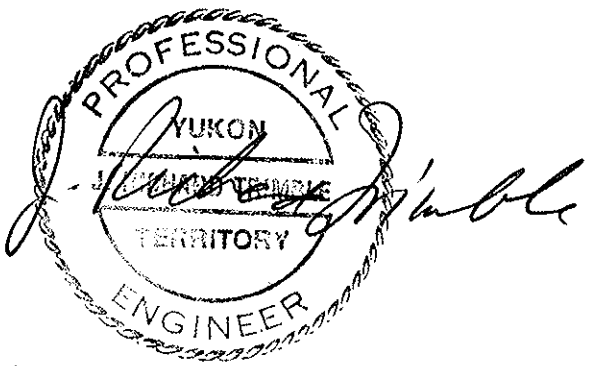
10.0 CLOSURE

The information and recommendations presented herein have been prepared for the Government of Yukon and are based on a limited field drilling, sampling and testing program. The conditions presented herein are believed to be representative of the site; however, should additional data become available in the

future, we should be notified so that our recommendations can be re-evaluated in the light of new findings. Further information regarding the use of this report can be found in the General Conditions at the front of Appendix A. It is anticipated that a continued liaison with Energy Mines and Resources Canada, Earth Physics Branch, Ottawa, will be maintained, and that regular readings from the ground temperature cable can be obtained. Should ground temperatures differ significantly from those used in this report, an update of the thermal calculations may be required.

Respectfully Submitted,

EBA Engineering Consultants Ltd.



J.R. Trimble, P.Eng.
SENIOR PROJECT ENGINEER
WHITEHORSE MANAGER

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GEOTECHNICAL REPORT
GENERAL CONDITIONS

A.1 USE OF REPORT AND OWNERSHIP

This geotechnical report pertains to a specific site and development. It is not applicable to adjacent sites nor is it valid for types of development other than that to which it refers. Any variation from the site, or development, necessitates a geotechnical review in order to determine the validity of the design concepts evolved herein.

This report is not to be reproduced in part or in whole without consent in writing from EBA Engineering Consultants Ltd. (EBA). Additional copies of the report, if required, may be obtained upon request. Isolated information, logs of borings, or profiles are not to be reproduced, copied or transferred.

A.2 NATURE AND EXACTNESS OF SOIL DESCRIPTION

Classification and identification of soils are based upon commonly accepted methods employed in professional geotechnical practice. This report contains descriptions of the systems and methods used. Where deviations from the system prevail, they are specifically mentioned.

Classification and identification of soil and geologic units are judgmental in nature as to both type and condition. EBA does not warrant conditions represented herein as exact, but infers accuracy only to the extent that is common in practice.

A.3 LOGS OF BORINGS

The boring logs are a compilation of conditions and classification of soils as obtained from field observations and laboratory testing of selected samples. Soil zones have been interpreted. Change from one geologic zone to the other, indicated on the logs as a distinct line, is in fact, transitional. The extent of transition is interpretive. Any circumstance which requires precise definition of soil zone transition elevations may require special evaluation.

A.4 STRATIGRAPHIC AND GEOLOGIC SECTIONS

The stratigraphic and geologic sections indicated on drawings contained in this report are evolved from logs of borings. Stratigraphy is known precisely only at the locations of the borings. Actual geology and stratigraphy between borings may vary from that shown on these drawings. Natural variations in geologic conditions are inherent and a function of historic environment. EBA does not represent the conditions illustrated as exact but recognizes that variations will exist. Where knowledge of exact locations of geologic units is necessary, it is cautioned that such determination requires special attention.

A.5 GROUNDWATER CONDITIONS

Groundwater conditions represented in this report refer only to those observed at the times recorded on logs of borings, and/or within the text of this report. These conditions vary with geologic detail between borings; annual, seasonal and special meteorologic conditions; and with construction activity. Where instruments have been established to record groundwater variations on an ongoing basis, the records will be specifically referred to. Interpretation of groundwater conditions from observations and records is judgmental and constitutes an evaluation of circumstances as influenced by geology, meteorology and construction activity. Deviations from these observations, may occur. No other warranty, express, or implied, is made by EBA.

A.6 PROTECTION OF EXPOSED GROUND

Excavation and construction operations expose geologic materials to meteorological elements. Many geologic materials deteriorate rapidly upon exposure to climatic elements. Severe deterioration of materials may be caused by precipitation and/or the action of frost on exposures. Unless otherwise specifically indicated in this report, walls and floors of excavations must be protected from elements, particularly all forms of moisture, desiccation from arid conditions and frost action.

A.7 SUPPORT OF ADJACENT GROUND AND STRUCTURES

Unless otherwise advised, support of excavation walls, ground adjacent to anticipated construction activity and of structures adjacent to the construction, must be provided. The support of ground and structures adjacent to the anticipated construction, with preservation of adjacent ground and structures from the adverse impact of construction activity, is therefore required.

A.8 INFLUENCE OF CONSTRUCTION ACTIVITY

There is a direct correlation between construction activity and adjacent structural performance. The influence of all anticipated construction activities should by considered by the contractor, owner, architect and prime engineer in consultation with a geotechnical engineer when the final design and construction techniques are known. EBA provides no warranty in respect to adverse circumstances resulting from construction activity.

A.9 OBSERVATIONS DURING CONSTRUCTION

Because of the nature of geologic deposits, the judgmental character of the art of soil and foundation engineering, as well the potential of adverse circumstances arising from construction activity, observations during site preparation, excavation and construction should be carried out by a geotechnical engineer. These observations then may serve as the basis for confirmation and/or alteration of geotechnical recommendations or design guidelines presented herein to the benefit of the project.

A.10 DRAINAGE SYSTEMS

Where drainage systems are installed within or around a structure, the systems which will be installed must protect the structure from loss of ground due to internal erosion and must be designed so as to assure continued performance of the drains. Specific design detail of such systems should be developed or reviewed by the geotechnical engineer. Unless otherwised specified, it is a condition of this report that effective drainage systems are required and that they must be considered in relation to project purpose and function.

A.11 BEARING CAPACITY

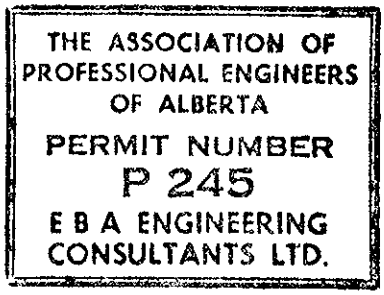
Design bearing capacities, loads and allowable stresses quoted in this report relate to a specific soil type and soil condition. Construction activity and environmental circumstances can materially change a soil condition. The elevation at which a soil type occurs is variable. It is a requirement of this report that structural elements be founded in and/or upon geologic materials of the type and in the condition assumed. Sufficient observations should be made by qualified geotechnical personnel during construction to assure that the soil conditions assumed in this report exist in fact.

A.12 SAMPLES

EBA will retain all soil and rock samples for 30 days. Further storage or transfer of samples can be made at owner expense upon written request.

A.13 STANDARD OF CARE

Services performed by EBA for this report are conducted in a manner consistent with that level and skill ordinarily exercised by members of the profession currently practicing under similar conditions. No other warranty, express or implied, is made.



SYSTEM INTERNATIONAL CONVERSIONS

AREA		
1 km^2	= 3.861 x 10^{-1} mi^2	1 km^2 = 100 hectares
1 km^2	= 2.471 x 10^{+2} acre	
1 m^2	= 1.196 yd^2	
1 m^2	= 1.076 x 10^{+1} ft^2	
1 mm^2	= 1.550 x 10^{-3} in^2	see note 1
DENSITY		
1 Mg/m^3	= 6.243 x 10^{+1} lb_m/ft^3	see note 2
1 kg/m^3	= 6.243 x 10^{-2} lb_m/ft^3	
FORCE		
1 N	= 2.248 x 10^{-1} lb_f	
HEAT		
ENERGY (E)		
1 kJ	= 9.478 x 10^{-1} BTU (IST)	1 BTU = 252 cal
1 J	= 2.388 x 10^{-1} cal (IST)	
HEAT FLUX (Q)		
1 W/m^2	= 3.170 x 10^{-1} $BTU/(ft^2 \cdot hr)$	
SPECIFIC HEAT CAPACITY (c)		
1 $kJ/(kg \cdot C^\circ)$	= 2.388 x 10^{-1} $BTU/(lb_m \cdot F^\circ)$	
THERMAL CONDUCTIVITY (k)		
$W/(m \cdot C^\circ)$	= 5.778 x 10^{-1} $BTU/(ft \cdot hr \cdot F^\circ)$	
COEFFICIENT OF HEAT TRANSFER (c_s)		
1 $W/(m^2 \cdot C^\circ)$	= 1.761 x 10^{-1} $BTU/(ft^2 \cdot hr \cdot F^\circ)$	see note 3
LENGTH		
1 km	= 6.214 x 10^{-1} mi (statute)	
1 m	= 1.094 yd	
1 m	= 3.281 ft	
1 mm	= 3.937 x 10^{-2} in	
MASS		
1 Mg	= 1.102 T	1 T = 2000 lb_m
1 Mg	= 2.205 x 10^3 lb_m	Mg is equivilant to tonne
1 kg	= 2.205 lb_m	
POWER		
1 W	= 1.341 x 10^{-3} HP	1 HP = 550 $ft \cdot lb_f/s$

PRESSURE, STRESS or ELASTIC MODULI		
1 MPa	= 1.044 x 10^{+1} T_f/ft^2 [TSF]	see note 4
1 kPa	= 1.044 x 10^{-2} T_f/ft^2 [TSF]	
1 kPa	= 1.450 x 10^{-1} lb_f/in^2 [psi]	
1 kPa	= 3.346 x 10^{-1} ft of water	hydrostatic pressure of water at 1 ft. depth
1 Pa	= 2.089 x 10^{-2} lb_f/ft^2 [psf]	
TEMPERATURE		
°C	= (°F - 32)/1.8	0°C = 273.15° K
C°	= 1.8 F°	1 C° = 1 K°
TIME		
1 Ms	= 3.171 x 10^{-2} yr	for one year equal to 365 days
1 ks	= 1.157 x 10^{-2} day	
1 s	= 3.171 x 10^{-8} yr	
VISCOSITY		
DYNAMIC (η)		
1 Pa · s	= 1.000 x 10^{+3} centipoise	
KINEMATIC (ν)		
1 mm^2/s	= 1.000 cenistoke	
VOLUME		
1 m^3	= 8.107 x 10^{-4} acre · ft	
1 m^3	= 1.308 yd^3	
1 m^3	= 3.531 x 10^{+1} ft^3	
1 m^3	= 2.200 x 10^{+2} gal (Imperial)	1 m^3 = 1000 L
1 cm^3	= 3.520 x 10^{-2} fl oz	see note 1
1 cm^3	= 6.102 x 10^{-2} in^3	
VOLUME RATE OF FLOW		
1 m^3/s	= 1.901 x 10^{-1} mgpd (Imperial)	
1 m^3/s	= 3.531 x 10^{+1} ft^3/s	
COEFFICIENTS		
VOLUME COMPRESSIBILITY OR SWELLING (m_v or m_s)		
1 m^2/MN;	= 9.579 x 10^{-2} ft^2/T_f	
CONSOLIDATION OR SWELLING (c_v or c_s)		
1 m^2/yr	= 1.076 x 10^{+1} ft^2/yr	
1 m^2/yr	= 2.949 x 10^{-2} ft^2/day	
1 m^2/yr	= 3.171 x 10^{-4} cm^2/s	
HYDRAULIC CONDUCTIVITY (k)		
1 m/s	= 2.835 x 10^{+5} ft/day	see note 5

NOTES.

1. *The use of cm^2 and cm^3 for area and volume is permissible.*
2. *To convert mass density (ρ) to weight per unit volume use:*
   $F = ma_g$
   i.e. $\rho Mg/m^3 \times 9.807\ m/s^2 = 9.807 \rho \frac{Mg \cdot m}{s^2 \cdot m^3} = 9.807 \rho \frac{kN}{m^3}$
   kg_f/m^3 is not a valid SI density unit.
3. *The inverse of the 'coefficient of heat transfer' is 'thermal resistance' or the 'R' value.*
4. *kg_f/m^2 is not a valid SI stress unit.*
5. *Hydraulic conductivity is a proportionality coefficient defined in Darcy's Law* $v = k_w \frac{dh}{ds}$, *where v = velocity of flow*
   $\frac{dh}{ds}$ = *hydraulic gradient*
6. *All conversion factors have been rounded to four significant figures.*

SYSTEM INTERNATIONAL UNITS

QUANTITY	NAME	SYMBOL	EXPRESSED IN TERMS OF OTHER SI UNITS	EXPRESSED IN TERMS OF BASE AND SUPPLEMENTARY UNITS
SI UNITS				
length	metre	m		
mass	kilogram	kg		
time	second	s		
electric current	ampere	A		
thermodynamic temperature	kelvin	K		
amount of substance	mole	mol		
luminous intensity	candela	cd		
SI SUPPLEMENTARY UNITS				
plane angle	radian	rad		
solid angle	steradian	sr		
EXAMPLES OF SI DERIVED UNITS WITH SPECIAL NAMES				
frequency	hertz	Hz	1/s	s^{-1}
force	newton	N	$m \cdot kg/s^2$	$m \cdot kg \cdot s^{-2}$
pressure, stress	pascal	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
energy, work, quantity of heat	joule	J	$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
power, radiant flux	watt	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
EXAMPLES OF SI DERIVED UNITS WITHOUT SPECIAL NAMES				
velocity - linear	metre per second		m/s	$m \cdot s^{-1}$
- angular	(radian per second)		rad/s	$rad \cdot s^{-1}$
acceleration - linear	(metre per second) per second		m/s^2	$m \cdot s^{-2}$
- angular	(radian per second) per second		rad/s^2	$rad \cdot s^{-2}$
concentration (of amount of substance)	mole per cubic metre		mol/m^3	$mol \cdot m^{-3}$
dynamic viscosity	pascal second		$Pa \cdot s$	$m^{-1} \cdot kg \cdot s^{-1}$
moment of force	newton metre		$N \cdot m$	$m^2 \cdot kg \cdot s^{-2}$
surface tension	newton per metre		N/m	$kg \cdot s^{-2}$
heat flux density, irradiance	watt per square metre		W/m^2	$kg \cdot s^{-3}$
heat capacity, entropy	joule per kelvin		J/K	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific heat capacity, specific entropy	joule per kilogram kelvin		$J/(kg \cdot K)$	$m^2 \cdot s^{-2} \cdot K^{-1}$
specific energy	joule per kilogram		J/kg	$m^2 \cdot s^{-2}$
thermal conductivity	watt per metre kelvin		$W/(m \cdot K)$	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$

OTHER UNITS PERMITTED FOR USE WITH SI

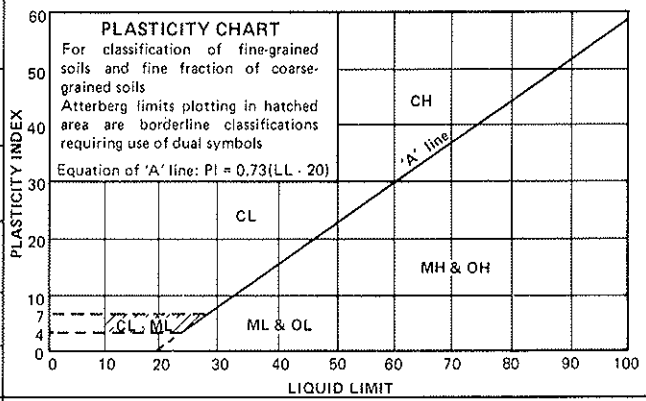
QUANTITY	NAME	SYMBOL	DEFINITION
time	minute	min	1 min = 60 s
	hour	h	1 h = 3,600 s
	day	d	1 d = 86,400 s
	year	a	
plane angle	degree	°	$1° = (\pi/180)$ rad
	minute	′	$1′ = (\pi/10{,}800)$ rad
	second	″	$1″ = (\pi/648{,}000)$ rad
area	hectare	ha	1 ha = 10,000 m^2
volume	litre	L	1,000 L = 1 m^3
temperature	degree Celsius	°C	0° C = 273.15° K
			temperature interval 1 C° = 1 K°
mass	tonne	t	1 t = 1,000 kg = 1 Mg

MULTIPLYING FACTOR	PREFIX	SYMBOL	MULTIPLYING FACTOR	PREFIX	SYMBOL
$1{,}000{,}000{,}000{,}000{,}000{,}000 = 10^{18}$	exa	E	$0.1 = 10^{-1}$	deci*	d
$1{,}000{,}000{,}000{,}000{,}000 = 10^{15}$	peta	P	$0.01 = 10^{-2}$	centi*	c
$1{,}000{,}000{,}000{,}000 = 10^{12}$	tetra	T	$0.001 = 10^{-3}$	milli	m
$1{,}000{,}000{,}000 = 10^{9}$	giga	G	$0.000{,}001 = 10^{-6}$	micro	μ
$1{,}000{,}000 = 10^{6}$	mega	M	$0.000{,}000{,}001 = 10^{-9}$	nano	n
$1{,}000 = 10^{3}$	kilo	k	$0.000{,}000{,}000{,}001 = 10^{-12}$	pico	p
$100 = 10^{2}$	hecto*	h	$0.000{,}000{,}000{,}000{,}001 = 10^{-15}$	femto	f
$10 = 10^{1}$	deca*	da	$0.000{,}000{,}000{,}000{,}000{,}001 = 10^{-18}$	atto	a

* *to be avoided where possible*

UNIFIED SOIL CLASSIFICATION†

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES	CLASSIFICATION CRITERIA	
COARSE-GRAINED SOILS More than 50% retained on No. 200 sieve*	GRAVELS 50% or more of coarse fraction retained on No. 4 sieve	CLEAN GRAVELS	GW	Well-graded gravels and gravel-sand mixtures, little or no fines	Classification on basis of percentage of fines Less than 5% pass No. 200 sieve GW, GP, SW, SP More than 12% pass No. 200 sieve GM, GC, SM, SC 5% to 12% pass No. 200 sieve Borderline classification requiring use of dual symbols	$C_u = D_{60}/D_{10}$ Greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			GP	Poorly-graded gravels and gravel-sand mixtures, little or no fines		Not meeting both criteria for GW
		GRAVELS WITH FINES	GM	Silty gravels, gravel-sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4
			GC	Clayey gravels, gravel-sand clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7
	SANDS More than 50% of coarse fraction passes No. 4 sieve	CLEAN SANDS	SW	Well-graded sands and gravelly sands, little or no fines		$C_u = D_{60}/D_{10}$ Greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ Between 1 and 3
			SP	Poorly-graded sands and gravelly sands, little or no fines		Not meeting both criteria for SW
		SANDS WITH FINES	SM	Silty sands, sand-silt mixtures		Atterberg limits plot below 'A' line or plasticity index less than 4
			SC	Clayey sands, sand-clay mixtures		Atterberg limits plot above 'A' line and plasticity index greater than 7
FINE-GRAINED SOILS 50% or more passes No. 200 sieve*	SILTS AND CLAYS Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands	Atterberg limits plotting in hatched area are borderline classifications requiring use of dual symbols	
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays		
			OL	Organic silts and organic silty clays of low plasticity		
	SILTS AND CLAYS Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts		
			CH	Inorganic silts of high plasticity, fat clays		
			OH	Organic clays of medium to high plasticity		
HIGHLY ORGANIC SOILS			PT	Peat, muck and other highly organic soils		



*Based on the material passing the 3 in. (75 mm) sieve
†ASTM Designation D 2487, for identification procedure see D 2488

GROUND ICE DESCRIPTION

ICE NOT VISIBLE

GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
N	Nf	Poorly-bonded or friable	
	Nbn	No excess ice, well-bonded	
	Nbe	Excess ice, well-bonded	

VISIBLE ICE LESS THAN 50% BY VOLUME

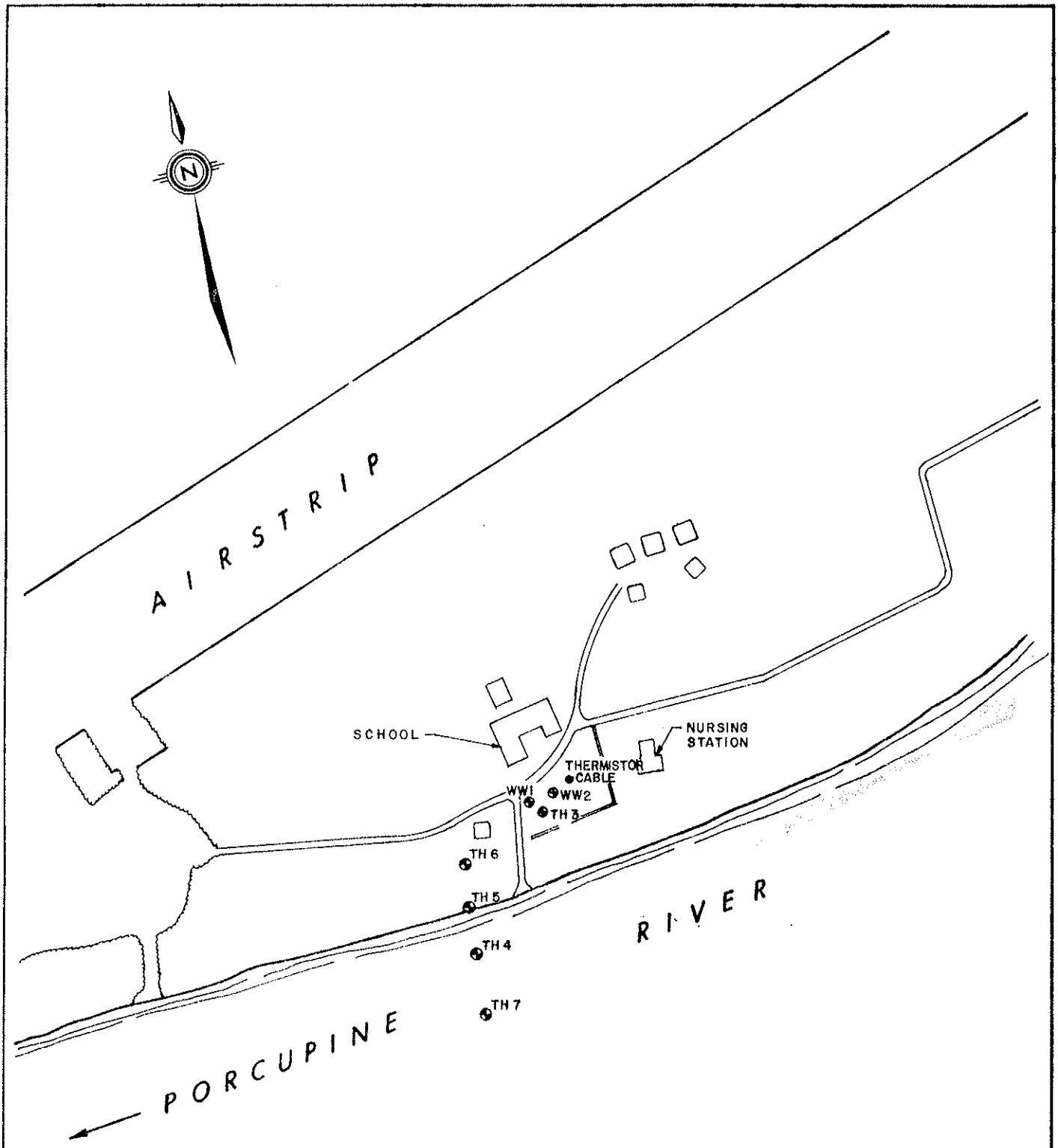
GROUP SYMBOLS	SYMBOLS	SUBGROUP DESCRIPTION	
V	Vx	Individual ice crystals or inclusions	
	Vc	Ice coatings on particles	
	Vr	Random or irregularly oriented ice formations	
	Vs	Stratified or distinctly oriented ice formations	

VISIBLE ICE GREATER THAN 50% BY VOLUME

ICE	ICE + Soil Type	Ice with soil inclusions	
	ICE	Ice without soil inclusions (greater than 25 mm (1 in.) thick)	

NOTE:
1. *Dual symbols are used to indicate borderline or mixed ice classifications*
2. *Visual estimates of ice contents indicated on borehole logs ± 5%*
3. *This system of ground ice description has been modified from NRC Technical Memo 79, Guide to the Field Description of Permafrost for Engineering Purposes*

LEGEND
Soil Ice



SITE PLAN AND BOREHOLE LOCATIONS
WATER WELLS (WW1,2) AND GEOTECHNICAL TEST HOLES
OLD CROW, YUKON

50 25 0 100 200
(METRES)

EBA Engineering Consultants Ltd.	
JOB No.: 209-3546	DATE: 1982-06-07
DRAWN BY: MW	DRAWING No.: 3546-A-1
REVIEWED BY: JRT	

PROJECT: Old Crow Water Supply	**HOLE NO.:** WW 1	**PROJECT NO.:** 209-3546
LOCATION: Old Crow, Yukon	**SURFACE ELEVATION:**	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION
	SNOW
1	SILT (Nbe) - some clay, trace of wood chips, olive-brown
	CLAY (Nbe) - silty, trace of wood, gray
2	
3	SILT (Vs, Vx, Vr 10%) - clayey, trace to some fine sand lenses, trace of wood
4	
	SAND - frozen, fine grained, brown
5	SILT - frozen, sandy, brown
	GRAVEL - sandy, medium grained, moist to damp, olive brown, probably unfrozen
6	
7	GRAVEL - possibly unfrozen, silty, medium grained, some fine grained sand, moist to wet, brown, very dirty
8	
9	
10	- frozen at 10 m
11	CLAY (Vs 15%) - silty, some silt and fine grained sand lenses, grey
12	
13	
14	
15	
16	
17	
18	SILT (Vr, Vs, 15%) - clayey, occasional ice lenses to 10 mm thick, grey
19	
20	SILT - (Vr, Vx, Vs, 20%) - clayey, brown, horizontal and vertical ice lenses with crystalline ice to 10 mm thick, some lenses at 45° also with crystalline ice
21	
22	
23	
24	
25	

UNIFIED SOIL CLASS. | SAMPLE | DEPTH (ft.)

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

6" = 60 blows, 3" spoon

26/4"/-, 3" spoon

44/6"/10 = 1", 3" spoon

50/8"/-, 3" spoon

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

STANDARD PENETRATION: N- ■ 20 40 60 80

eba

DEPTH TO WATER: ▼

DEPTH TO SLOUGH: —

COMPLETION DEPTH: 79.3 m	DATE DRILLED: 1982 02 17
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply | **HOLE NO.:** WW 1 | **PROJECT NO.:** 209-3546

LOCATION: Old Crow, Yukon | **SURFACE ELEVATION:**

DRILL: Schramm Rotadrill

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION
24	
25	SILT - as above, frozen
26	
27	CLAY - silty to some silt, grey
28	
29	SAND - frozen, clayey, trace of gravel and cobbles, quartz-rich, fine grained, brown, ice lenses
30	
31	SILT AND SAND - frozen, trace of clay, brown
32	
33	SILT AND SAND - frozen, trace of clay, medium grained sand, brown, ice crystals
34	SAND - frozen, fine grained, uniform, grey
35	
36	SAND - frozen, fine grained, uniform, golden brown, ice crystals
37	
38	SANDSTONE - small quartz/quartzite pebbles, fine grained, uniform, dense, well indurated, brown
39	
40	- possibly siltstone
41	
42	
43	
44	
45	
46	
47	
48	- dark brown, trace of mafic minerals
49	

UNIFIED SOIL CLASS. | SAMPLE | DEPTH (ft.): 80, 82, 84, 86, 88, 90, 92, 94, 96, 98, 100, 102, 104, 106, 108, 110, 112, 114, 116, 118, 120, 122, 124, 126, 128, 130, 132, 134, 136, 138, 140, 142, 144, 146, 148, 150, 152, 154, 156, 158, 160

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

Casing Originally Set To This Depth---
Reset to 78 m (256 feet) on March 24, 1982

WET UNIT WEIGHT-$\frac{kN}{m^3}$ 16 18 20 22
P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

eba

DEPTH TO WATER: ▼

DEPTH TO SLOUGH: —

COMPLETION DEPTH: 79.3 m

DATE DRILLED: 1982 02 17, 18

LOGGED BY: PKG

DRAWING NO.:

PROJECT: Old Crow Water Supply | **HOLE NO.:** WW 1 | **PROJECT NO.:** 209-3546

LOCATION: Old Crow, Yukon | **SURFACE ELEVATION:**

DRILL: Schramm Rotadrill

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft)
48	SANDSTONE-as above, frozen			158
49				160
				162
50				164
				166
51				168
52				170
				172
53				174
54				176
				178
55	- finer grained, light golden brown			180
				182
56	- ice lenses up to approximately 250 mm thick from 56.4m to 57.9 m			184
57				186
				188
58				190
				192
59				194
60	- possible unfrozen zones			196
				198
61	- more pebbles to 8 mm diameter, frozen from 61.0 m to 64.0 m, darker brown colour			200
62				202
				204
63	- medium grained quartzitic sandstone			206
				208
64	SHALE - appears unfrozen, some sandstone lenses, friable, platy, grey, graphitic			210
65				212
				214
66				216
				218
67	SILTSTONE AND SHALE - unfrozen, uniform, dry to damp, feels "talcy", grey			220
68	- interbeds of fine, brown, uniform sand and some graphite (?) from 67.1m to 71.6m			222
				224
69				226
				228
70				230
				232
71	- poorly lithified			234
72	SANDSTONE - trace shale, fine grained, uniform, damp to moist, brown, thin shale interbeds			236
				238
73				

BOTTOM OF PERMAFROST ?

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 79.3 m	DATE DRILLED: 1982 02 17, 18
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: WW 1	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
72	SANDSTONE (as above)			238
73	SILTSTONE - uniform, light brown to white, sandstone interbeds, quartzitic			240 242
74				244
75				246
76				248 250
77				252 254
78	LIMESTONE - dark grey, crystalline, fractured, water-bearing			256 BOTTOM OF CASING
79				258 (Reset on March 24, 1982)
80	END OF HOLE (79.3 m)			260 262
81	Note: Artesian water conditions encountered at 78.0 m. Initial flow from top of casing at approximately 6.1 L/s Could not drill further.			264 266 268
82				270
83				272 274
84				276
85				278
86				280 282
87				284 286
88				288
89				290
90				292 294
91				296 298
92				300 302
93				304
94				306 308
95				310 312
96				314
97				316

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▽
DEPTH TO SLOUGH: —

COMPLETION DEPTH:	79.3 m	DATE DRILLED:	1982 02 17, 18
LOGGED BY:	PKG	DRAWING NO.:	

PROJECT: Old Crow Water Supply | **HOLE NO.:** WW 2 | **PROJECT NO.:** 209-3546

LOCATION: Old Crow, Yukon | **SURFACE ELEVATION:**

DRILL: Schramm Rotadrill

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
1	SILT AND CLAY - frozen, trace of wood, olive brown, to grey			2
2				4
				6
3				8
				10
4				12
				14
5	SAND AND SILT - frozen, brown			16
	GRAVEL - possibly unfrozen, silty, some sand, medium grained			18
6				20
				22
7				24
				26
8				28
				30
9				32
10				34
				36
11	CLAY - frozen, silty, grey			38
				40
12				42
				44
13				46
				48
14				50
				52
15				54
				56
16				58
				60
17				62
				64
18	SILT - frozen, clayey, grey, ice lenses			66
				68
19				70
				72
20				74
				76
21				78
				80
22				
23				
24				

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) ⟷ LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m

DATE DRILLED: 1982 02 18, 19, 20

LOGGED BY: PKG

DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: WW 2	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▧ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
25	SILT - as above, frozen			80
				82
26				84
				86
27	CLAY - some silt, grey, frozen			88
				90
28				92
				94
29	SAND - frozen, clayey, trace of gravel, fine grained, brown			96
				98
30				100
31				102
32	- silty from 32.0 to 33.5 m			104
				106
33				108
				110
34				112
35				114
				116
36	SANDSTONE - frozen, trace of pebbles, fine grained, uniform, brown			118
				120
37				122
				124
38				126
39				128
				130
40				132
41				134
				136
42				138
43				140
				142
44				144
				146
45				148
				150
46				152
				154
47				156
				158
48				160

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT WEIGHT-O $\frac{kN}{m^3}$ 16 18 20 22
P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ●

eba

DEPTH TO WATER: ▽

DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m	DATE DRILLED: 1982 02 18, 19, 20
LOGGED BY: PKG	DRAWING NO.:

This log is a compilation of subsurface conditions and soil or rock classification obtained from the field as well as from laboratory testing of samples from the borehole. Soil zones have been interpreted according to commonly accepted practice. The change from one zone to another, as indicated on the log, may be transitional and approximate in nature. Groundwater conditions refer only to those observed at the times and places indicated and they may vary with time, geologic conditions, and construction activity.

PROJECT: Old Crow Water Supply	HOLE NO.: WW 2	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ▦ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
49	SANDSTONE - as above, frozen			158 160
50				162 164
51				166 168
52				170 172
53				174 176
54				178 180
55				182 184
56				186 188
57				190 192
58				194 196
59				198 200
60				202 204
61				206 208
62				BOTTOM OF PERMAFROST? 210
63				212 214
64	SILTSTONE AND SHALE - highly weathered, faulted(?), fractured, grey, trace of biotite			216 218
65				220 222
66				224 226
67				228 230
68				232 234
69				236 238
70				
71				
72				

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) ⊢—⊣ LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m	DATE DRILLED: 1982 02 18, 19, 20
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: WW 2	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ▦ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
72				238
73	SILTSTONE AND SHALE - as above			240
74				242
75				244
76				246
77				248
78	ROCK FLOUR - silty, clayey, damp, orange-brown, no free water, may be fault gouge or an erosional surface, mylonite?			250
79	- water at 79.3 m			252
80	LIMESTONE - grey, lithology uncertain, little water			254
81				256
82				258
83	LIMESTONE - shaley, fractured, grey, water bearing but little water to 83.8 m			260
84				262
85	- grey brown, thinly bedded, dolomitic			264
86				266
87				268
88	DOLOMITE - dark grey-green, clayey bands approximately 5 - 10 mm thick that contain numerous rock fragments and could possibly be called mylonite zones, extensively fractured, fractures are water bearing but mylonite debris is preventing proper well development and keeping a high sediment load in the water			270
89				272
90				274
91				276
92	- interbedded clayey bands and shale from 91.4 m			278
93				280
94	- fractured, appears weathered			282
95				284
96				286
				288
				290
				292
				294
				296
				298
				300
				302
				304
				306
				308
				310
				312
				314
				316

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... Δ
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

eba

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m	DATE DRILLED: 1982 02 18, 19, 20
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: WW 2	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ▦ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
97	DOLOMITE - as above			316
				318
98				320
				322
				324
99				326
100				328
	- occasional "mylonite like" layers up to 250 mm thick, from 100.6 m			330
101				332
102				334
				336
103				338
104				340
				342
105				344
				346
106				348
				350
107				352
108				354
				356
109				358
110				360
				362
111				364
				366
112				368
113				370
				372
114				374
				376
115				378
116				380
				382
117				384
118				386
				388
119				390
				392
120				394
				396

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

BOTTOM OF CASING

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... Δ
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT WEIGHT-O $\frac{kN}{m^3}$ P.C.F. 16 18 20 22 / 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m	DATE DRILLED: 1982 02 18, 19, 20
LOGGED BY: PKG	DRAWING NO.:

This log is a compilation of subsurface conditions and soil or rock classification obtained from the field as well as from laboratory testing of samples from the borehole. Soil zones have been interpreted according to commonly accepted practice. The change from one zone to another, as indicated on the log, may be transitional and approximate in nature. Groundwater conditions refer only to those observed at the times and places indicated and they may vary with time, geologic conditions, and construction activity.

PROJECT: Old Crow Water Supply	HOLE NO.: WW 2	PROJECT NO.: 209-3546
LOCATION: Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
121	DOLOMITE - as above			394
				396
	- increased water flow noted at 121.3 m			398
122				400
	END OF HOLE (121.9 m)			402
123				404
124	NOTE: No more drill stem; artesian water conditions encountered. Flow from top of casing approximately 2.3 L/s at time of drilling.			
125				
126				
128				
129				
130				
131				
132				
133				
134				
135				
136				
137				
138				
139				
140				
141				
142				
143				
144				
145				

WATER CONTENT-% : ●
PLASTIC LIMIT (Wp) ⊢—⊣ LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 121.9 m	DATE DRILLED: 1982 02 18, 19, 20
LOGGED BY: PKG	DRAWING NO.:

BOREHOLE LOG – PERMAFROST

DEPTH (metres)	SOIL DESCRIPTION	SAMPLE	GROUND ICE DESCRIPTION
	SNOW	C	Nbn
	SILT - some sand and organics, trace of clay, light greyish brown	C	Nbn, trace Vs
1	- trace of organics (25 mm dia.roots)	C	Nbn, Nbe?
	- trace to some sand and clay	C	Nbn, possible Vx
	- some sand, trace of clay and organics	C	Nbn, Nbe
2	- trace of organics (25 mm dia. roots)	C	Vr, Vs 10%
	- trace of organics (12 mm dia. roots)	C	Vs, Vr, Vc 10%
	- trace of organics (25 mm dia. roots)	C	Nbn
3		C	Vs, Vr 10%
		C	Vs, Vc 10%
4		C	Vr, Vs 15%
		C	Vs, Vr 5%
		C	Nbn, possible Vx
	- increase in clay content	C	Nbn
5		C	Vs, Vr 15%
		C	Nbn
	GRAVEL - medium to coarse grained, silty, sandy, trace of clay, brown	G	
6		G	POSSIBLY UNFROZEN
7			

BULK DENSITY (Mg/m^3) ▲
1.4 1.6 1.8 2.0 2.2
MOISTURE CONTENT
10 20 30 40 50

63%

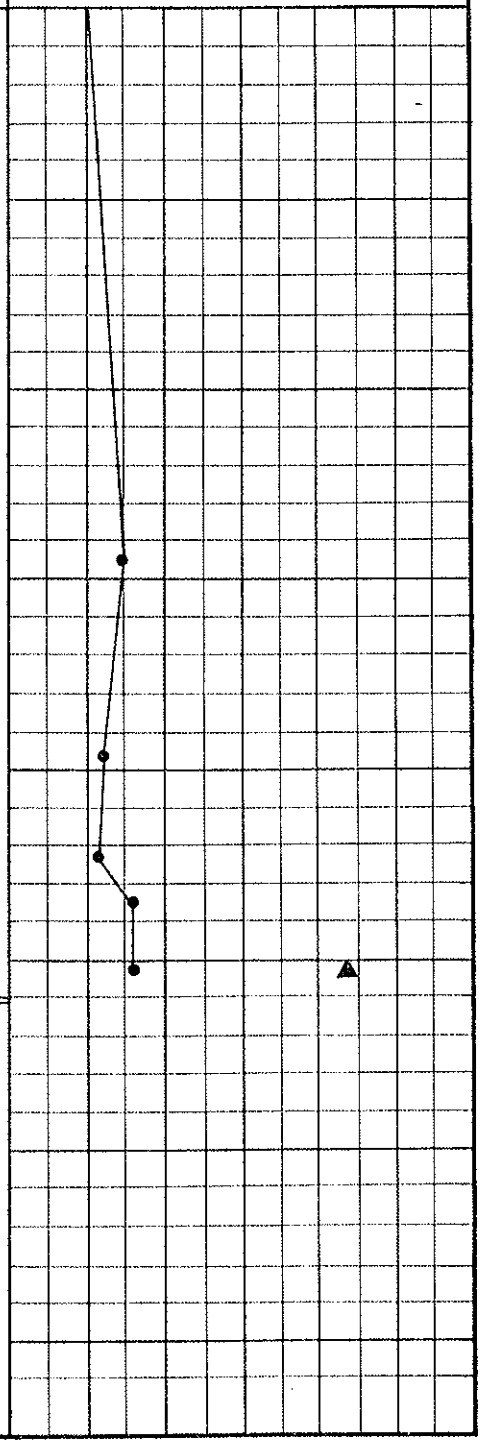
SFC. ELEVATION (m)	DATE DRILLED 1982 03 21	BOREHOLE No. TH 3
COMPLETION DEPTH (m) 12.2	LOGGED BY PKG/TRM	
DRILLING RIG Schramm	LOCATION Old Crow, Yukon	PAGE 1 OF 2

This log is a compilation of subsurface conditions and soil or rock classification obtained from the field as well as from laboratory testing of samples from the boreholes. Soil zones have been interpreted according to commonly accepted practice. The change from one zone to another, as indicated on the log, may be transitional and approximate in nature. Groundwater conditions refer only to those observed at the times and places indicated and that may vary with time, geologic conditions, and construction activity.

BOREHOLE LOG – PERMAFROST

DEPTH (metres)	SOIL DESCRIPTION	SAMPLE	GROUND ICE DESCRIPTION
8	GRAVEL - medium to coarse, silty, sandy, trace of clay, brown		POSSIBLY UNFROZEN
9			
10		G	
11	SILT AND CLAY - trace of fine sand, greyish brown		FROZEN
		C	Vs, Vr 5%
		C	Vs, Vr 5%
		C	Vs, Vr 5%
12		C	Vs, Vr 5%
	END OF HOLE (12.2 m)		
13			
14			

BULK DENSITY (Mg/m^3) ▲
1.4 1.6 1.8 2.0 2.2
MOISTURE CONTENT
10 20 30 40 50



eba	SFC. ELEVATION (m)	DATE DRILLED 1982 03 21
	COMPLETION DEPTH (m) 12.2	LOGGED BY PKG/TRM
	DRILLING RIG Schramm	LOCATION Old Crow, Yukon

BOREHOLE No. TH 3

PAGE 2 OF 2

This log is a compilation of subsurface conditions and soil or rock classification obtained from the field as well as from laboratory testing of samples from the boreholes. Soil zones have been interpreted according to commonly accepted practice. The change from one zone to another, as indicated on the log, may be transitional and approximate in nature. Groundwater conditions refer only to those observed at the times and places indicated and that may vary with time, geologic conditions, and construction activity.

PROJECT: Old Crow Water Supply	HOLE NO.: TH 4	PROJECT NO.: 209-3546
LOCATION: Porcupine River, Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
1	RIVER ICE			2, 4
2	WATER			6, 8
3	GRAVEL - silty, some sand, medium grained, brown, saturated			10, 12
4	SILT AND SAND - trace of clay, fine grained sand, very soft, grey, saturated			14, 16
5				18
6	CLAY - unfrozen, silty, trace of sand, dry to damp, crumbly, grey			20, 22
7				24
8				26, 28
9				30
10				32, 34
11				36, 38
12				40

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... Δ
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT WEIGHT: $\frac{kN}{m^3}$ 16 18 20 22 — P.C.F. 100 110 120 130 140 150

STANDARD PENETRATION: N- ■ 20 40 60 80

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 18.3 m	DATE DRILLED: 1982 02 22
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: TH 5	PROJECT NO.: 209-3546
LOCATION: Porcupine River, Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ▦ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
0	GRAVEL - frozen, sandy, trace of clay, brown			
2	- may or may not be frozen from 2.1 m			
4	CLAY - appears unfrozen, gravelly, moist, grey			
6	CLAY - unfrozen, silty to sandy, moist, grey			
7	CLAY - unfrozen, some to trace of silt, moist, medium plasticity, grey			
9	SAND - unfrozen, clayey, silty, some clay layers, fine grained, uniform, brown			
12				

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) ⟷ LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-0 P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▼
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 16.8 m	DATE DRILLED: 1982 02 22
LOGGED BY: PKG	DRAWING NO.:

PROJECT:	Old Crow Water Supply	HOLE NO.:	TH 5	PROJECT NO.:	209-3546
LOCATION:	Porcupine River Old Crow, Yukon	SURFACE ELEVATION:			
		DRILL:	Schramm Rotadrill		

SAMPLE TYPE: ▩ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
13	SAND - as above			40
	SILT AND SAND - unfrozen, clay interbeds, fine grained sand, grey			42
				44
14				46
				48
15				50
				52
16				54
17	END OF HOLE (17.8 m)			56
				58
18				60
				62
19				64
20				66
				68
21				70
				72
22				74
23				76
				78
24				

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

eba

DEPTH TO WATER: ▽

DEPTH TO SLOUGH: —

COMPLETION DEPTH:	16.8 m	DATE DRILLED:	1982 02 22
LOGGED BY:	PKG	DRAWING NO.:	

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PROJECT:	Old Crow Water Supply	HOLE NO.: TH 6	PROJECT NO.: 209-3546
LOCATION:	Porcupine River Bank Old Crow, Yukon	SURFACE ELEVATION:	
		DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ☒ NO RECOVERY ⊞ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION
1	SILT AND CLAY - frozen, some sand, interbedded
2	
3	GRAVEL - frozen, sandy, brown
4	
5	
6	
7	
8	
9	CLAY (Vx 5%) - frozen, trace of silt, grey
10	
11	END OF HOLE (10.7 m)
12	NOTE: Probe hole only, no sampling or testing

UNIFIED SOIL CLASS. | SAMPLE | DEPTH (ft.): 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40

WATER CONTENT-% : ●
PLASTIC LIMIT (Wp) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT $\frac{kN}{m^3}$ 16 18 20 22
WEIGHT-O P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

DEPTH TO WATER: ▽
DEPTH TO SLOUGH: —

COMPLETION DEPTH: 10.7 m	DATE DRILLED: 1982 02 22
LOGGED BY: PKG	DRAWING NO.:

PROJECT: Old Crow Water Supply	HOLE NO.: TH 7	PROJECT NO.: 209-3546
LOCATION: Porcupine River, Old Crow, Yukon	SURFACE ELEVATION:	
	DRILL: Schramm Rotadrill	

SAMPLE TYPE: ■ THIN WALLED TUBE ☒ SPLIT SPOON ▤ DISTURBED ▨ NO RECOVERY ▦ CORE ☐ OTHER

DEPTH (m.)	SOIL DESCRIPTION	UNIFIED SOIL CLASS.	SAMPLE	DEPTH (ft.)
	ICE			1
				2
	WATER			3
1				4
				5
				6
2				7
				8
				9
3				10
	END OF HOLE (3.1 m)			11
	Note: Hole abandoned due to ice deflection under weight of drill rig			12
				13
4				14
				15
				16
5				17
				18
				19
6				20

WATER CONTENT-% : ●
PLASTIC LIMIT (W_P) — LIQUID LIMIT (W_L)
20 40 60 80

COMPRESSIVE STRENGTH
Unconfined..... ▲
Pocket Penetrometer..... △
TSF 1 2 3 4 5
kPa 100 200 300 400

WET UNIT WEIGHT-O $\frac{kN}{m^3}$ 16 18 20 22
P.C.F. 100 110 120 130 140 150

20 40 60 80
STANDARD PENETRATION: N- ■

eba

DEPTH TO WATER: ▼

DEPTH TO SLOUGH: —

COMPLETION DEPTH: 3.1 m	DATE DRILLED: 1982 02 23
LOGGED BY: PKG	DRAWING NO.:

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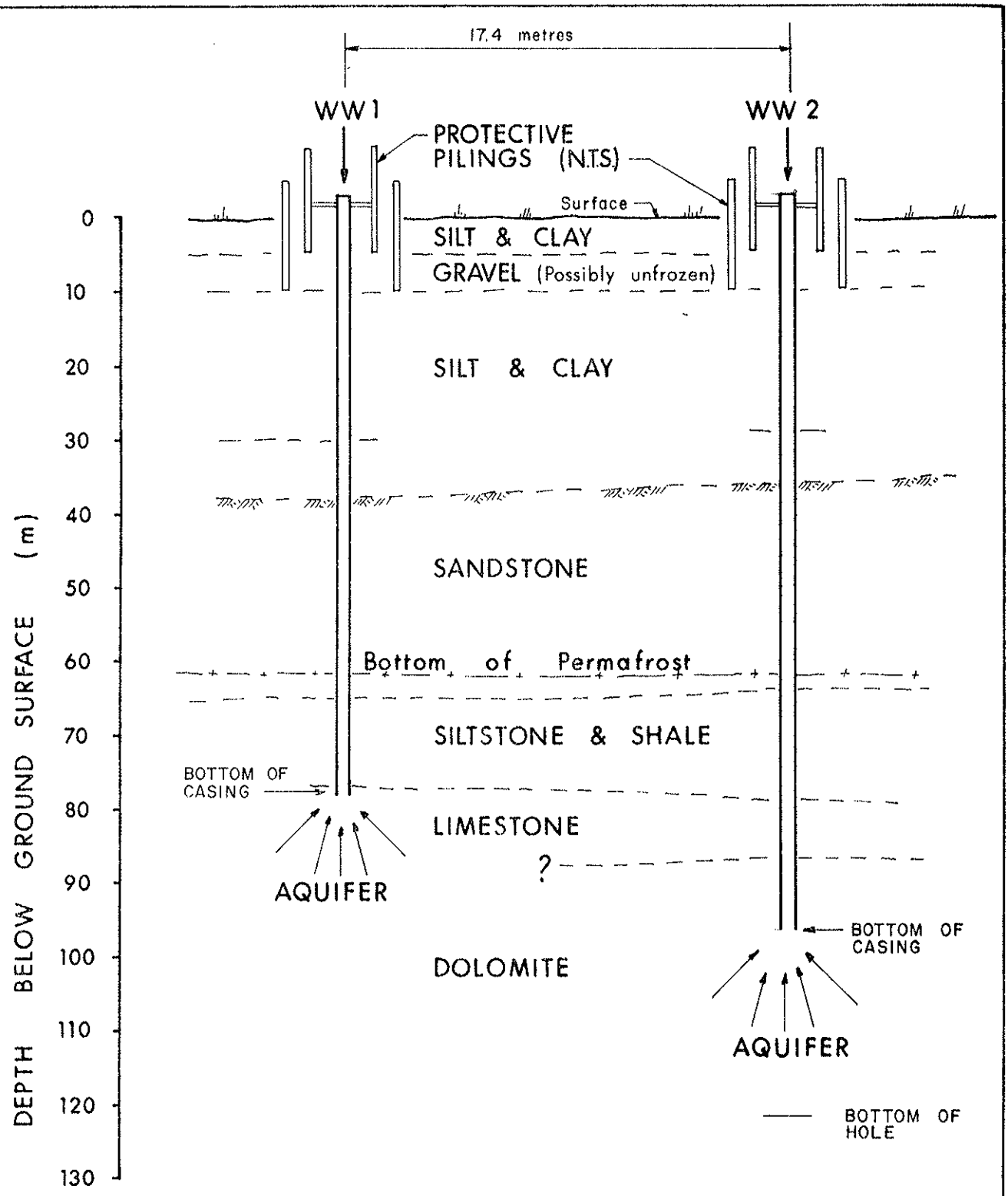
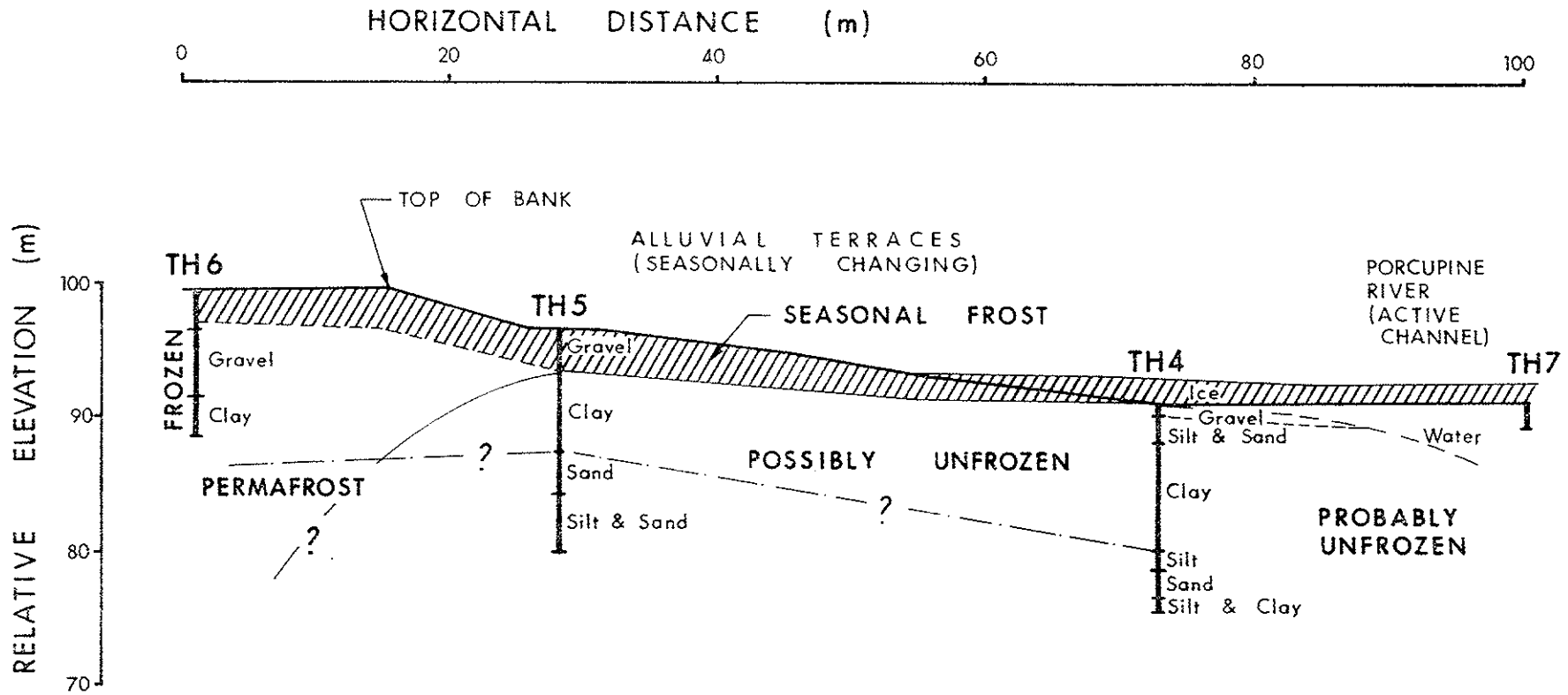


GENERALIZED SUBSURFACE CONDITIONS
WATER WELL SITE
OLD CROW, YUKON

NOTE
HORIZONTALLY N.T.S.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982-06-07
DRAWN BY: MW	DRAWING NO.: 3546 - A - 2
REVIEWED BY:	



GENERALIZED SUBSURFACE CONDITIONS
PORCUPINE RIVER
OLD CROW, YUKON

NOTES:

1. BOREHOLE LOCATIONS ARE ONLY APPROX.
2. *The geologic and stratigraphic sections shown on this drawing are interpreted from borehole logs. Stratigraphy is known with certainty only at the borehole locations. Actual stratigraphy and geologic conditions between boreholes may vary from that indicated on this drawing.*

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JOB NO.: 209-3546	DATE: 1982-07-23
DRAWN BY: MW	DRAWING NO.: 3546 - A - 3
REVIEWED BY:	

EBA Engineering Consultants Ltd.

14535 - 118th AVENUE
EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 82-04-19

Borehole Number: WW-1

Depth: 3.00 - 3.50 M

Soil Description: SILT, TRACE CLAY, TRACE SAND

Cu: 5.2

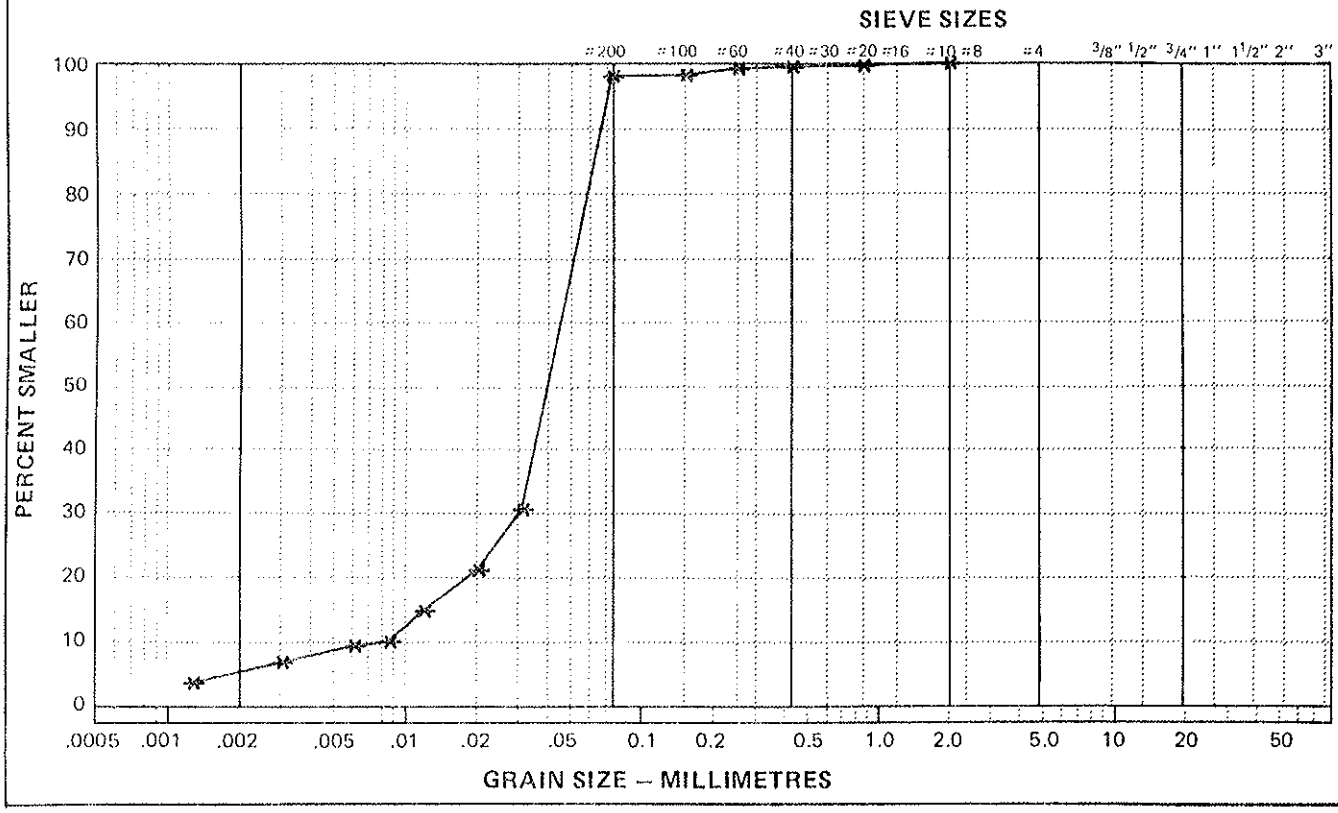
Cc: 2.4

Natural Moisture Content: _____ %

Remarks: _____

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	100.0
No. 20	99.6
No. 40	99.4
No. 60	99.2
No. 100	98.2
No. 200	98.0

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 82-04-19

Borehole Number: WW-1

Depth: 11.00 - 11.00 M

Soil Description: SILT, SANDY, TRACE CLAY

Cu: 19.2

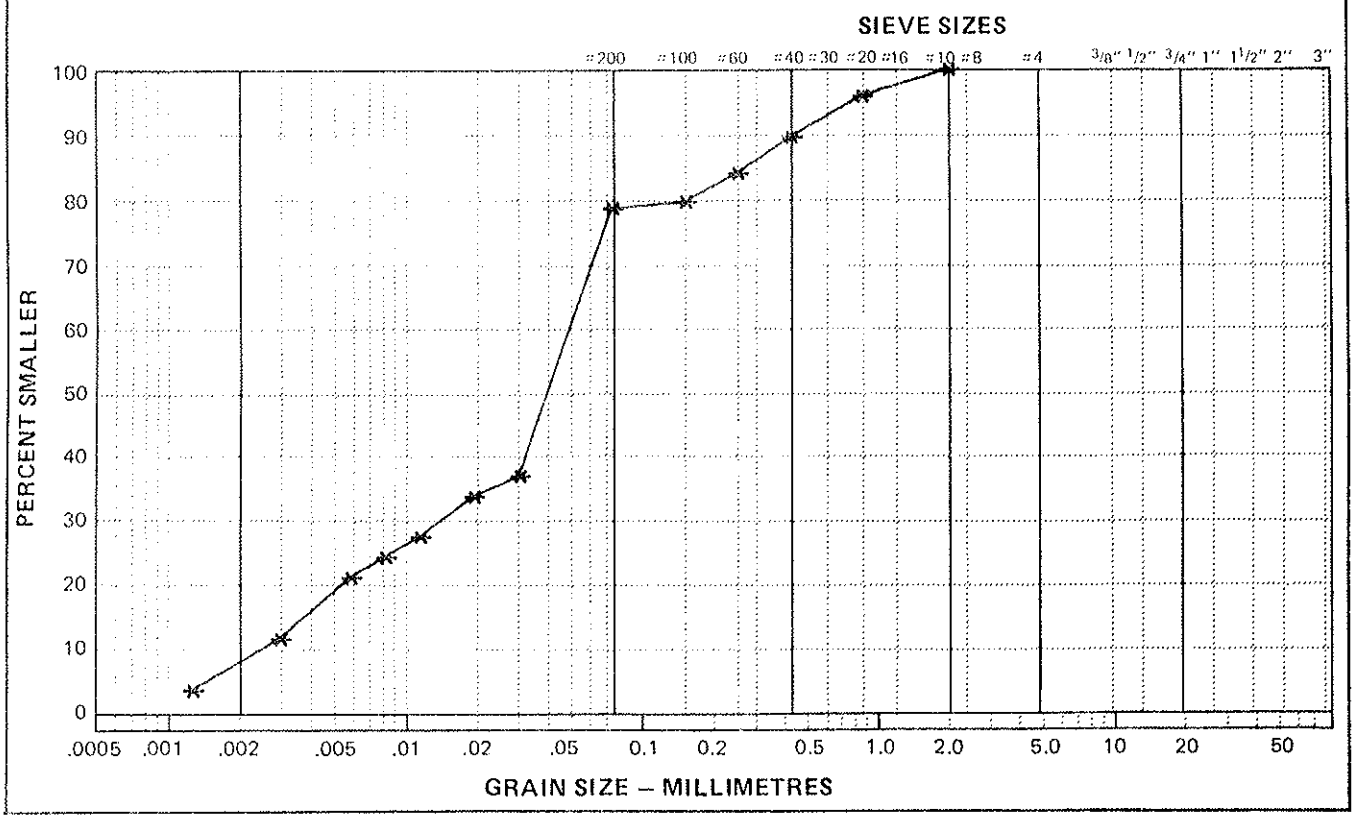
Cc: 1.6

Natural Moisture Content: ____ %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	100.0
No. 20	95.8
No. 40	89.4
No. 60	83.8
No. 100	79.4
No. 200	78.4

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 82-04-19

Borehole Number: WW-1

Depth: 17.40 - 17.40 M

Soil Description: SILT, CLAYEY, SOME SAND

Cu:

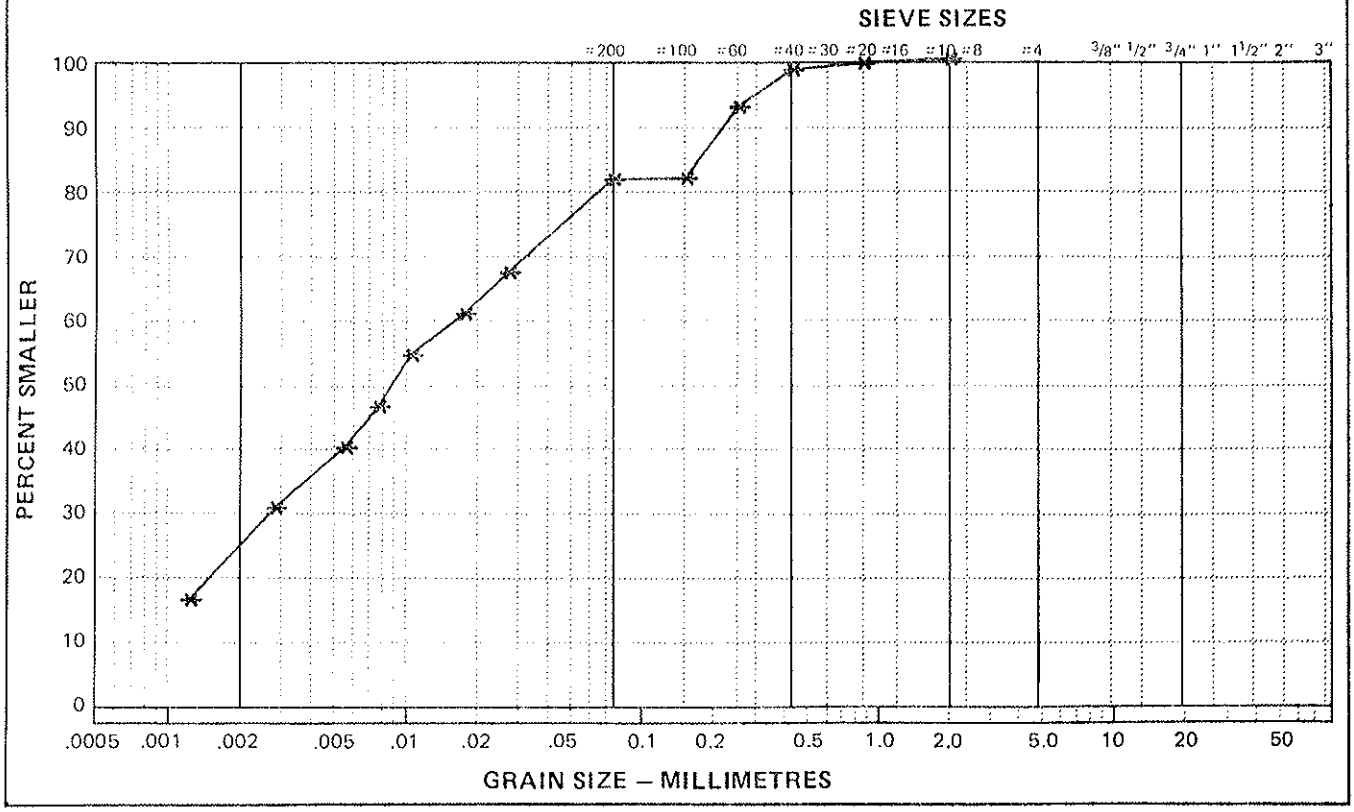
Cc:

Natural Moisture Content: %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	100.0
No. 20	99.4
No. 40	98.4
No. 60	92.6
No. 100	81.4
No. 200	81.2

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 82-04-19

Borehole Number: WW-1

Depth: 23.50 - 23.50 M

Soil Description: SILT, TRACE CLAY

Cu: 1.6

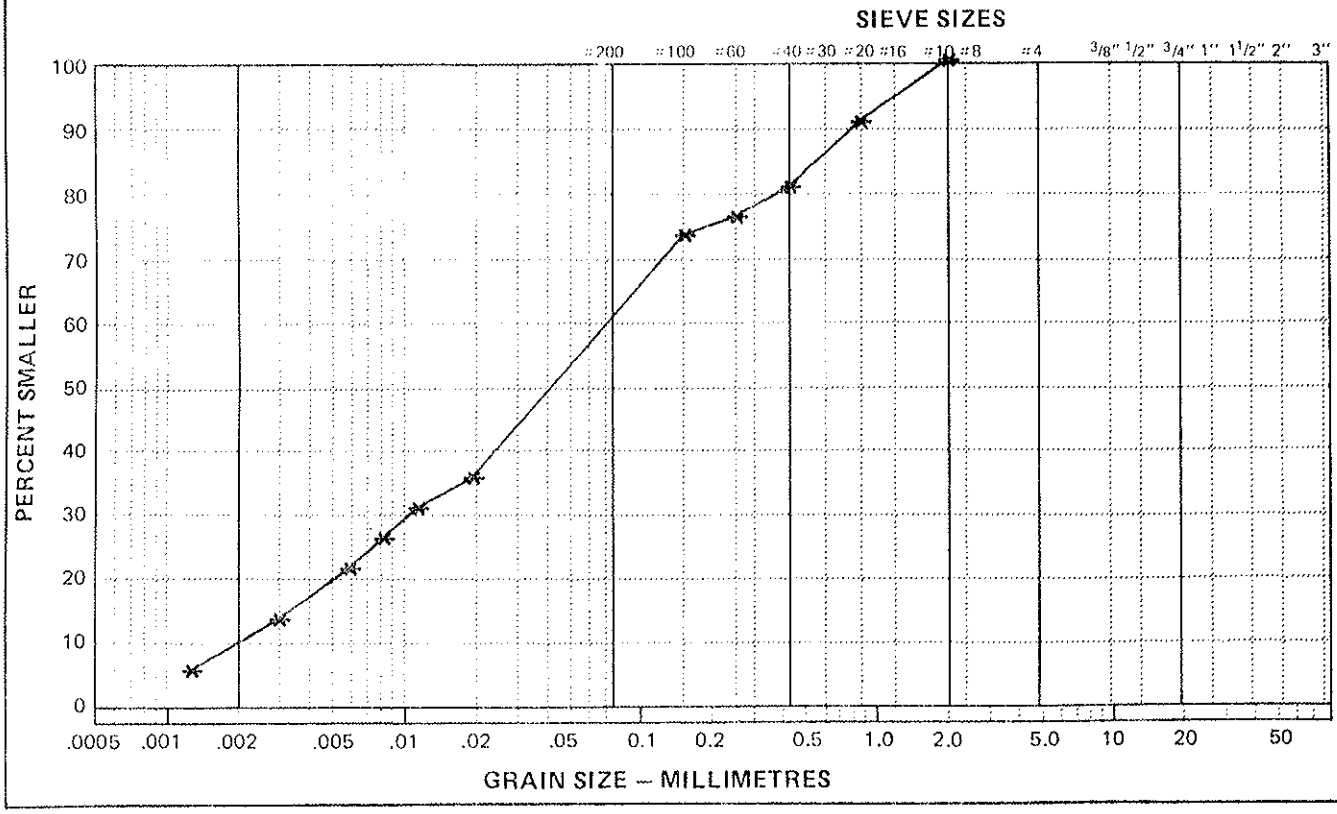
Cc: .9

Natural Moisture Content: ____ %

Remarks: ____

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	100.0
No. 20	90.4
No. 40	80.2
No. 60	75.6
No. 100	72.8
No. 200	

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



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EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 1982 05 11

Borehole Number: TH 3

Depth: 0.91 - 1.36 m

Soil Description: Olive Brown Silt some sand trace of clay

Cu:

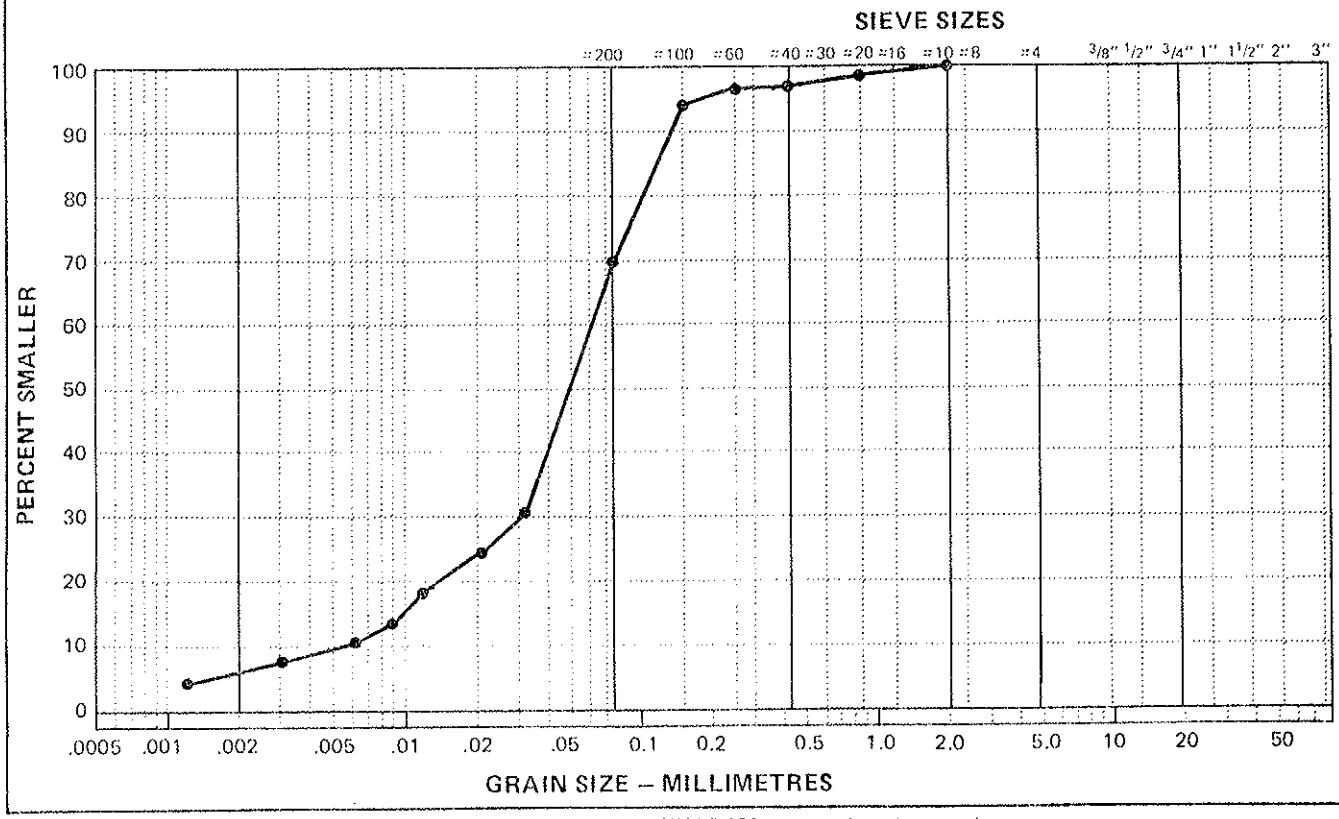
Cc:

Natural Moisture Content: %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	100.0
No. 20	98.6
No. 40	97.8
No. 60	96.8
No. 100	94.0
No. 200	70.0

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering Consultants Ltd.

14535 - 118th AVENUE
EDMONTON, ALBERTA
Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 1982 05 11

Borehole Number: TH 3

Depth: 4.4 - 4.7 m

Soil Description: Greyish Brown Silt, trace of sand and clay

Cu:

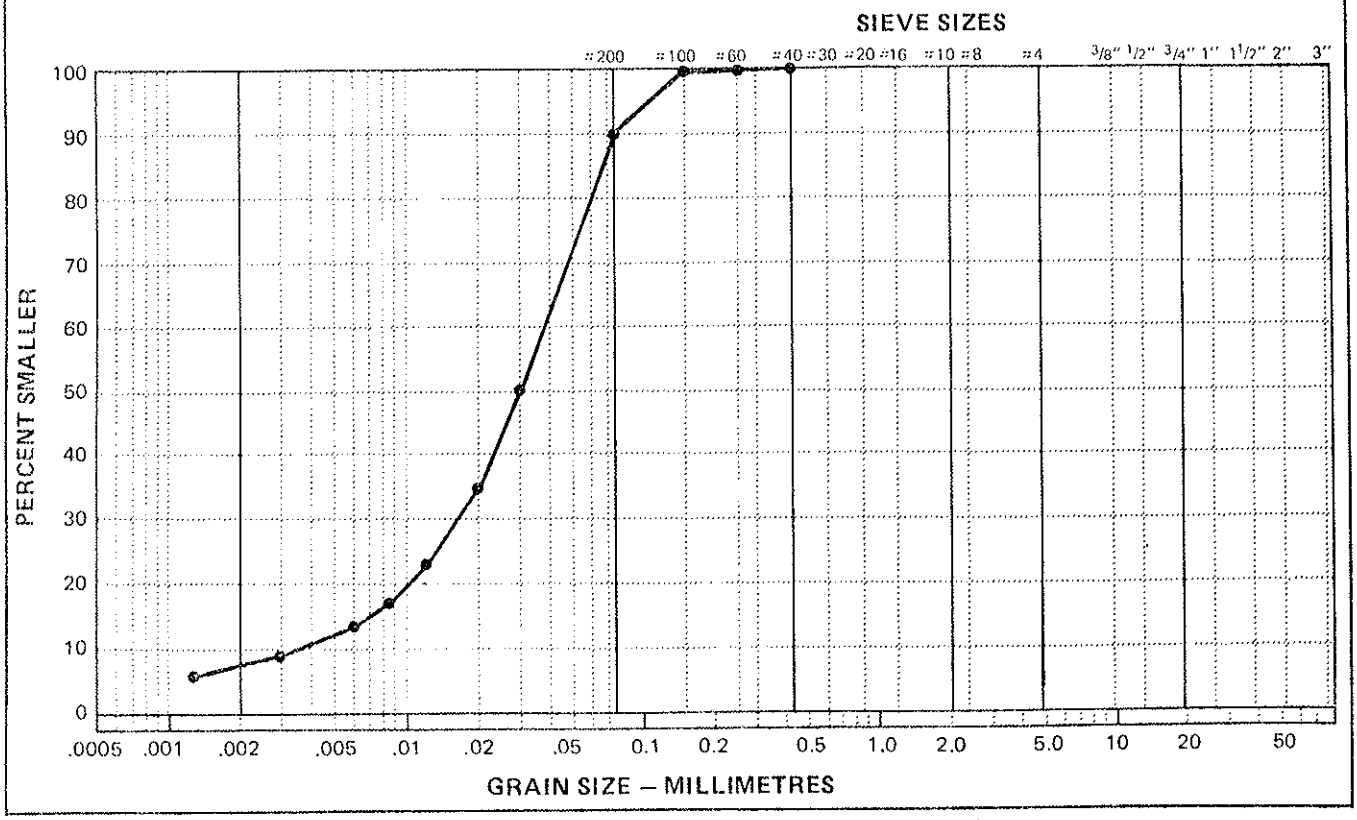
Cc:

Natural Moisture Content: %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	
1 1/2"	
1"	
3/4"	
3/8"	
No. 4	
No. 10	
No. 20	
No. 40	100.0
No. 60	99.8
No. 100	99.2
No. 200	90.0

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering Consultants Ltd.

14535 - 118th AVENUE
EDMONTON, ALBERTA
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5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 1982 05 11

Borehole Number: TH 3

Depth: 5.49 to 6.71 m

Soil Description: Olive Brown Sand gravelly some silt trace of clay

Cu:

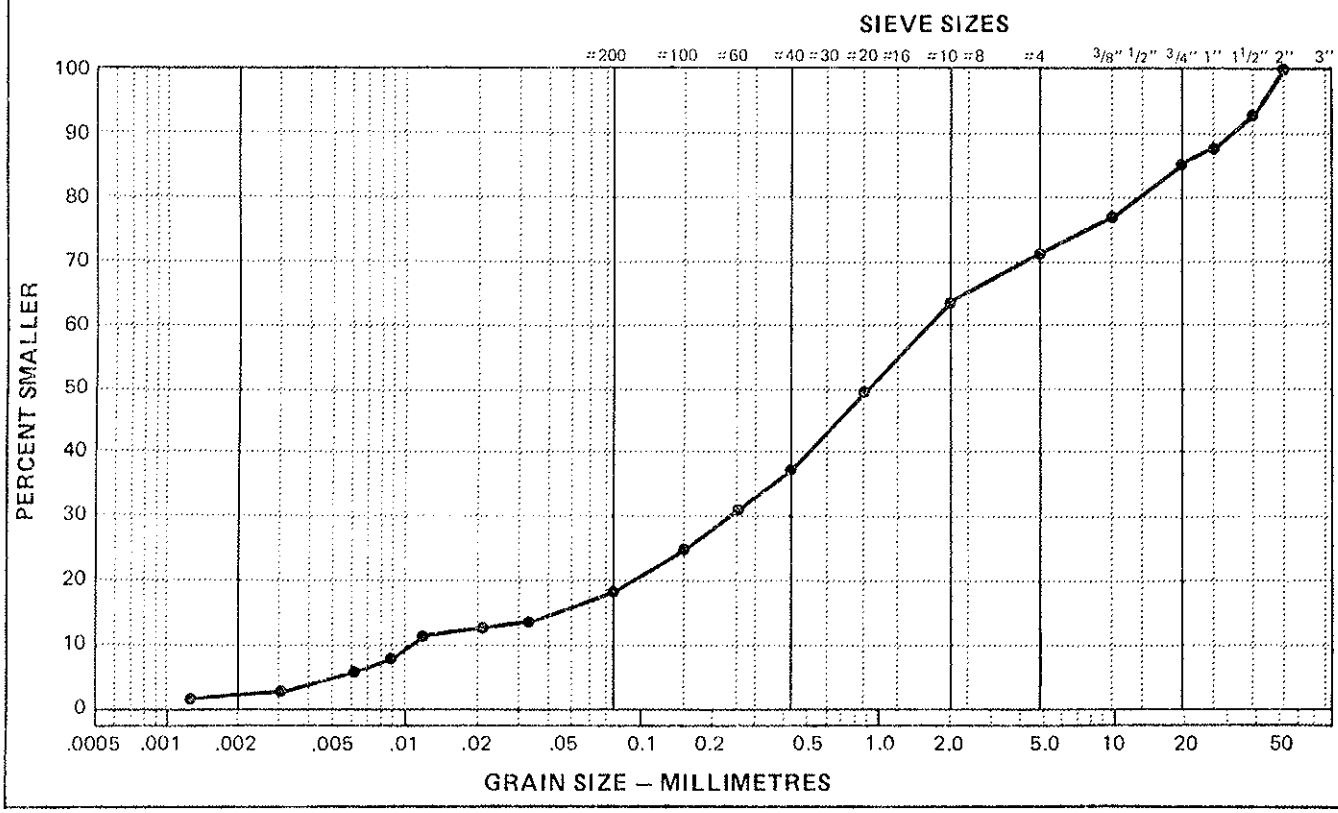
Cc:

Natural Moisture Content: %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	100.0
1 1/2"	92.4
1"	87.5
3/4"	85.6
3/8"	77.0
No. 4	71.1
No. 10	63.2
No. 20	49.8
No. 40	37.5
No. 60	30.8
No. 100	24.9
No. 200	18.6

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



Tested in accordance with ASTM D422 unless otherwise noted.

EBA Engineering Consultants Ltd.

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Phone (403) 451-2121

5664 BURLEIGH CRES. S.E.
CALGARY, ALBERTA
Phone (403) 253-7121

PARTICLE - SIZE ANALYSIS OF SOILS

Project: Old Crow Water Supply

Project Number: 209-3546

Date Tested: 1982 03 18

Borehole Number: River Channel

Depth:

Soil Description: Light Greyish Brown Sand, some gravel, trace of silt

Cu:

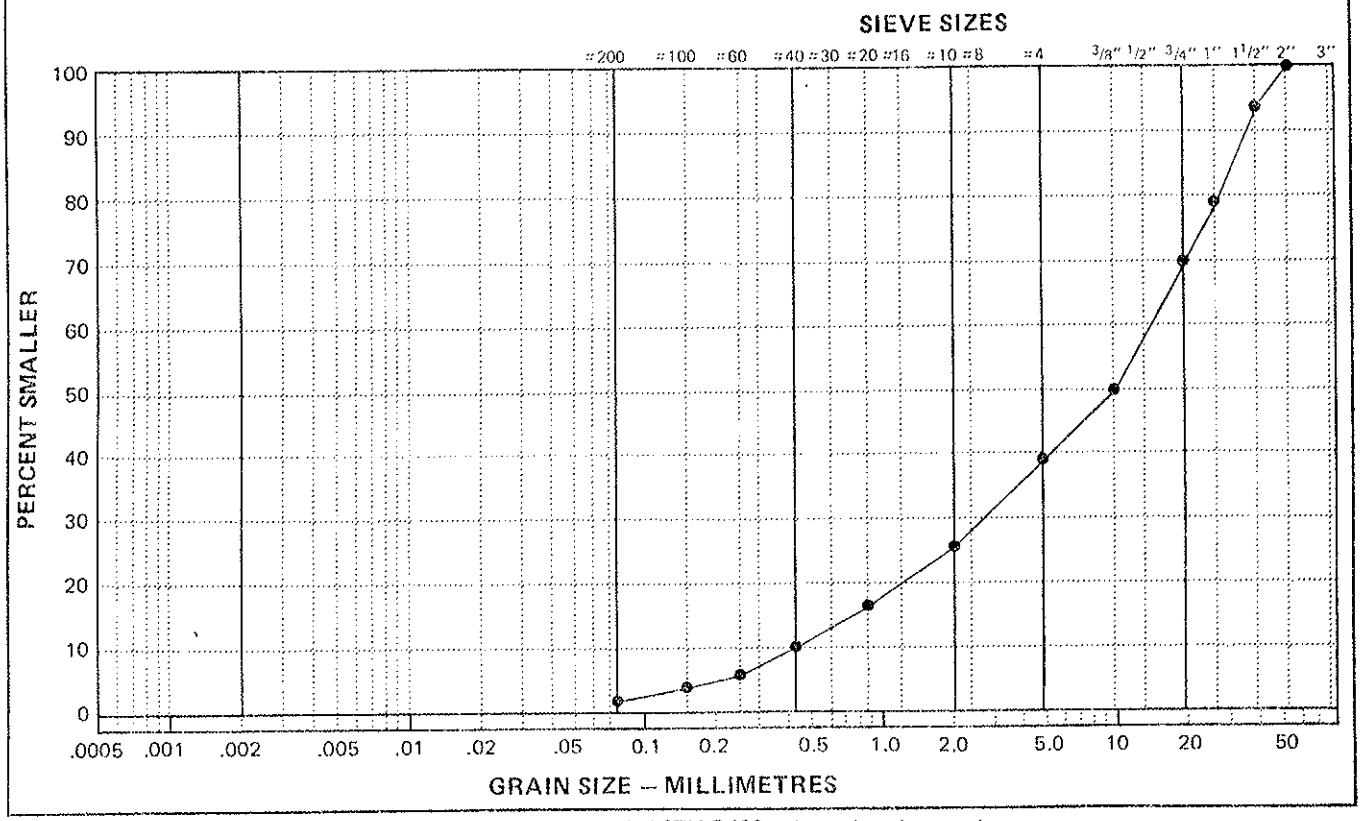
Cc:

Natural Moisture Content: 2.7 %

Remarks:

SIEVE	PERCENTAGE PASSING
3"	
2"	100
1 1/2"	94
1"	79
3/4"	70
3/8"	50
No. 4	39
No. 10	26
No. 20	17
No. 40	10
No. 60	6
No. 100	4
No. 200	2

CLAY	SILT	SAND			GRAVEL	
		FINE	MEDIUM	COARSE	FINE	COARSE



Tested in accordance with ASTM D422 unless otherwise noted.

SUMMARY OF LABORATORY TESTING RESULTS – PERMAFROST

BOREHOLE NUMBER	DEPTH INTERVAL	MOIST. CONT.	BULK DENS.	GROUND ICE DESCRIPTION	ATTERBERG LIMITS			GRAIN SIZE DISTRIBUTION				SOIL DESCRIPTION
					LL	PL	PI	CLAY	SILT	SAND	GRAV	
	(metres)	(%)	(Mg/m^3)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
WW 1	3.0-3.5	42		Vx 15%		N/P		7	91	2		See Particle Size Analysis *
WW 1	11.0	18		Vx, Vc 10%	36	26	10	8	70	22		See Particle Size Analysis
WW 1	17.4	23		Vx 5%	43	42	1	26	55	19		See Particle Size Analysis
WW 1	23.5	25		Vc 5%	39	31	8	10	51	39		See Particle Size Analysis
River Channel	--	3							2	37	59	See Particle Size Analysis

* N/P = Non-Plastic

PROJECT NUMBER 209-3546

Old Crow Water Supply

SUMMARY OF LABORATORY TESTING RESULTS – PERMAFROST

BOREHOLE NUMBER	DEPTH INTERVAL	MOIST. CONT.	BULK DENS.	GROUND ICE DESCRIPTION	ATTERBERG LIMITS			GRAIN SIZE DISTRIBUTION				SOIL DESCRIPTION
					LL	PL	PI	CLAY	SILT	SAND	GRAV	
	(metres)	(%)	(Mg/m^3)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	
TH 3	0-0.3	45		Nbn								
TH 3	0.3-0.9	51	1.57	Nbn - tr. Vs								
TH 3	0.9-1.4	24		Nbn		N/P		7	63	30		See Particle Size Analysis N/P = Non-Plastic
TH 3	1.4-1.5	49		Nbn - Vx								
TH 3	1.5-2.0	34	1.82	Nbn - Nbe								See Thaw Strain Summary
TH 3	2.0-2.1	47		Vr, Vs 10%								
TH 3	2.1-2.4	63		Vs, Vr, Vc 10%								
TH 3	2.4-3.0	37	1.78	Nbn								
TH 3	3.0-3.4	35		Vs, Vr 10%								
TH 3	3.4-3.7	37		Vs, Vc 10%								
TH 3	3.7-4.3	35	1.76	Vr, Vs 15%								See Thaw Strain Summary
TH 3	4.3-4.4	51		Vs, Vc 5%								
TH 3	4.4-4.7	41		Nbn Vx?		N/P		8	82	10		See Particle Size Analysis N/P = Non-Plastic
TH 3	4.7-4.9	48		Nbn								
TH 3	4.9-5.3	45	1.67	Vs, Vr 15%								
TH 3	5.3-5.6	45		Nbn								
TH 3	5.5-6.1	10		Possibly Unfrozen				2	17	52	29	See Particle Size Analysis
TH 3	6.1-6.7	9		Possibly Unfrozen								
TH 3	9.1-10.7	15		Possibly Unfrozen Vs, Vr 15%								
TH 3	10.7-11.3	13										
TH 3	11.3-11.6	13		Vs, Vr 15%								
TH 3	11.6-11.9	16		Vs, Vr 15%								
TH 3	11.9-12.2	16	2.09	Vs, Vr 15%								

PROJECT NUMBER 209-3546 Old Crow Water Supply

SUMMARY OF THAW STRAIN TESTING RESULTS

BOREHOLE NUMBER	DEPTH INTERVAL	DIAM d	LENGTH ℓ	DENSITY γ	SPECIFIC GRAVITY G_s	MOIST. CONT. w	VOID RATIO e	STRESS σ	DEFLECTION δ	THAW STRAIN	PERMEABILITY DIRECT k	PERMEABILITY INDIRECT k	COEFF. OF COMPRESS. m_v	COEFFICIENT OF CONSOLIDATION c_v	COEFFICIENT OF CONSOLIDATION c_v	SAMPLE DESCR. USC / ICE	PHOTO
		mm	mm	Mg/m^3		%		kPa	mm	%	m/s	m/s	kPa^{-1}	m^2/yr	cm^2/s		
3	5.00– 6.50	88.6	79.9	1.82F	2.68	33.6	.981 .968M .897	37	3.4 3.4C −.4	4.3	2.2E−06					DL NBN	N D
				1.89 1.42D		33.8	.907	4	3.0C	3.8							
3	12.00– 14.00	88.7	68.7	1.76F	2.68	34.7	1.063 1.048M .980	77	2.8 2.8C −.5	4.1	2.4E−06					DL NBN	N D
				1.86 1.35D		37.1	.995	4	2.3C	3.3							

JOB No: 209-3546
2018

F - Assumed Spec. Grav.
C - Cumulative Deflection
D - Dry Density
F - Frozen Bulk Density
M - Void Ratio from initial measurements

EBA Engineering Consultants Ltd. eba

TABLE C - 1

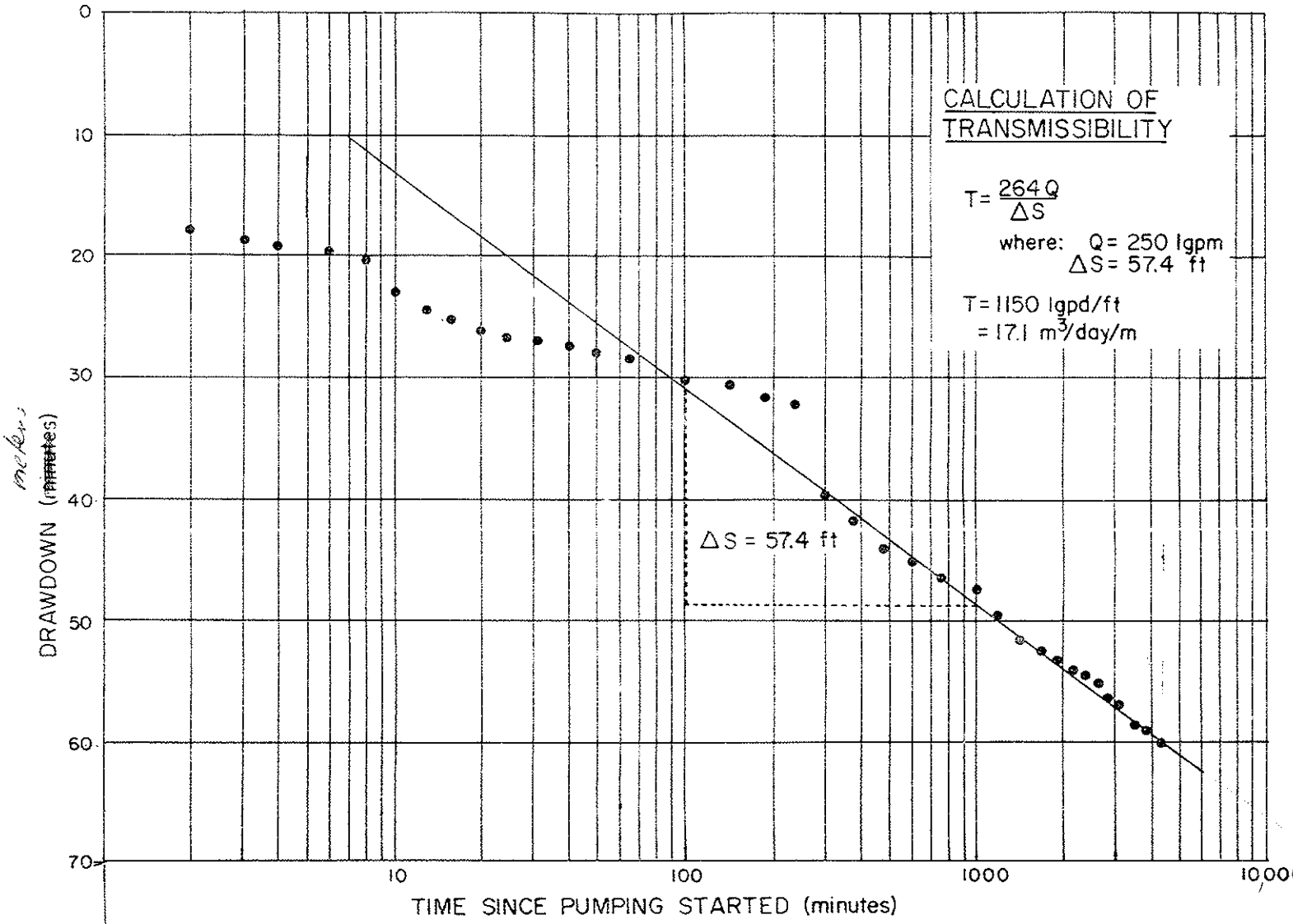
OLD CROW - WELL NO. 1

PUMP TEST DATA

****

TIME SINCE PUMPING STARTED t (minutes)	WATER LEVEL BELOW GROUND (metres)	DRAWDOWN * (metres)
0	7.5 above ground	0
1	7.45 below ground	14.95
2	9.98	17.48
3	10.98	18.48
4	11.60	19.10
6	12.15	19.65
8	12.95	20.45
10	15.64	23.14
13	17.34	24.84
16	18.17	25.67
20	18.84	26.34
25	19.18	26.68
32	19.58	27.08
40	20.09	27.59
50	20.57	28.07
64	21.08	28.58
80	missed reading	-
100	22.38	30.28
120	missed reading	-
150	23.09	30.59
190	24.23	31.73
240	24.60	32.10
300	32.03	39.53
380	34.28	41.78
480	36.23	44.18
600	37.68	45.18
760	38.80	46.30
1000	39.89	47.39
1240	41.92	49.42
1440	43.87	51.37
1680	45.03	52.53
1920	45.87	53.37
2160	46.46	53.96
2400	47.15	54.65
2640	47.82	55.32
2880	49.28	56.78
3150	49.78	57.28
3510	51.20	58.70
3900	51.58	59.08
4320	52.67	60.17

* A calculated Static Water level of 7.5 m was used in all calculations.



OLD CROW - WELL NO. 1
PUMP TEST DATA

(see DATA on TABLE 1)

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.:
REVIEWED BY:	3546-C-1

T A B L E C - 2

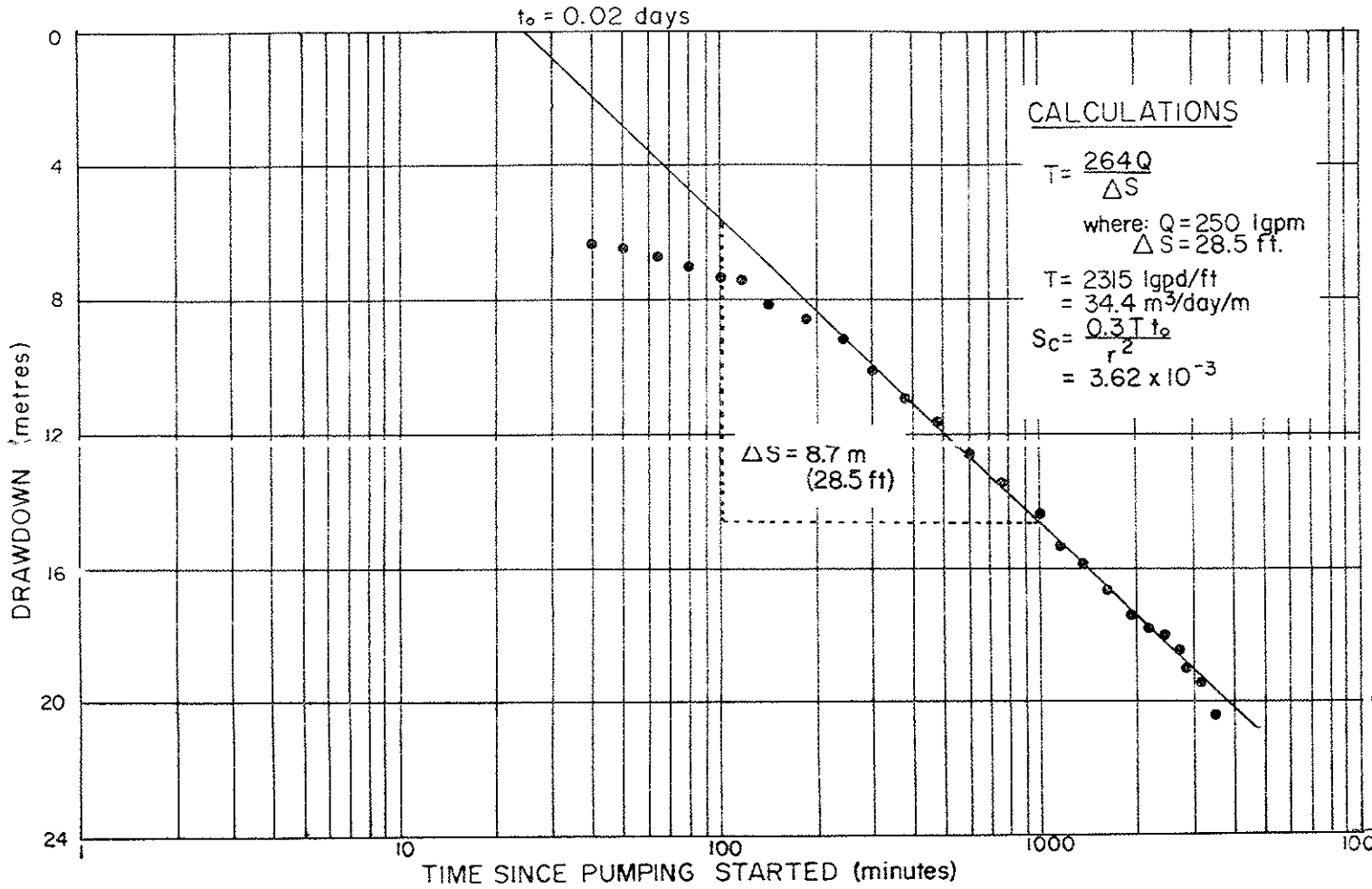
OLD CROW - WELL NO. 2
(Observation Well)

PUMP TEST DATA

****

TIME SINCE PUMPING STARTED t (minutes)	WATER LEVEL BELOW GROUND (metres)	DRAWDOWN * (metres)
32	Well Stopped Flowing	
40	1.21 above ground	6.29
50	1.05 above ground	6.45
64	0.82 above ground	6.68
80	0.51 above ground	6.99
100	0.21 above ground	7.29
120	0.10 above ground	7.40
150	0.60 below ground	8.10
190	0.97	8.47
240	1.55	9.05
300	2.46	9.96
380	3.26	10.76
480	4.12	11.62
600	4.97	12.47
760	5.86	13.36
1000	6.80	14.30
1240	7.74	15.24
1440	8.41	15.91
1680	9.06	16.56
1920	9.68	17.18
2160	10.13	17.63
2400	10.47	17.97
2640	10.93	18.43
2880	11.43	18.93
3150	11.85	19.35
3510	12.93	20.43

* A calculated Static Water level of 7.5 m above ground was used in all calculations.



OLD CROW - WELL NO. 2
(Observation Well)
PUMP TEST DATA

(see DATA on TABLE 2)

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.:
REVIEWED BY:	3546-C-2

TABLE C - 3

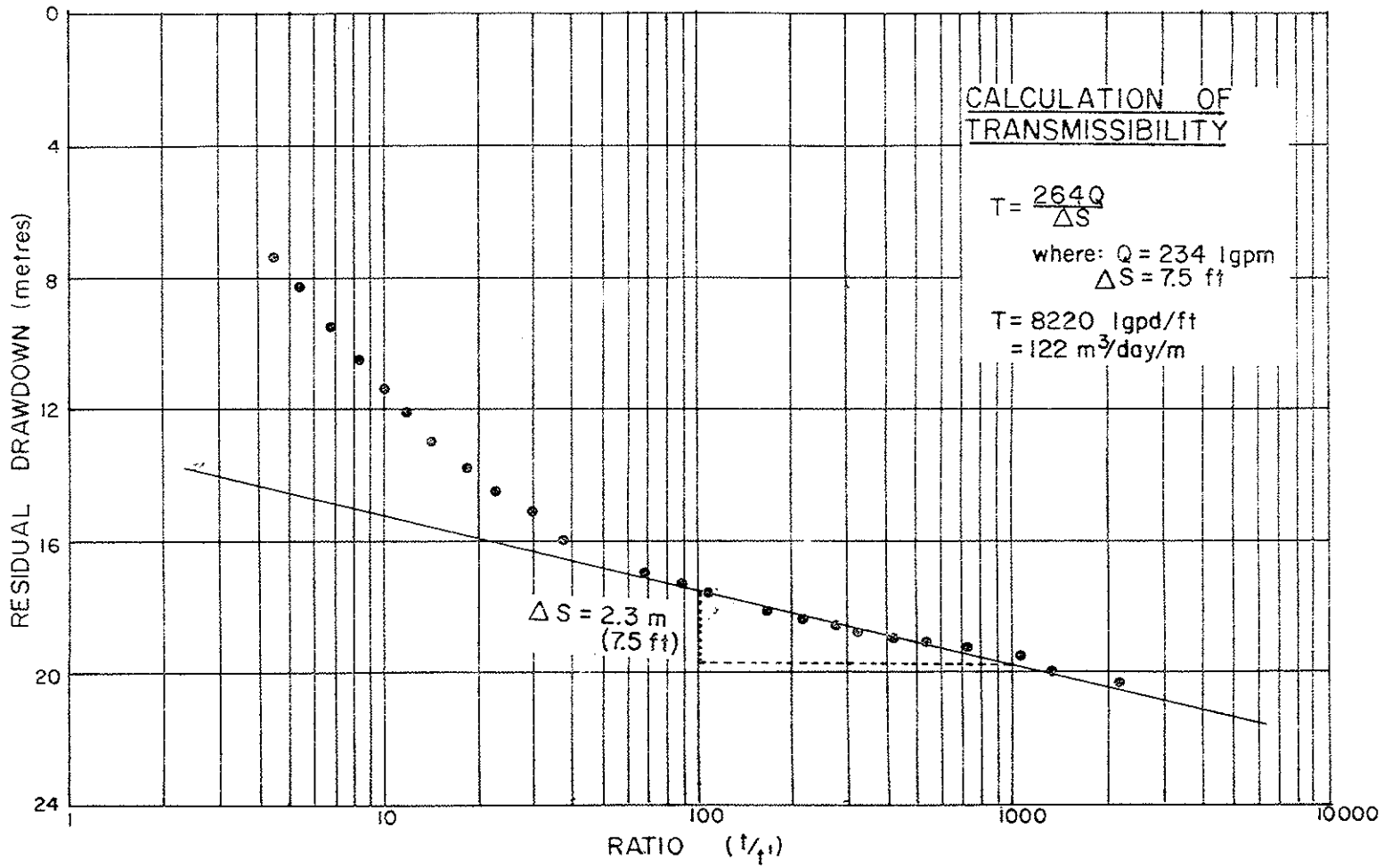
OLD CROW - WELL NO. 1

RECOVERY DATA

****

t	t'	RATIO t/t'	DEPTH TO WATER (metres)	RESIDUAL DRAWDOWN *
4320	0	-	52.67	60.17
4321	1	4321	-	-
4322	2	2161	12.85	20.35
4323	3	1441	12.50	20.0
4324	4	1081	12.18	19.68
4326	6	721	11.71	19.21
4328	8	541	11.52	19.02
4330	10	433	11.38	18.88
4333	13	333	11.26	18.76
4336	16	271	11.03	18.53
4340	20	217	10.84	18.34
4345	25	173.8	10.65	18.15
4352	32	136	10.41	17.91
4360	40	109	10.13	17.63
4370	50	87.4	9.83	17.33
4384	64	68.5	9.45	16.95
4400	80	55	missed reading	-
4420	100	44.2	missed reading	-
4440	120	37.0	8.45	15.95
4470	150	29.8	7.65	15.15
4490	190	23.6	6.90	14.40
4560	240	19	6.23	13.73
4620	300	15.4	5.5	13.00
4700	380	12.4	4.61	12.11
4800	480	10.0	3.73	11.23
4920	600	8.2	2.87	10.37
5080	760	6.7	1.89	9.39
5320	1000	5.3	0.76	8.26
5560	1240	4.5	0.06above ground	7.44
5760	1440	4.0		

* A calculated Static Water level of 7.5 m above ground was used in all calculations.

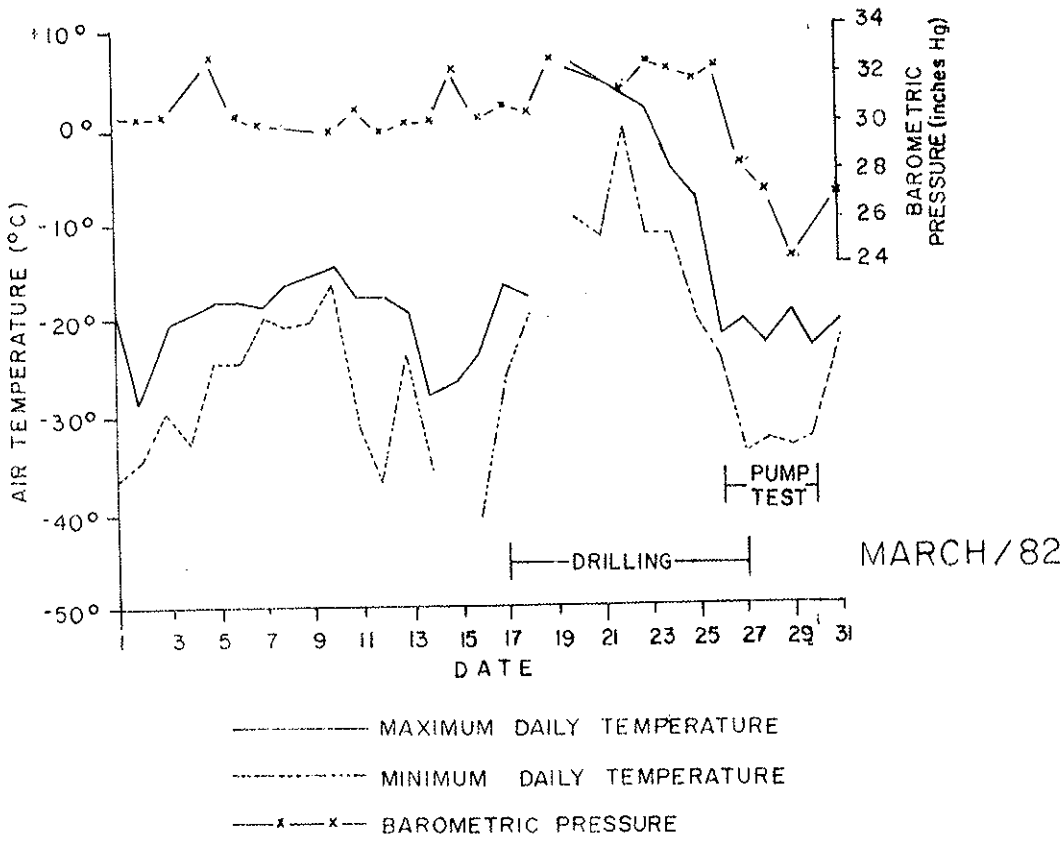


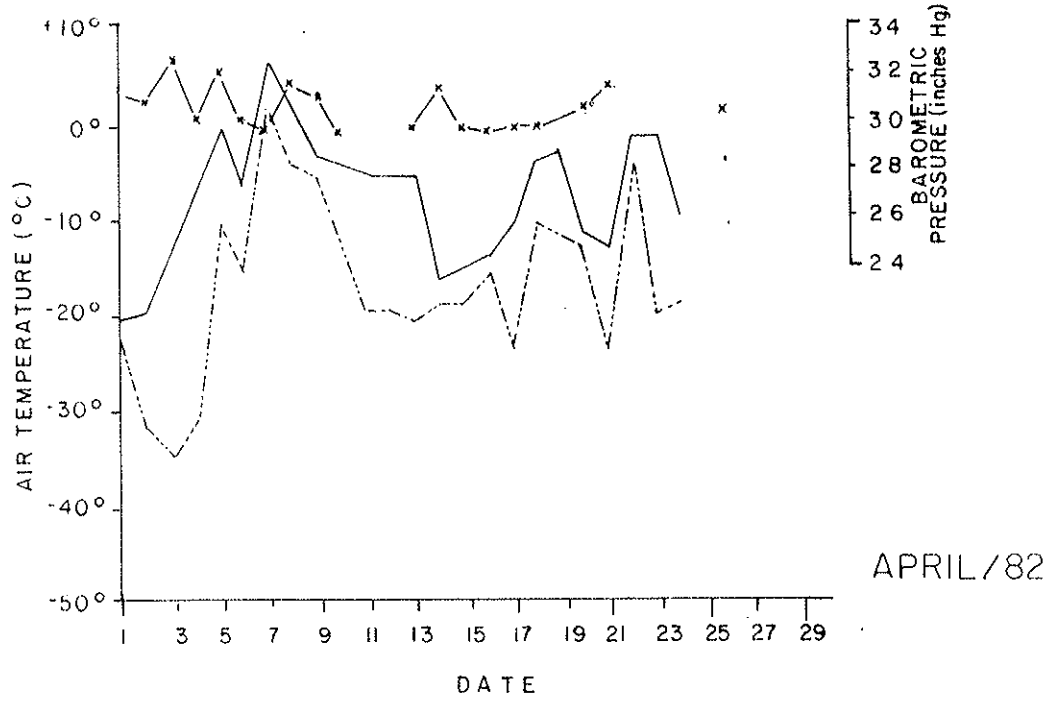
OLD CROW - WELL NO. 1

RECOVERY DATA

(see DATA on TABLE 3)

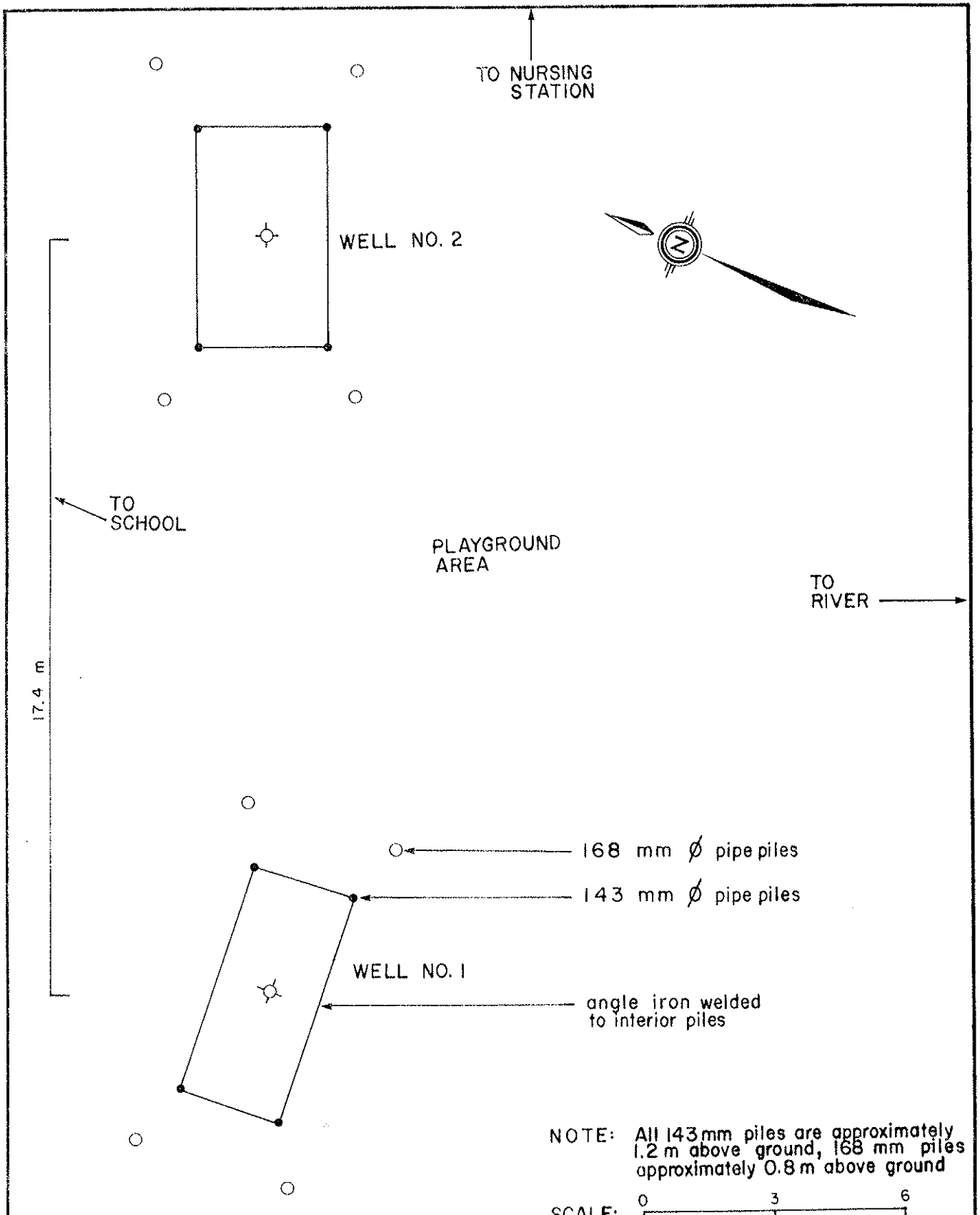
EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.: 3546-C-3
REVIEWED BY:	





SUMMARY OF METEOROLOGICAL DATA
OLD CROW, YUKON
MARCH - APRIL, 1982

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 05 30
DRAWN BY: NLH	DRAWING NO.: 3546-C-4
REVIEWED BY:	



NOTE: All 143 mm piles are approximately 1.2 m above ground, 168 mm piles approximately 0.8 m above ground

SCALE: 0 3 6 metres

DETAILS OF PROTECTIVE PILING FOR WATER WELLS

OLD CROW, Y.T.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 14
DRAWN BY: NLH	DRAWING NO.: 3546-C-5
REVIEWED BY:	

CHEMEX

CALGARY SUITE 100 - 2021 - 41 AVENUE N.E.
CALGARY, ALBERTA, CANADA T2E 6P2
TELEPHONE (403) 276-9627 TELEX 038-25541

EDMONTON 8764 - 50th AVENUE
EDMONTON, ALBERTA, CANADA T6E 5K8
TELEPHONE (403) 465-9877

GRANDE PRAIRIE 11037 - 92 AVENUE
GRANDE PRAIRIE, ALBERTA, CANADA T8V 3J3
TELEPHONE (403) 532-0227

CERTIFICATE OF ANALYSIS

• MINERAL • GAS • WATER • OIL • SOILS • VEGETATION • ENVIRONMENTAL ANALYSIS

EBA ENGINEERING CONSULTANTS LTD.
3167 - 3 AVENUE
WHITEHORSE, YUKON

DATE APRIL 22, 1982

PROJECT NO. 0999-4-8698

WATER ANALYSES

GOVT OF YUKON HIGHWAY & PUBLIC WORKS
OLD CROW

-1 SAMPLED: 82-03-18-10:30
-2 SAMPLED: 82-03-22-20:00

PARAMETER	WW-1	WW-2
pH (UNITS)	7.7	7.7
CONDUCTIVITY (UMHOS/CM)	517	488
CARBONATE (PPM)	<1	<1
BICARBONATE (PPM)	176	176
CHLORIDE (PPM)	78	54
SULPHATE (PPM)	22	24
SODIUM (PPM)	18	16
POTASSIUM (PPM)	5	4
CALCIUM (PPM)	34	33
MAGNESIUM (PPM)	22	23
IRON (PPM)	1	1
NITRATE-NITRITE (PPM AS N)	0.12	<0.01
TOTAL HARDNESS (PPM Ca CO_3)	176	177
FLUORIDE (PPM)	0.36	0.33
ALKALINITY (PPM Ca CO_3)	151.0	143.43
ANTIMONY (PPM)	*	<0.0002
ARSENIC (PPM)	0.044	0.006
BARIUM (PPM)	0.3	<0.1
BORON (PPM)	*	0.07
CADMIUM (PPM)	0.001	<0.001
COPPER (PPM)	0.005	0.001
LEAD (PPM)	0.058	0.009
MANGANESE (PPM)	0.20	0.14
MERCURY (PPM)	0.0019	0.00010
SELENIUM (PPM)	*	<0.0002
SILVER (PPM)	*	<0.001
ZINC (PPM)	0.015	0.11
TURBIDITY (JTU)	*	12.0
COLOUR	*	5
TOTAL COLIFORM (COUNTS/100 mls)	0	0
FECAL COLIFORM (COUNTS/100 mls)	0	0
TOTAL DISSOLVED SOLIDS (mg/l)	356	338
NON FILTERABLE FIXED RESIDUE (mg/l)	1480	16.8

* INSUFFICIENT SAMPLE

CTA MEMBER CANADIAN TESTING ASSOCIATION

Certified by

COPY TO EBA

CHEMEX

CALGARY — SUITE 100 - 2021 - 41 AVENUE N.E.
CALGARY, ALBERTA, CANADA T2E 6P2
TELEPHONE (403) 276-9627 TELEX 038-25541

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GRANDE PRAIRIE — 11037 - 92 AVENUE
GRANDE PRAIRIE, ALBERTA, CANADA T8V 3J3
TELEPHONE (403) 532-0227

CERTIFICATE OF ANALYSIS

• MINERAL • GAS • WATER • OIL • SOILS • VEGETATION • ENVIRONMENTAL ANALYSIS

GOVERNMENT OF YUKON
HIGHWAY & PUBLIC WORKS
BOX 2703
WHITEHORSE, YUKON
Y1A 2C6

DATE MAY 5, 1982

PROJECT NO. 0999-4-8792

WELL #1, OLD CROW, YUKON — SAMPLED APRIL 15, 1982

PARAMETER	
ALKALINITY (ppm as $CaCO_3$)	147
ANTIMONY (ppm)	<0.0002
ARSENIC (ppm)	0.0090
BARIUM (ppm)	<0.1
BORON (ppm)	<0.05
CADMIUM (ppm)	<0.001
CALCIUM (ppm)	44.4
CARBONATE (ppm)	<1
[illegible] (p,m)	179
CHLORIDE (ppm)	55.2
CHROME (ppm)	<0.001
FLUORIDE (ppm)	0.19
TOTAL HARDNESS (as $CaCO_3$)	209
IRON (ppm)	<0.01
LEAD (ppm)	<0.002
MAGNESIUM (ppm)	23.7
MANGANESE (ppm)	0.18
MERCURY (ppm)	0.00018
NITRATE (ppm as N)	0.005
NITRITE (ppm as N)	<0.003
POTASSIUM (ppm)	2.95
pH (pH units)	7.85
SELENIUM (ppm)	<0.0002
SILVER (ppm)	<0.001
SODIUM (ppm)	14.3
SULPHATE (ppm)	25.0
SULPHIDE (ppm)	<0.01
ZINC (ppm)	0.002
CONDUCTIVITY (umhos/cm)	475
TURBIDITY (JTU)	0.47
COLOUR (Pt-Co units)	<5
TOTAL DISSOLVED SOLIDS (mg/l)	280
% VOLATILE SOLIDS (mg/l)	1.2
FECAL COLIFORM (counts/100 mls)	0
TOTAL COLIFORM (counts/100 mls)	0
TOTAL SUSPENDED SOLIDS (mg/l)	1.6

EBA Engineering Consultants Ltd.
WHITEHORSE
MAY 11 1982
RECEIVED

CTA MEMBER CANADIAN TESTING ASSOCIATION

Certified by .....

EBA Engineering Consultants ltd.

EARTH-SCIENCES ENGINEERING

E. W. Brooker, President
D. W. Hayley, Vice President
L. A. Balanko
C. B. Dawley
C. T. Hwang
A. B. MacDonald
D. H. Seibt

1982 06 21

EBA Engineering Consultants Ltd.
3167 - 3rd Avenue
WHITEHORSE, Yukon Territory
Y1A 1G4

Attention: Mr. J.R. Trimble, P. Eng.

Dear Richard:

RE: Old Crow Water Supply
Thermal Analysis
EBA Project No: 209-3546

This letter serves as a brief summary of analytical work undertaken to predict the radius of thaw around the proposed Old Crow water supply line.

It is understood that the proposed 6" diameter well will be approximately 200 feet deep, and that water temperature will be approximately 1°C (33.8°F). Ground temperature is approximately -3.5°C (25.7°F). A uniform soil profile consisting of sandy silt with 10% clay was assumed. The given soil properties were dry density of 1.3 Mg/m^3 and moisture content of 40%. Thermal properties were calculated on the basis of the given information, and an assumed specific gravity of 2.70, and are summarized on the following page:

Frozen thermal conductivity	3.09 W/m/°C
Unfrozen thermal conductivity	1.63 W/m/°C
Specific heat (frozen)	1.2 kJ/kg/°C
Specific heat (unfrozen)	1.7 kJ/kg/°C
Latent heat	174 MJ/m^3

Unfrozen moisture content was assumed to be approximately 4% at -3.5°C.

Both finite element and quasi-static solutions were used to predict the radius of thaw. The solutions are valid at sufficient depth that meteorological conditions will not affect ground temperature. Constant temperature boundary conditions were imposed at the pipe surface (+1°C), and at a distance of 30 feet away from the pipe (-3.5°C).

The following table summarizes long term predictions for the maximum radius of thaw (from pipe surface):

METHOD OF PREDICTION	PIPE TEMPERATURE (°C)	GROUND TEMPERATURE (°C)	TIME TO MAXIMUM THAW (Days)	RADIUS OF THAW (inches)
Finite Element	1.0	-3.5	826	2.8
Quasi-Static	1.0	-3.5	31	3.7
Quasi-Static	2.0	-3.5	236	10.4

For your information, a plot of temperature history for a point 1 foot away from centreline of the pipe is enclosed. Steady state temperature is 30.8°F. The geothermal model was also used to simulate the condition of a stoppage in the flow of water through the pipe. In this case, nodal temperatures after one year of operation were assigned, and the constant temperature boundary condition at the pipe surface was removed. Freeze-back to the soil/pipe interface took place almost immediately; a duration of less than 1.5 days. This points out the need for a heat-trace on the well, in the event of a breakdown of pumping equipment.

We trust that the foregoing meets your requirements, Richard, but if you have any questions please don't hesitate to call.

Yours truly,

EBA Engineering Consultants Ltd.

J.A. Boyes, P. Eng.

A.V.G Krishnayya, P. Eng.

JAB/wml

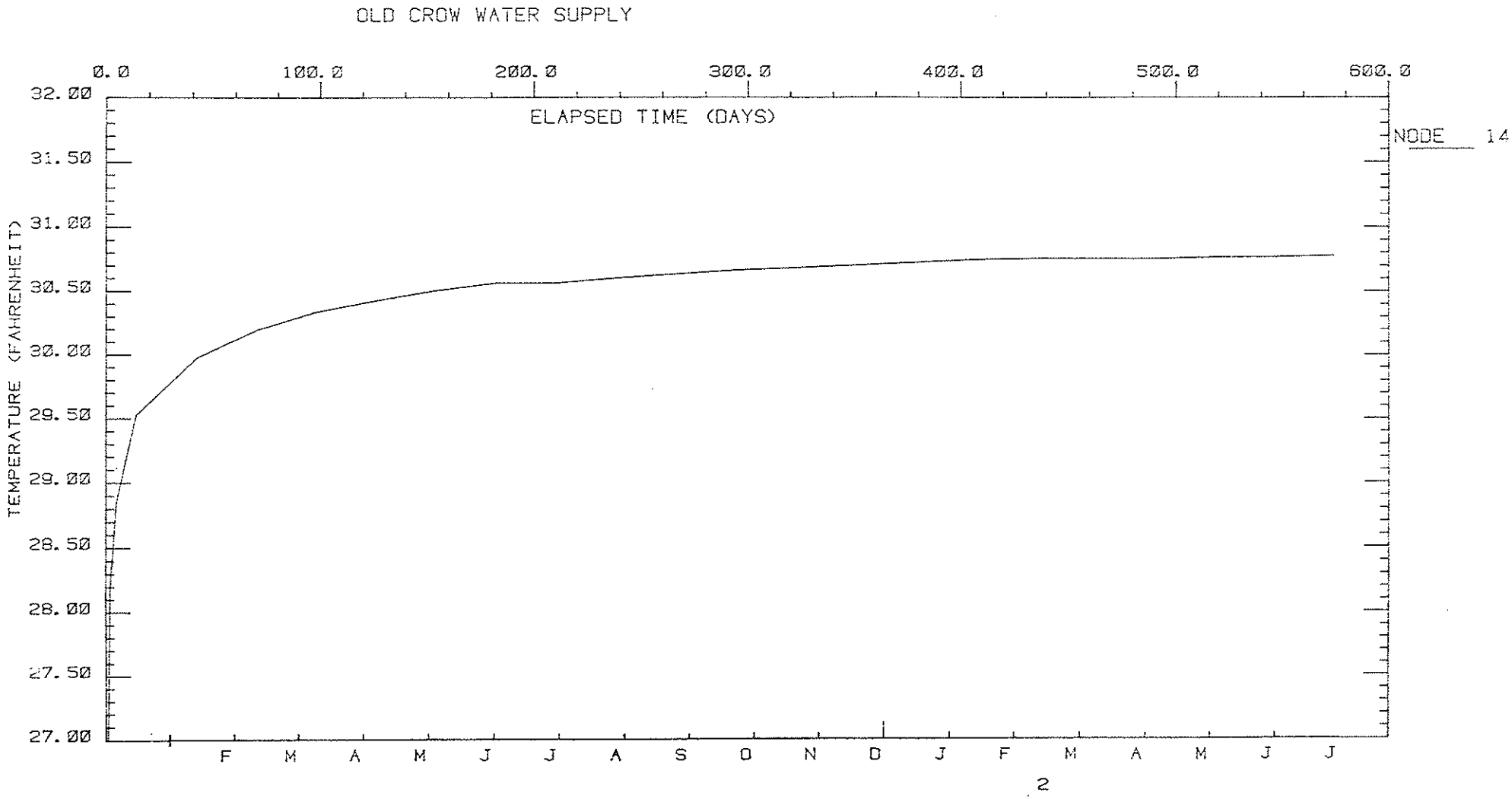
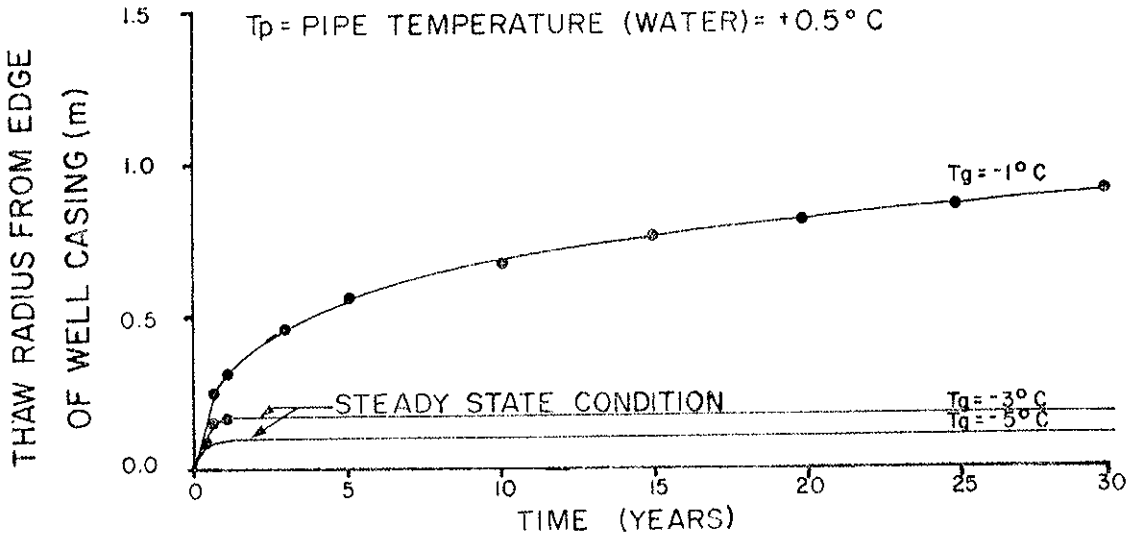
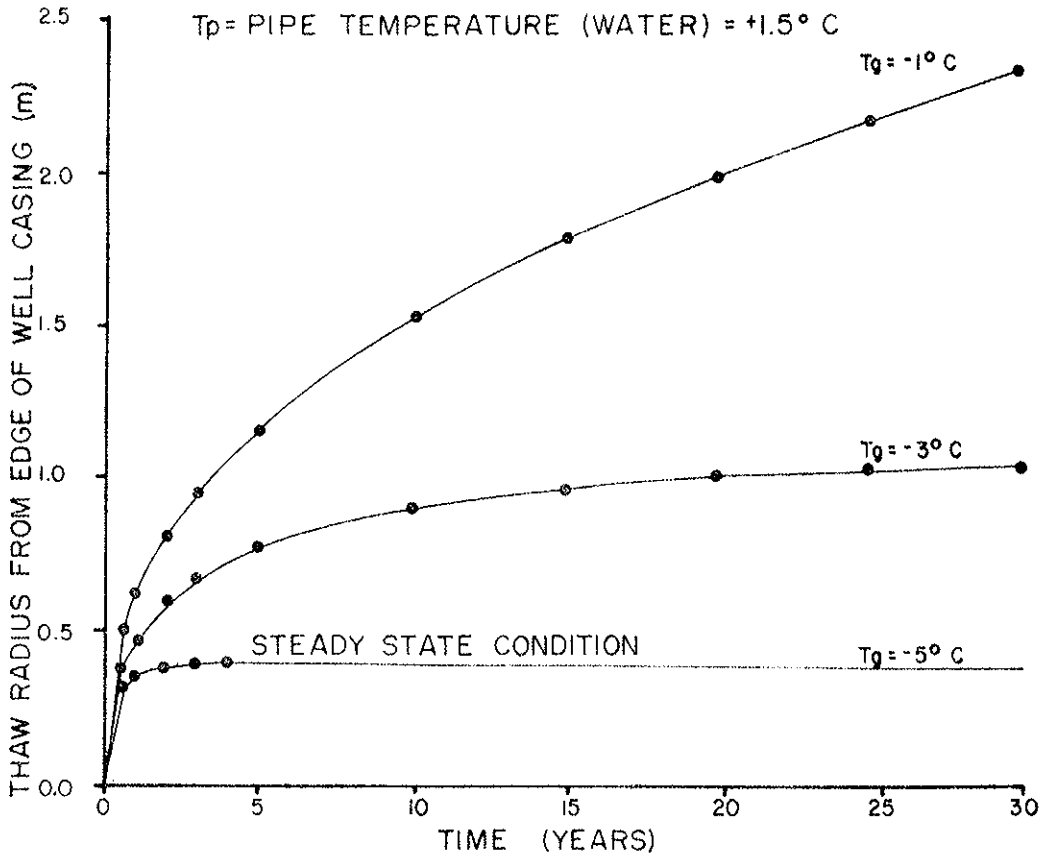


FIG TEMPERATURE HISTORIES FOR GIVEN NODES



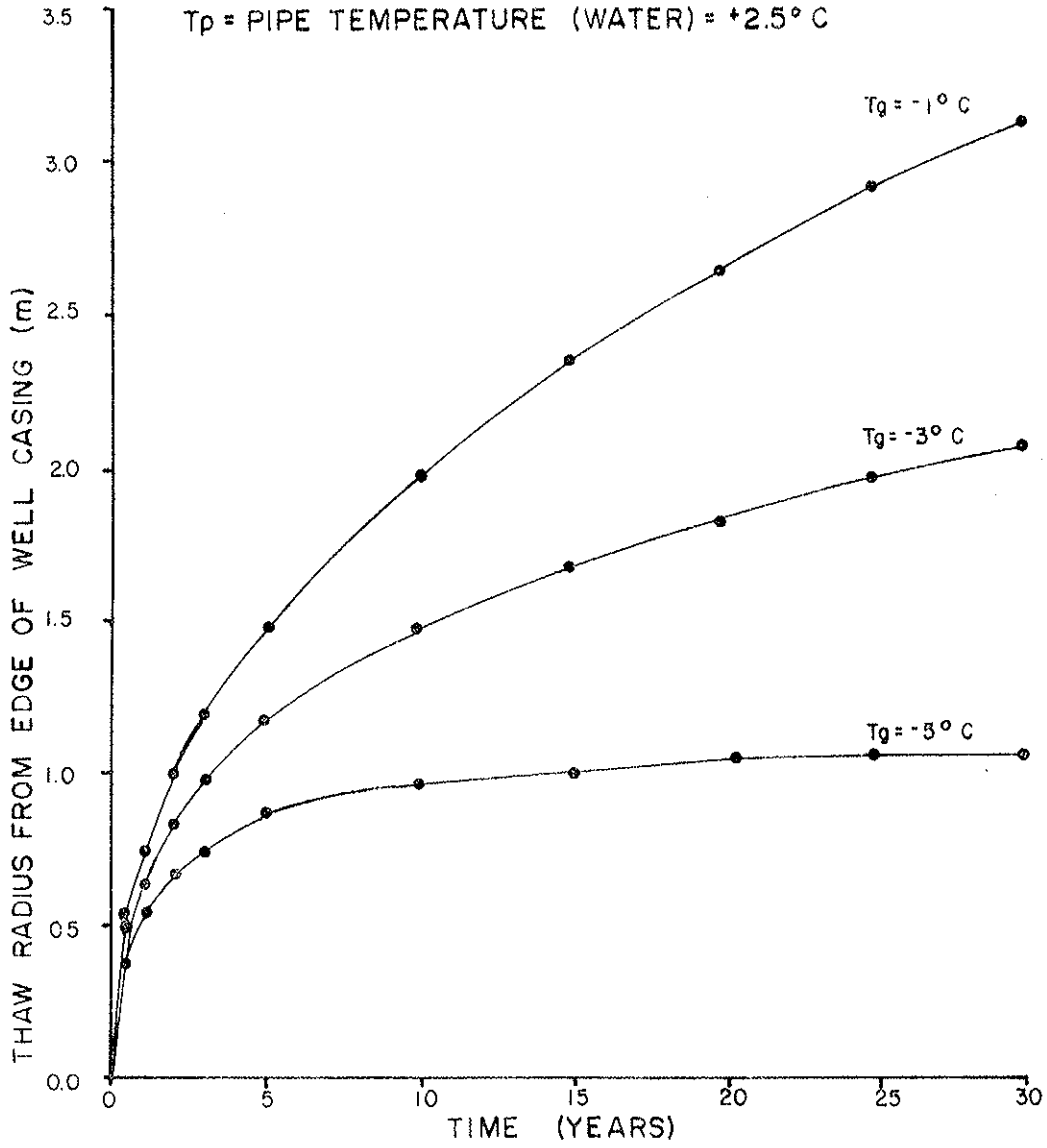
RESULTS OF
QUASI-STATIC THERMAL ANALYSIS
OLD CROW WATER SUPPLY
OLD CROW, Y.T.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.: 3546-E-1
REVIEWED BY:	



RESULTS OF
QUASI-STATIC THERMAL ANALYSIS
OLD CROW WATER SUPPLY
OLD CROW, Y.T.

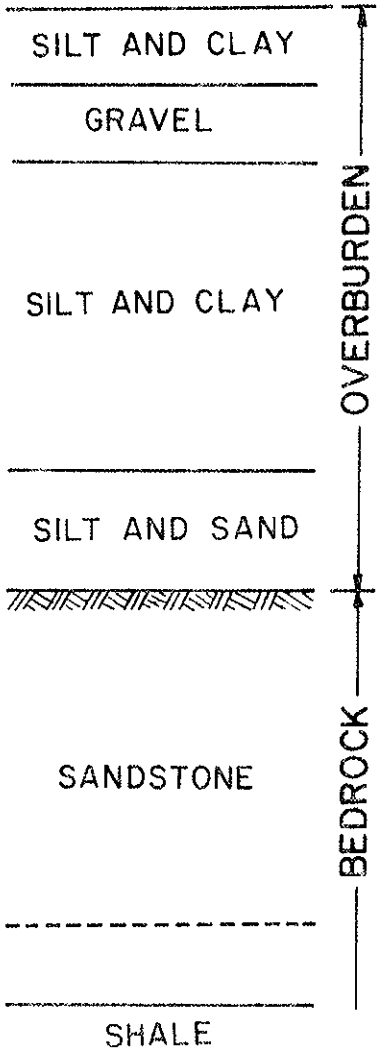
EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.: 3546-E-2
REVIEWED BY:	



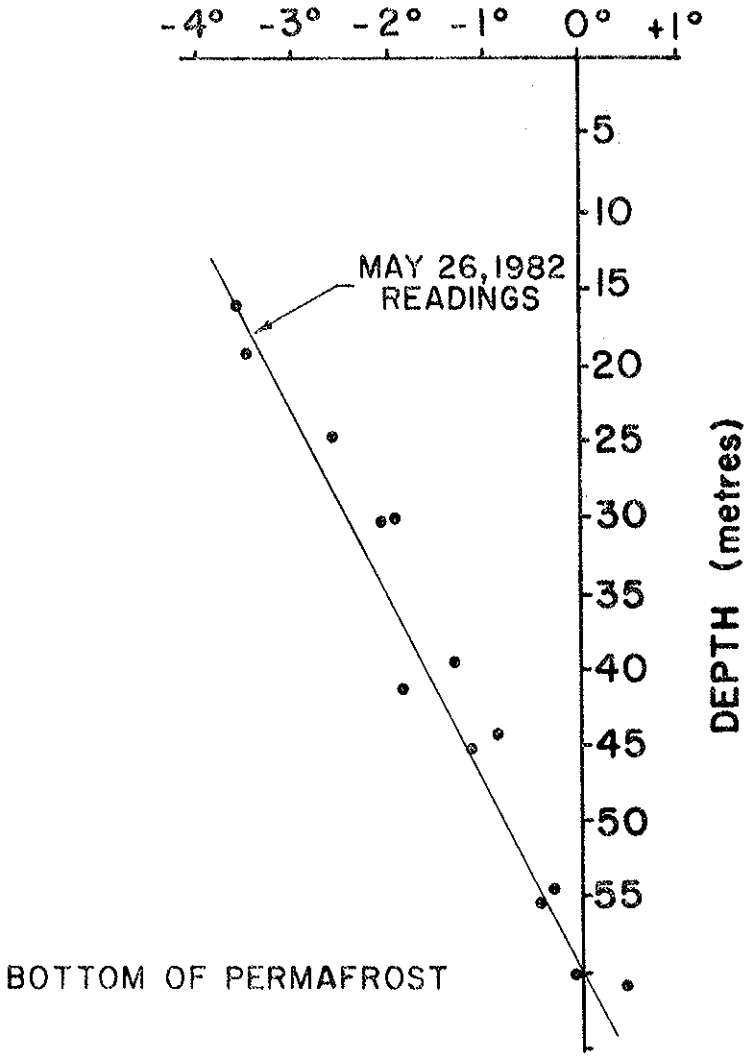
RESULTS OF
QUASI-STATIC THERMAL ANALYSIS
OLD CROW WATER SUPPLY
OLD CROW, Y. T.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 1982 07 16
DRAWN BY: NLH	DRAWING NO.: 3546-E-3
REVIEWED BY:	

LITHOLOGY (WWI)



GROUND TEMPERATURE (°C)



GROUND TEMPERATURE DATA

OLD CROW, Y.T.

EBA Engineering Consultants Ltd.	
JOB NO.: 209-3546	DATE: 82-07-26
DRAWN BY: TRM	DRAWING NO.:
REVIEWED BY:	3546-E-4

Appendix D

Past Bacteriological Water Analysis Results, 1999-2010

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Water Delivery Truck	19-Aug-99	0	0
Community Supply	19-Aug-99	0	0
Nursing Station	30-Aug-99	0	0
Nursing Station	25-May-00	0	0
Community Supply	25-May-00	0	0
Water Delivery Truck	25-May-00	0	0
Community Well	18-Sep-00	0	0
Water Delivery Truck	18-Sep-00	0	0
Nursing Station, Coffee Room	18-Sep-00	0	0
Nursing Station, Visitor Suite	18-Sep-00	0	0
Water Delivery Truck	30-Oct-00	0	0
Community Well	30-Oct-00	0	0
Community Well	28-Nov-00	0	0
Water Delivery Truck	28-Nov-00	0	0
Water Delivery Truck	10-Dec-00	0	0
Community Well	10-Dec-00	0	0
Water Delivery Truck	13-Jan-01	0	0
Community Well	13-Jan-01	0	0
Community Well	08-Mar-01	0	0
Water Delivery Truck	08-Mar-01	0	0
Water Delivery Truck	23-Apr-01	0	0
Community Well	23-Apr-01	0	0
Water Delivery Truck	23-May-01	0	0
Raw water	23-May-01	0	0
Community Well	23-May-01	0	0
Water Delivery Truck	19-Jun-01	0	0
Community Well	19-Jun-01	0	0
Raw water	19-Jun-01	0	0
Water Delivery Truck	16-Jul-01	0	0
Community Well	13-Aug-01	0	0
Water Delivery Truck	13-Aug-01	0	0
Water Delivery Truck	18-Sep-01	0	0
Community Well	18-Sep-01	0	0
Community Well	18-Sep-01	0	0
Water Delivery Truck	19-Nov-01	0	0
Community Well	19-Nov-01	0	0
Community Well	19-Nov-01	0	0
Community Well	17-Dec-01	0	0
Community Well	17-Dec-01	0	0
Water Delivery Truck	17-Dec-01	0	0
Water Delivery Truck	21-Jan-02	0	0
Community Well	21-Jan-02	0	0
Water Delivery Truck	25-Feb-02	0	0
Community Well	25-Feb-02	0	0
Raw water (unchlorinated well water)	26-Feb-02	0	0

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Water Delivery Truck	18-Mar-02	0	0
Community Well	18-Mar-02	0	0
Community Well (Raw water)	15-Apr-02	0	0
Water Delivery Truck	15-Apr-02	0	0
Community Well	15-Apr-02	0	0
Community Well (Raw water)	17-Jul-02	0	0
Water Delivery Truck	17-Jul-02	0	0
Community Well	17-Jul-02	0	0
Water Delivery Truck	21-Aug-02	0	0
Community Well	21-Aug-02	0	0
Water Delivery Truck	02-Oct-02	0	0
Community Well (Raw water)	02-Oct-02	0	0
Community Well	18-Nov-02	0	0
Water Delivery Truck	18-Nov-02	0	0
Community Well	18-Dec-02	absent	absent
Water Delivery Truck	18-Dec-02	absent	absent
Water Delivery Truck	15-Jan-03	absent	absent
Community Well	15-Jan-03	absent	absent
Water Delivery Truck	03-Mar-03	absent	absent
Community Well	03-Mar-03	absent	absent
Community Well	24-Apr-03	absent	absent
Water Delivery Truck	24-Apr-03	absent	absent
Community Well	26-May-03	absent	absent
Water Delivery Truck	26-May-03	absent	absent
Community Well Inside Tap	26-Jun-03	absent	absent
Water Delivery Truck Hose	26-Jun-03	absent	absent
Community Well Inside Tap	06-Aug-03	present	absent
Water Delivery Truck Hose	06-Aug-03	present	absent
Community Well Inside Tap	12-Aug-03	present	absent
Overhead Pipe	12-Aug-03	absent	absent
Water Delivery Truck Hose	12-Aug-03	present	absent
Water Delivery Truck Hose	13-Aug-03	present	absent
Community Well Inside Tap	13-Aug-03	absent	absent
Water Delivery Truck Hose	19-Aug-03	absent	absent
Community Well Inside Tap	19-Aug-03	absent	absent
Overhead Pipe	19-Aug-03	absent	absent
Water Delivery Truck	11-Sep-03	absent	absent
Pump House Raw	11-Sep-03	absent	absent
Nursing Station Kithcen Tap	11-Sep-03	absent	absent
Nursing Station Kithcen Tap	29-Oct-03	absent	absent
Pump House Raw	29-Oct-03	absent	absent
Water Delivery Truck	29-Oct-03	absent	absent
Water Delivery Truck	12-Nov-03	absent	absent
Pump House Raw	12-Nov-03	absent	absent
Nursing Station Kithcen Tap	12-Nov-03	absent	absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Water Delivery Truck	10-Dec-03	absent	absent
Pump House Raw	10-Dec-03	absent	absent
Nursing Station Kithcen Tap	10-Dec-03	absent	absent
Pump House Raw	21-Jan-04	absent	absent
Water Delivery Truck	21-Jan-04	absent	absent
Pump House Raw	18-Feb-04	absent	absent
Overhead Hose	18-Feb-04	absent	absent
Water Delivery Truck	18-Feb-04	absent	absent
Overhead Hose	10-Mar-04	absent	absent
Pump House Raw	10-Mar-04	absent	absent
Water Delivery Truck	10-Mar-04	absent	absent
Water Delivery Truck	28-Apr-04	absent	absent
Transient Suite Kitchen Tap	28-Apr-04	absent	absent
Pump House Raw	28-Apr-04	absent	absent
Pump House Raw	20-May-04	absent	absent
Overhead Hose	20-May-04	absent	absent
Water Delivery Truck	20-May-04	absent	absent
Well Tap	16-Jun-04	absent	absent
Overhead Hose	16-Jun-04	absent	absent
Water Delivery Truck	28-Jul-04	absent	absent
Overhead Hose	28-Jul-04	absent	absent
Well Tap	28-Jul-04	absent	absent
Overhead Hose	25-Aug-04	absent	absent
Water Delivery Truck	25-Aug-04	absent	absent
Well Tap	25-Aug-04	absent	absent
Well Tap	15-Sep-04	absent	absent
Water Delivery Truck Fill Hose	15-Sep-04	present	absent
Overhead Hose	20-Sep-04	present	absent
Water Delivery Truck Fill Hose	20-Sep-04	absent	absent
Well Tap	20-Sep-04	absent	absent
Overhead Hose	23-Sep-04	absent	absent
Water Delivery Truck Fill Hose	13-Oct-04	absent	absent
Well Tap	13-Oct-04	present	absent
Overhead Hose	13-Oct-04	present	absent
Well Tap	20-Oct-04	absent	absent
Water Delivery Truck Fill Hose	17-Nov-04	absent	absent
Well Tap	17-Nov-04	absent	absent
Overhead Hose	17-Nov-04	absent	absent
Well Tap	15-Dec-04	absent	absent
Overhead Hose	15-Dec-04	absent	absent
Water Delivery Truck Fill Hose	15-Dec-04	absent	absent
Water Delivery Truck Fill Hose	27-Jan-05	absent	absent
Well Tap	27-Jan-05	absent	absent
Overhead Hose	27-Jan-05	absent	absent
Overhead Hose	09-Feb-05	absent	absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Well Tap (raw)	09-Feb-05	present	absent
Water Delivery Truck Fill Hose	09-Feb-05	absent	absent
Water Delivery Truck Fill Hose	09-Mar-05	absent	absent
Well Tap (raw)	09-Mar-05	absent	absent
Overhead Hose	09-Mar-05	absent	absent
Overhead Hose	14-Apr-05	absent	absent
Water Delivery Truck Fill Hose	14-Apr-05	absent	absent
Well Tap (raw)	14-Apr-05	absent	absent
Water Delivery Truck Fill Hose	11-May-05	absent	absent
Well Tap (raw)	11-May-05	absent	absent
Overhead Hose	11-May-05	absent	absent
Water Delivery Truck Fill Hose	08-Jun-05	absent	absent
Overhead Hose	08-Jun-05	absent	absent
Well Tap (raw)	08-Jun-05	absent	absent
Water Delivery Truck Fill Hose	30-Aug-05	absent	present
Overhead Hose	30-Aug-05	absent	absent
Well Tap (raw)	30-Aug-05	absent	absent
Well Tap (raw)	01-Sep-05	absent	absent
Water Delivery Truck Fill Hose	01-Sep-05	present	present
Well Tap (raw)	04-Sep-05	absent	absent
Water Delivery Truck Fill Hose	04-Sep-05	absent	absent
Water Delivery Truck Fill Hose	05-Sep-05	absent	absent
Well Tap (raw)	05-Sep-05	absent	absent
well tap	25-Jan-06	absent	absent
Water Delivery Truck Fill Hose	25-Jan-06	absent	absent
Overhead Hose	25-Jan-06	absent	absent
Water Delivery Truck Fill Hose	25-Jan-06	absent	absent
Well Tap (raw)	06-Feb-06	absent	absent
Water Delivery Truck Fill Hose	08-Feb-06	absent	absent
Overhead Hose	08-Feb-06	absent	absent
truck hose	08-Mar-06	absent	absent
well tap	08-Mar-06	absent	absent
Well Tap (raw)	08-Mar-06	absent	absent
Overhead Hose	08-Mar-06	absent	absent
overhead hose	08-Mar-06	absent	absent
Overhead Hose	12-Apr-06	resample	resample
Water Delivery Truck Fill Hose	12-Apr-06	resample	resample
Well Tap (raw)	12-Apr-06	resample	resample
Overhead Hose	19-Apr-06	absent	absent
Water Delivery Truck Fill Hose	19-Apr-06	absent	absent
Well Tap (raw)	19-Apr-06	absent	absent
well tap	19-Apr-06	absent	absent
truck hose	19-Apr-06	absent	absent
overhead hose	19-Apr-06	absent	absent
Water Delivery Truck Fill Hose	10-May-06	absent	absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Well Tap (raw)	10-May-06	absent	absent
Overhead Hose	10-May-06	absent	absent
truck hose	07-Jun-06	absent	absent
well tap	07-Jun-06	absent	absent
overhead hose	07-Jun-06	absent	absent
truck hose	12-Jul-06	absent	absent
overhead hose	12-Jul-06	absent	absent
well tap	12-Jul-06	absent	absent
Well Tap	12-Jul-06	absent	absent
Overhead Hose	12-Jul-06	absent	absent
Truck Hose	12-Jul-06	absent	absent
overhead hose	06-Sep-06	absent	absent
well tap	06-Sep-06	absent	absent
truck hose	06-Sep-06	present	absent
truck hose	18-Sep-06	absent	absent
well tap	18-Sep-06	present	absent
overhead hose	18-Sep-06	absent	absent
Truck hose	11-Oct-06	present	absent
overhead hose	11-Oct-06	absent	absent
well tap	11-Oct-06	absent	absent
overhead hose	18-Oct-06	absent	absent
truck hose	18-Oct-06	absent	absent
well tap	18-Oct-06	absent	absent
Overhead hose	08-Nov-06	absent	absent
truck hose	08-Nov-06	absent	absent
well tap	08-Nov-06	absent	absent
Truck hose	13-Dec-06	absent	absent
well tap	13-Dec-06	absent	absent
overhead hose	13-Dec-06	absent	absent
overhead hose	10-Jan-07	absent	absent
truck hose	10-Jan-07	absent	absent
well tap	10-Jan-07	absent	absent
Overhead hose	07-Mar-07	absent	absent
truck hose	07-Mar-07	absent	absent
Well tap	07-Mar-07	absent	absent
truck hose	09-May-07	absent	absent
overhead hose	09-May-07	absent	absent
truck hose	09-May-07	absent	absent
well tap	09-May-07	absent	absent
overhead hose	09-May-07	absent	absent
well tap	09-May-07	absent	absent
Well Head tap	09-Oct-07	absent	absent
well to truck	21-Nov-07	absent	absent
truck hose	21-Nov-07	absent	absent
inside well drain	21-Nov-07	absent	absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
well tap	13-Dec-07	absent	absent
truck hose	13-Dec-07	absent	absent
pump	13-Dec-07	absent	absent
well tap	16-Jan-08	absent	absent
truck hose	16-Jan-08	absent	absent
pump	16-Jan-08	absent	absent
well tap	31-Mar-08	absent	absent
top of truck	31-Mar-08	absent	absent
truck nozzle	31-Mar-08	absent	absent
top of truck	05-May-08	absent	absent
truck nozzle	05-May-08	absent	absent
well tap	05-May-08	absent	absent
top of truck	09-Jun-08	absent	absent
truck nozzle	09-Jun-08	absent	absent
well tap	09-Jun-08	absent	absent
well tap	30-Jul-08	rejected-expired	rejected- expired
truck nozzle	30-Jul-08	rejected-expired	rejected-expired
truck fill hatch	30-Jul-08	rejected-expired	rejected-expired
Nozzle on back of truck	04-Aug-08	absent	absent
Truck fill point	04-Aug-08	absent	absent
Tap inside of well	04-Aug-08	absent	absent
Nozzle on back of truck	18-Sep-08	absent	absent
Truck fill point	18-Sep-08	absent	absent
Tap inside of well	18-Sep-08	absent	absent
well tap	09-Oct-08	absent	absent
Nozzle on back of truck	27-Oct-08	absent	absent
truck hose	27-Oct-08	absent	absent
Tap inside of well	27-Oct-08	absent	absent
well tap	27-Oct-08	absent	absent
Truck fill point	27-Oct-08	absent	absent
overhead hose	27-Oct-08	absent	absent
tap inside well	14-Jan-09	absent	absent
nozzle back of truck	14-Jan-09	absent	absent
Overhead Nozzle	14-Jan-09	absent	absent
Well tap	14-Jan-09	absent	absent
truck fill point	14-Jan-09	absent	absent
truck nozzle	14-Jan-09	absent	absent
raw	04-Feb-09	absent	absent
truck nozzle	04-Feb-09	absent	absent
overhead	04-Feb-09	absent	absent
truck fill point	18-Feb-09	absent	absent
tap inside well	18-Feb-09	absent	absent
nozzle back of truck	18-Feb-09	absent	absent
raw	11-Mar-09	absent	absent
truck fill point	11-Mar-09	absent	absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
nozzle on back of truck	11-Mar-09	absent	absent
raw water	25-Mar-09	absent	absent
nozzle on back of truck	25-Mar-09	absent	absent
truck fill point	25-Mar-09	absent	absent
Nozzle on Back of Truck	27-Apr-09	absent	absent
Tap inside of well	27-Apr-09	absent	absent
Truck fill point	27-Apr-09	absent	absent
HWS Public Works	20-May-09	Absent	Absent
HWS Public Works	20-May-09	Absent	Absent
HWS Public Works	20-May-09	Absent	Absent
Nozzle on back of Truck	03-Jun-09	Absent	Absent
Raw Water	03-Jun-09	Absent	Absent
Truck Fill Point	03-Jun-09	Absent	Absent
Truck fill point	17-Jun-09	Absent	Absent
Nozzle on back of truck	17-Jun-09	Absent	Absent
Raw Water	17-Jun-09	Absent	Absent
Nozzle on back of truck	08-Jul-09	Absent	Absent
Truck Fill Point	08-Jul-09	Absent	Absent
Tap inside of well	08-Jul-09	Absent	Absent
Nozzle on back of truck	22-Jul-09	absent	absent
Truck fill point	22-Jul-09	absent	absent
Raw Water	22-Jul-09	absent	absent
Nozzle on Back of Truck	05-Aug-09	Absent	Absent
Raw Water	05-Aug-09	Absent	Absent
Truck fill Point	05-Aug-09	Absent	Absent
Truck Fill Point	12-Aug-09	Absent	Absent
Raw Water	19-Aug-09	Absent	Absent
Nozzle on back of truck	19-Aug-09	Absent	Absent
Nozzle on back of truck	09-Sep-09	Absent	Absent
Raw Water	09-Sep-09	Absent	Absent
Truck Fill Point	09-Sep-09	Absent	Absent
Nozzle on back of Truck	23-Sep-09	Absent	Absent
Truck Fill Point	23-Sep-09	Absent	Absent
Raw Water	23-Sep-09	Absent	Absent
Nozzle on Back of Truck	07-Oct-09	Absent	Absent
Truck Fill Point	07-Oct-09	Absent	Absent
Raw Water	07-Oct-09	Absent	Absent
Truck fill point	21-Oct-09	Absent	Absent
Raw Water	21-Oct-09	Absent	Absent
Nozzle on back of truck	21-Oct-09	Absent	Absent
Raw Water	16-Nov-09	Absent	Absent
Truck fill point	16-Nov-09	Absent	Absent
Nozzle on back of truck	16-Nov-09	Absent	Absent
Raw Water	08-Dec-09	Absent	Absent
Nozzle on Back of Truck	08-Dec-09	Absent	Absent

Old Crow - Bacteriological Sampling Results - 1999 to 2010

(source : Yukon Government, Community Services Operations)

Location of sampling	Date	Total Coliforms	Fecal Coliforms
Truck Fill Point	08-Dec-09	Absent	Absent
Raw	16-Dec-09	Absent	Absent
Truck Fill point	16-Dec-09	Absent	Absent
Nozzle on back of truck	16-Dec-09	Absent	Absent
Driven Well	30-Dec-09	Absent	Absent
Driven Well	30-Dec-09	Absent	Absent
	30-Dec-09	Absent	Absent
	04-Jan-10	Absent	Absent
Driven Well	04-Jan-10	Absent	Absent
Driven Well	04-Jan-10	Absent	Absent
Nozzle on back of truck	13-Jan-10	Absent	Absent
Truck Fill Point	13-Jan-10	Absent	Absent
Raw Water	13-Jan-10	Absent	Absent

Appendix E

Comparison of different Water Treatment Technologies

Old Crow Water Treatment Plant — Treatment System Proposal

Contact Information

Customer / Utility:	Old Crow Water Treatment Plant	**Date:**	**4/30/2010**
Site or Well Identity / Location:	Old Crow, Yukon	**Site Contact:**	**Virginia Sarrazin**
Local Engineer / Firm:	Yukon Engineering Services	**Contact Phone:**	**867-338-2000**
	Facility owned by Yukon Government	**Rep Contact:**	
Operator:	Ron Benjamin	**Cell Phone:**	
Target Date for Installation:	2011	**Email:**	vsarrazin@yes-group.ca
Other Pertinent Notes:	Iron and Hardness reduction		

eb04.30.10en

System Parameters / Site Specific Info

System Type / Application:	Community (see notes)
Population Served:	250
Number of Connections:	130 sites for bulk delivery
Number of Wells to be treated:	1 existing, 1 to be drilled
Design Flow (GPM):	127
Ave Flow (GPM):	127
Adedge Sizing Basis (GPM):	127
Gallons per day:	22,825gpm max 12839 gpm ave
Est. Usage (Gals / Year):	3.9 millions gal.
Existing Pretreatment In Place:	Post disinfection
Existing Disinfection:	
Pump Operation / Pressure:	Artesian well (10 PSI) + pump
Electrical Power Availability:	1 phase
Atm Storage Tank Present at the site:	None but will be added
Hydropneumatic Tank Present:	
Building present:	New building to be built
Any additives ie, phosphates, fluoride:	
Discharge Options:	Sewage holding tank

Site Specific Notes:

The community is on delivery.
The raw water comes from an artesian well at 48 gpm.
There is a pump to accelerate the fill rate of the water truck.
With the pump, the total flow rate is 110 gpm.
New plant to be built for treatment.
Well>>Cl2>>AD26>>Softener>>Distribution

**** denotes priority parameters**

	Parameters			Parameters	
pH	8.10	units	**Sodium**	14.0	mg/L Na
Total As	0.009	mg/L As	**Sulfate**	23.0	mg/L as SO4
As(III)	no data	mg/L (if known)	**Nitrates**	<0.1	mg/L as NO3
Sulfides	no data	mg/L	**Chlorides**	51.6	mg/L Cl^-
Calcium	44.4	mg/L @ Ca	**Boron**	0.1	mg/L B
Magnesium	23.5	mg/L @ Mg	**Gross Alpha**	no data	pCi/L
Silica	no data	mg/L SiO2	**TDS:**	287.0	mg/L
Phosphate	no data	mg/L P04	**Fluoride**	0.4	mg/L F
Bicarbonate	no data	mg/L HCO3	**Turbidity**	7.1	NTU
Iron	0.84	mg/L Fe	**Uranium**	0	mg/L U
Manganese	0.18	mg/L Mn	**Suspended Solids**	no data	mg/L TSS
Zinc	0.01	mg/L Zn	**Temperature**	no data	degrees F

AD26 System

Treatment System :	AD26-3072-S-3-B	**Target Contaminants:**	Mn and Fe	
No of vessels	(3) 30" x 72"- side shell	**Ave flow rate:**	127.0	(typical expected)
Qty of media (cu ft):	39.0	**Ave gallons/ day :**	22,825	(based on utilization)
Est. Installation footprint:	120"L x 54"W x 100"H	**Hydraulic Utilization %**	12.5%	(actual system utilization 24-7)
Media:	AdEdge AD26	**Est. working capacity:**	281,000	(bed volumes to breakthrough
Operation:	Intermittent	**Bed volumes / day:**	78	(throughput)
Backwashing Rate:	98 gpm (20gpm/sqft)	**Est. Gallons to breakthrough:**	81,973,320	(arsenic breakthrough)
Est. BW water (gallons) per event / tank:	1,176	**AD26 Est. Media life (months):**	119.7	(est frequency of changeout)
Backwashing frequency:	Once per week	**AD26 Est. Media life (Years):**	10.0	(est frequency of changeout)
Filtration Rate (gpm / sq ft)::	8.63			

Water Softener

Treatment System :	ADIX-2472-ALT-9-3-B	**Filtration Rate**	5.5 gpm / cu ft	(based on One vessel on Line)
No of vessels	(3) 24" x 72"- side shell	**Ave flow rate:**	127.0	(typical expected)
Qty of media (cu ft):	30.0	**Ave gallons/3 day :**	22,825	(based on utilization)
Est. Installation footprint:	104" L x 54" W x 100" H	**Hydraulic Utilization %**	12.5%	(actual system utilzation 24-7)
Media:	AdEdge AD-IXC	**Est. working capacity:**	277,200	(bed volumes to breakthrough
Operation:	Intermittent	**Bed volumes / day:**	102	(throughput)
Backwashing Rate:	12 gpm (4 gpm/sqft)	**Est. Gallons to breakthrough:**	62,203,680	(arsenic breakthrough)
Est.Regen water (gallons) per vessel :	1,062	**ADIX Est. Media life (months):**	120.0	(est frequency of changeout)
Backwashing frequency per vessel:	Every other day estimated	**ADIX Est. Media life (Years):**	10.0	(est frequency of changeout)

Old Crow Water Treatment Plant — Treatment System Proposal

Contact Information

Customer / Utility:	Old Crow Water Treatment Plant	**Date:**	**4/30/2010**
Site or Well Identity / Location:	Old Crow, Yukon	**Site Contact:**	**Virginia Sarrazin**
Local Engineer / Firm:	Yukon Engineering Services	**Contact Phone:**	**867-338-2000**
	Facility owned by Yukon Government	**Rep Contact:**	
Operator:	Ron Benjamin	**Cell Phone:**	
Target Date for Installation:	2011	**Email:**	vsarrazin@yes-group.ca
Other Pertinent Notes:	Iron and Hardness reduction		

eb04.30.10en

System Costs

AD26 Treatment System;	included	**Replacement AD26 media:**	$10,530	(media, excluding labor)
ADIX Softening System	included	**Replacement ADIX media:**	$3,450	(media, excluding labor)
Chlorine Module:	Exisitng	**Est. NaCl Annual Usage:**	$3,000	(regenerate - consumable)
Startup and Commissioning:	included	**Est. Chlorine Annual Usage:**	$189	(chemical - consumable)
AdEdge Equipment Shop Drawings:	included	**Est. Annual Oper. Costs**	$4,590	(annualized media, consumables)
Installation:	by others	**Operating Costs per 1000 gal:**	$0.55	(ave calculated over 5 years)
Engineering / Permitting:	Yukon Engineering Services	**Est. disposal of spent media:**	not applicable	(est. disposal of media)
Estimated Freight:	not included			
Total capital, startup costs (sans freight):	**$97,900**			

Options			
Backwash Recycle Module	**$13,500**	**Total System Cost with Options**	**$114,250**
Brine Reclaim Module:	**$2,850**		

AD26 Oxidation/Filtration System for Iron and Manganese Removal System Scope of Supply & Features

AdEdge Technologies, Inc.

System Vessels/Media

Model AD26-3072-S-3-B
Treatment system rated for up to 110 gpm design flow
Skid Mounted System for ease of Installation
100 psi rated composite vessels
Three 30" diameter composite vessels
Sch 80 PVC Hub and lateral collection system, diffusers
AD26 oxidation / filtration media, 39 cu ft total
Garnet underbedding
Media fill: top flanged opening fill port on vessels

AD26-2162-S-3B

Process Valves, Piping and Instrumentation

Top mounted automatic flow control package with Fleck Controllers
Automatic functions/cycles
(3) 3150NXT LCD timers / valve combinations (top mount)
2-inch inlet/outlet Sch 80 PVC inter connecting piping on vessels;
(3) 0-100psi pressure gauges; Inline digital flow meter / totalizer
2" Auxiliary Backwash Inlet actuated valve and controls

Instrumentation & Controls

Common NEMA 4X control panel (stainless steel or painted steel)
Stainless steel hydraulic panel for local instruments / reading
Flow meter, flow totalizers
Pressure gauges differential pressure switches
Differential pressure switches
Stainless steel sample ports for monitoring influent and effluent

Customer Provided Support

All Inlet, outlet, interconnecting piping for system
Single phase 115v, 15 amp electrical service to each valve controller
Drain or discharge piping and location for periodic backwash water
Concrete slab or base for treatment unit
Enclosure / protected area if outdoors as necessary
Consistent water supply at 30 PSIG

Field Services & Miscellaneous

System installation (by others)
AdEdge On-Site system startup and training
Basic O&M manual and Training (at time of startup)

Terms

Lead time is 6-8 weeks for shipment to site upon receipt of PO/Release to Manufacturing
Freight is not included in capital pricing; FOB mfg location or Atlanta, GA
Terms; 30% due with P.O./Contract Letter, 60% due upon shipment, 10% due upon start-up or 45 days from shipment
1 year manufacturer's warranty on equipment (terms and conditions to be provided)
Sales / Use Tax - Not Included (if applicable)

ADIX Cation Softening System
for Hardness Reduction
System Scope of Supply & Features

AdEdge Technologies, Inc.

System Vessels/Media

ADIX-2472-S-ALT-9-3-B
Treatment system rated for up to 110 gpm design flow
Skid Mounted System for ease of installation
100 psi rated composite vessels
Three 24" diameter composite vessels
Sch 80 PVC Hub and lateral collection system, diffusers
ADIX Exchange media, 10 cu ft per vessel
Gravel underbedding
Media fill: top flanged opening fill port on vessels

Ex. ADIX-2472-ALT-7-2B

Process Valves, Piping and Instrumentation

Top mounted automatic flow control package with Fleck Controllers
Automatic functions/cycles - Alternating System Configuration
(3) 2900NT LCD timers / valve combinations (top mount)
2 -inch inlet/outlet Sch 80 PVC inter connecting piping on vessels;
2" effluent meter for initiation of regeneration and alternating functions
(3) 0-100psi pressure gauges;
System will regenerate with treated water from AD26 system

Instrumentation & Controls

Common NEMA 4X control panel (stainless steel or painted steel)
Stainless steel hydraulic panel for local instruments / reading
Flow meter, flow totalizers
Pressure gauges differential pressure switches
Differential pressure switches
Stainless steel sample ports for monitoring influent and effluent

Basic Regeneration Components

39" x 50" Brine Storage Tank with Grid Plate (Shelf)
1/2" Dual Safety Brine Valve
Tank Over-Flow fitting
Dust Cover
1/2" Poly Tubing for Brine Draw and Refill Cycles
98% Pure - NON-Rock Salt provided by others

Field Services & Miscellaneous

System installation (by others)
AdEdge On-Site system startup and training
Basic O&M manual and Training (at time of startup)

Customer Provided Support

All Inlet, outlet, interconnecting piping for system
Single phase 115v, 15 amp electrical service to each valve controller
Drain or discharge piping and location for periodic backwash water
Concrete slab or base for treatment unit
Enclosure / protected area if outdoors as necessary
Consistent water supply at 30 PSIG

Terms

Lead time is 6 -7 weeks for shipment to site upon receipt of PO/Release to Manufacturing
Freight is not included in capital pricing; FOB mfg location or Atlanta, GA
Terms; 30% due with P.O./Contract Letter, 60% due upon shipment, 10% due upon start-up or 45 days from shipment
1 year manufacturer's warranty on equipment (terms and conditions to be provided)
Sales / Use Tax - Not Included

AD26 Arsenic, Iron and Manganese Treatment System
Backwash Recycle Option Scope of Supply and Features

Backwash Storage Tank
5,000 Gallon Backwash Tank
Polyethylene vertical storage tank; dimension
102" dia. X 152" h
Bulkhead fittings, level controls
Level Transmitter with 4-20mA signal
installation by others

Standard Poly Storage Tank

Backwash Recycle Pump
Automated Control and system integration
Grundfos vertical centrifugal pump skid
10-15 GPM @ 45psi;
Local control panel with HOA switch

Post Filtration
(1) BFN-12 Stainless Steel bag filter housings rated @ 100 gpm each
Pressure Gauge and Stainless Steel sample valve
(50) 5 Micron Polydepth bag filters
2" Offset Inlet & Outlet

Recycle Pump Skid

Terms
Lead time is 9 weeks for shipment upon receipt of PO
Freight for media and systems is estimated FOB mfg site
Payment Terms: 30% on order; 60% on shipment; 10% on startup
AdEdge to assist with startup at the site
1 year manufacturer's warranty on equipment
Pricing valid for 45 days

BFN-12 Stainless Steel Bag Filter

Field Services & Misc
System installation by adedge optional
Two days AdEdge On-Site system startup and training
Operator training and O&M Manual

Customer Provided Support
All Inlet, outlet, interconnecting piping for system
Single phase 115v, 15 amp electrical service to each valve controller
Drain or discharge piping and location for periodic backwash water
Concrete slab or base for treatment unit
Enclosure / protected area if outdoors as necessary
Consistent water supply at 30 PSIG

Project Profile

Resort Village of Kannata Valley
Silton, Saskatchewan, Canada
150 GPM AD26 Arsenic, Iron Removal System

Background

In November 2009 AdEdge was selected by the Resort Village of Kannata Valley (R.V.K.V.) to supply an arsenic, iron, manganese and turbidity treatment system for their community in Silton, Saskatchewan. A 132 gpm artesian well serves potable water to 260 connections. Several options were considered based on the need to remove the 1.7 - 2.14 mg/L iron, and arsenic from 31 ppb to below the new MCL of 10 ppb. An AdEdge AD26 oxidation /filtration system was selected as the best overall approach to simultaneously remove both contaminants while having a small footprint. Work was closely coordinated with R.V.K.V. site to design and permit the treatment system. Appropriate permitting documents were prepared and submitted to the Province for approval with the permit being granted in January 2010. The AdEdge scope of work included system design, supply and start-up assistance. The AdEdge system was selected based on overall cost, the small footprint, and simplicity of operation.The raw water quality of the well is shown to the right.

Parameters			Parameters	
pH	7.8 - 7.9	units	Total Organic Carbon	no data mg/L TOC
Total As	0.031	mg/L As	Sulfate	865.70 mg/L as SO4
As(III)	no data	mg/L	Nitrates	0.90 mg/L as NO3
Sulfides	865.70	mg/L	Chlorides	185.00 mg/L Cl
Hardness	446.00	mg/L @ CaCO3	Uranium	0.30 ug/L U
Alkalinity	516.0	mg/L @ CaCO3	Gross Alpha	no data pCi/L
Silica	no data	mg/L SiO2	TDS:	2,353.00 mg/L
Phosphate	no data	mg/L P04	Fluoride	0.30 mg/L F
Bicarbonate	627.00	mg/L HCO3	Turbidity	10.00 NTU
Iron	1.70	mg/L Fe	Suspended Solids	no data mg/L TSS
Manganese	0.09	mg/L Mn	Temperature	no data degrees F

Treatment System

The AdEdge AD26 system treatment train consists of one skid mounted triplex packaged treatment unit with three vessels in parallel to treat up to 150 gallons per minute (gpm). A design filtration rate of 3.98 gpm/sq was chosen to allow for filtration of the high level of contaminants including turbidity in a range of 6.34 - 12.0 NTU The system uses AdEdge manganese dioxide media (AD26) that is excellent for co-contaminant removal. The AD26 automated system is equipped with the AdEdge INGenius™ PLC, automated butterfly valves, and control panel, and is integrated with chlorine addition and monitoring for process control and disinfection purposes. The system also includes air wash and a complete AdEdge H2Zero™ recycle/backwash, zero discharge system. The system is pre-engineered, pre-piped, and skid mounted for ease of installation and operation. A continuous free chlorine monitor on the system allows the operator to maintain desired disinfection residual in the distribution system. The AD26 technology has been deployed successfully by AdEdge on many high arsenic, iron, and manganese wells to date including 5 full scale EPA arsenic demonstration projects. Installation was completed and the system was officially started up in August 2010.

Performance

Since operations began, the system has consistently met all the EPA MCLs for arsenic, iron, and manganese. Arsenic in the treated water has been recorded consistently below detection (<2 ppb) and Turbidity to 0.014 NTU. Monitoring and periodic sampling of the system is performed by the site's certified operator in accordance with the MDEQ permit.

For More Information Contact

AdEdge Technologies, Inc.
Mr. Greg Gilles, Vice President
5152 Belle Wood Court, Suite A
Buford, Georgia 30518
678-835-0052 * 678-835-0057 Fax
www.adedgetechnologies.com

Resort Village of Kannata Valley
Arnie Flagel
306-729-2889
office@kannatavalley.com

Operator
Al Yorkoski
306-729-4940

Project Profile

McGraw Hill, East Windsor, NJ
Iron & Manganese Removal System

Background

In late 2007, AdEdge began working with Maser & Associates to assist with design and implementation of an iron and manganese removal system to serve the water supply for the McGraw Hill data center in East Windsor, New Jersey. The site had an existing groundwater supply well with unacceptably high levels of iron and manganese to serve as feed water for the facilities cooling towers. The water chemistry presented some challenges with a pH of 5 and iron levels of nearly 5 mg/L. AdEdge was selected to design, build, and startup an integrated treatment system to remove the iron and manganese to meet secondary MCLs of 0.3 mg/L and 0.05 mg/L respectively. AdEdge worked closely with the selected contractor Central Jersey Mechanical to supply the treatment system which included chemical feed (chorine and pH correction), an AdEdge AD26 packaged iron and manganese removal filtration system, treated water backwash pump skid, finished water supply booster pump package, and instrumentation. AdEdge also furnished the system with a PLC communications module to interface and allow for continuous monitoring via the data center's existing SCADA system. The system was constructed and deployed in the summer of 2008.

Priority Parameters		
pH **	4.4-4.9	
Total As **	n/a	mg/L As
As(III)	n/a	mg/L (if known)
Sulfides**	ND	mg/L
Hardness **	33.0	mg/L as CaCO3
Alkalinity **	10.0	mg/L @ CaCO3
Silica **	no data	mg/L SiO2
Calcium **	4.0	mg/L Ca
Sulfate **	10.0	mg/L SO4
Iron **	5.00	mg/L Fe
Manganese **	0.11	mg/L Mn

Treatment System

The AdEdge treatment system featured a skid-mounted AD26 oxidation and filtration package unit sized for a maximum design flow rate of 130 gpm. The model AD26-3660CS-S-3-AVH utilizes AdEdge AD26 MnO2 media in a three vessel carbon steel configuration in parallel. The system is equipped with automated control valves and harness, central control panel with programmable logic controller (PLC) and a color user interface screen. System features also include differential pressure switches, control panel and local gauges, flow sensors & totalizers, and a central hydraulic panel with sample ports for a complete functioning packaged unit. A hypochlorite feed & monitoring Module and pH adjustment module using sodium hydroxide (NaOH) are also integrated into the system package. Each 36-inch diameter treatment vessel contains approximately 20 cubic feet of AdEdge AD26 oxidation filtration media. Other ancillary equipment which was totally integrated with the treatment module included the auxiliary finished water backwash supply, distribution booster pumps, the two 5,000 gallon finished water holding tanks and instrumentation. All of these components were integrated into the design and controlled by a single master control panel in the AD26 system.

Performance

The system was started up and commenced in July, 2008. The system has a very high utilization factor receiving water nearly 22 hours per day to meet the demand of the cooling towers. Approximately 100-110 gpm is being consistently treated with high iron and manganese levels exceeding 4 mg/L and 0.1 mg/L to below the treatment goals of 0.3 mg/L and 0.05 respectively. The system has experienced little to no down time since installation.

For More Information Contact

AdEdge Technologies, Inc.
Mr. Greg Gilles, Vice President
5152 Belle Wood Court, Suite A
Buford, Georgia 30518
678-835-0052 * 678-835-0057 Fax

Project Profile

Troyer Water System – Middlefield, Ohio
Arsenic, Iron & Manganese Removal

Background

In early 2008, AdEdge was selected by EcoWater Servisoft in Burton, Ohio to design, build, and startup an integrated treatment system to remove arsenic, iron, and manganese levels at the Troyer Water System in Middlefield to below the primary and secondary MCLs of 0.010 mg/L, 0.3 mg/L and 0.05 mg/L respectively. AdEdge first piloted a treatment system in spring of 2007 to satisfy OEPA requirements. Showing successful pilot results, AdEdge subsequently designed and implemented an AD26 oxidation and filtration systems for arsenic, iron and manganese removal. The site has two existing groundwater supply wells with arsenic levels ranging from 13 – 32 ppb and high levels of iron and manganese that serve the manufacturing facility and community. AdEdge worked in conjunction with EcoWater throughout the permitting, installation, and start up phase of the work to provide an automated, skid mounted AD26 packaged filtration system. The system included a chlorine module and a PLC controls and panel. Water Quality is shown in the table below.

Priority Parameters		
pH **	7.1 - 7.4	
Total As **	0.013 - 0.032	mg/L As
As(III)	No data	mg/L (if known)
Sulfides**	No data	mg/L
Hardness **	310	mg/L @ CaCO3
Alkalinity **	295.0	mg/L @ CaCO3
Silica **	15.0	mg/L SiO2
Phosphate **	No data	mg/L P04
Sulfate **	No data	mg/L SO4
Iron **	0.82 - 2.5	mg/L Fe
Manganese **	0.075 - 0.137	mg/L Mn

Treatment System

The AdEdge treatment system features a skid-mounted AD26 oxidation and filtration package unit sized for a maximum design flow rate of 150 gpm. The model AD26-3660CS-S-3-AVH utilizes AdEdge's catalytic AD26 MnO2 media in three carbon steel vessels in parallel configuration. The system is equipped with automated control valves and valve harness, a central control panel with programmable logic controller (PLC), and a Color touch user interface screen. System features also include a central hydraulic panel with differential pressure switches, local gauges, and flow sensors & totalizers for a complete functioning packaged unit. A hypochlorite feed module was included and controlled by the PLC to aid in the oxidation of iron and manganese. Other ancillary equipment that was integrated with the treatment skid and PLC included a finished water backwash supply connection and corresponding valve programming. It is now one of several of AdEdge AD26 systems permitted by OEPA in Ohio.

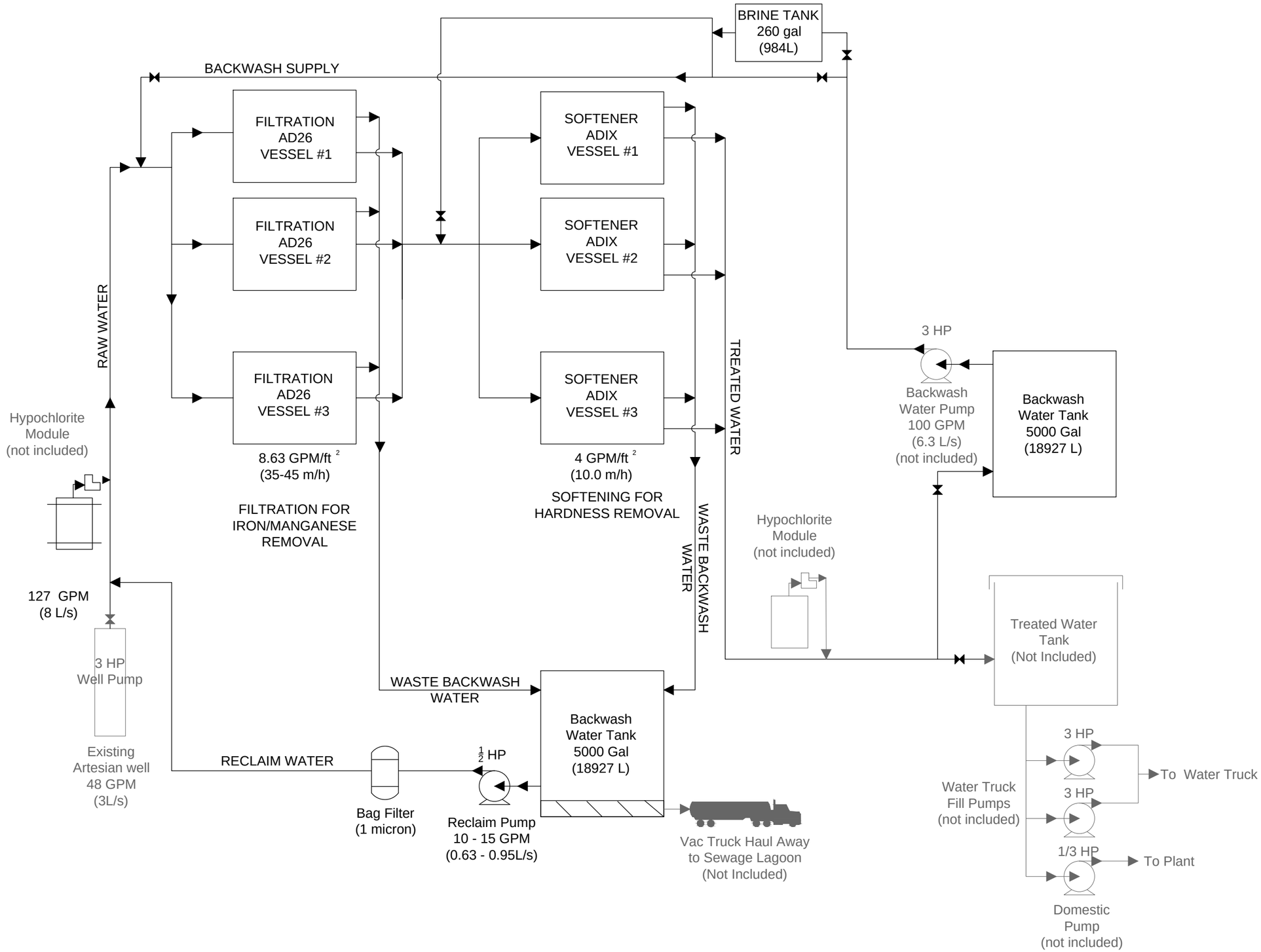
Performance

The system was started up and commissioned in June, 2009. The treatment system utilizes half of the well pumps capacity in order to meet the demand of the facility. The manufacturing facility uses 99% of the water produced as process water. Approximately 150 gpm is being consistently treated, removing arsenic, iron and manganese levels to well below the treatment goals of 0.010 mg/L, 0.3 mg/L and 0.05 respectively.

For More Information Contact

AdEdge Technologies, Inc.
Mr. Greg Gilles, Vice President
5152 Belle Wood Court, Suite A
Buford, Georgia 30518
678-835-0052 * 678-835-0057 Fax
greg@adedgetechnologies.com
www.adedgetechnologies.com

EcoWater Servicesoft
Mr. Denny Hall
14299 Kinsman Road
P.O. Box 174
Burton, Ohio 44021
440-834-4612
Info@EcoWaterServisoft.com



LEGEND:

YUKON ENGINEERING SERVICES

REVISIONS:

NO.	DATE	ENG.	SUBJECT
0A	17/05/10	VS	FOR INFO

PROJECT:

OLD CROW
WATER TREATMENT
PLANT

DRAWING TITLE:

PROPOSED CONCEPT
PROCESS FLOW DIAGRAM
ADEDGE TECHNOLOGIES

DATE: 2010

DRAWN: RSC

DESIGN: VS

CHECKED: LF

APPROVED: VS

PROJECT: E10003

SHEET 1 of 5

LAYOUT: Process Flow - Adedge Technologies PLOT DATE: Jul 07, 2010 FILENAME: S:\JOBS\E10003\Proposed Concept.dwg

West Coast Filters Inc.

Design, Manufacture & Distribution of Water Filtration Equipment

In USA - West Coast Filters International, Inc. In Canada - West Coast Filters Inc.

PROPOSAL

CUSTOMER:
Yukon Engineering Services
#1, 151 – Industrial Road
Whitehorse, Yukon Territory
Y1A 2V3

PROJECT:
Old Crow Community
Hardness and Manganese Removal
Groundwater Treatment Plant

CONSULTANT:
Yukon Engineering Services
#1, 151 – Industrial Road
Whitehorse, Yukon Territory
Y1A 2V3

AGENT:
Preliminary Proposal
TBD

BID DATE:
May 14, 2010

DESIGN PARAMETERS:

8.0 L/s (127 USGPM) - Potable Water System
Targeting removal of Hardness and Manganese
Ion Exchange Units with Fusion WS2 Control Valve

Web site: www.westcoastfilters.com Toll Free: 1.800.375.7744 E-mail: richard@westcoastfilters.com
Hillside P. O. 35008 Victoria, BC Canada V8T 5G2 Ph: (250) 595-7370 Fax: (250) 595-7306

Scope of supply:

The intended scope is for WEST COAST FILTERS INC. to supply a completely operational and functional Ion-exchange system for a project at the Old Crow, Yukon site capable of producing 8.0 L/s (127 USGPM) USGPM of product water. This proposal includes the supply all necessary AutoCAD prints, shop drawings and details of construction complete with four (4) hard bound, installation and operating manuals in English only (translation to foreign language will be performed at an additional cost). We will design, manufacture and test all components of the system prior to delivery to the site.

The system shall operate as follows:

Un-oxidized raw water will be supplied by the well pump at the design rate of 127 USGPM while maintaining a constant pressure on the system. The minimum required operating pressure for this system is 35 PSI.

The influent will flow through a common header (SBO) where flow will be distributed evenly between **Two (2)** 36” x 86” Fibre wound Ion exchange vessels. Each vessel shall operate at a flow rate of 60 USGPM. The exchange process shall be of the special media type using 20 cubic feet of Strong Acid Gel Polystyrene Cation Exchange Beads and two grades of Quartz media support gravel. The lower distributor shall be constructed from schedule 40 PVC.

The WS2 softener control valve shall be mounted on top of each vessel using and shall be capable of controlling all the requirements of the service operation, backwash, rinse to waste, brine draw, fast rinse and brine tank refill. Auxiliary motorized valves (MAV) shall be mounted to eliminate hard water during regeneration and to allow for a separate BW source.

Regeneration of the Ion Exchange resin shall be initiated by the following methods:

Accumulated Flow / Manual Selection

Upon initiation of the Regeneration Cycle signal input from the flow meter, the WS2 controller will sequence the valve to commence the Regeneration cycle for the first unit taking it through the programmed cycles of backwash, brine draw, rinse, fast rinse, brine refill and return to service. The second unit will be staggered chronologically to sequentially regenerate after successful regeneration of the first unit. The Regeneration / backwash water will be supplied from the distribution system or by an independent supply pump (SBO). There will be an elapsed time interval between the BW of the first and second unit.

The required regeneration flows are as follows:

Backwash	35 USGPM	8 Minutes	280 Gallons
Slow Rinse and Brine Draw	7 USGPM	60 Minutes	420 Gallons
Fast Rinse	25 USGPM	8 Minutes	200 Gallons
Total volume used per regeneration cycle			900 Gallons

Items Included in This Proposal:

Two (2) 36”' diameter x 86" side-shell Resin Tanks c/w
- Gravel Support
- Ion Exchange Media
- Clack WS2 Control Valves

Two (2) - Clack WS2 Bronze body top-mounted valves c/w
electrically actuated MAV valve for no hard water during regeneration

Two (2) Clack SS meters for digital flow indicator / totalizer / converter

Two (2) MAV Motorized Alternating valves for Separate Source Regen Supply

Two (2) Salt Brine Tank 39” x 48”

Shop drawings and IOM’s as required

Items Not Included in This Proposal:

- Separate Source Regen /Backwash supply pump (To follow if requested)

The following items must be supplied by the contractor / owner on site:

- Electrical service (Standard 120volt ground fault duplex required)
- Off-loading of equipment
- Installation service

The total cost of this system (Duplex System) …… **$ 31, 800.00(CND)**

This equipment is quoted FOB our facility in Victoria, BC

Delivery is 8 - 10 weeks from receipt of approved construction drawings.

Off loading is the responsibility of the contractor / owner

Applicable taxes are extra.

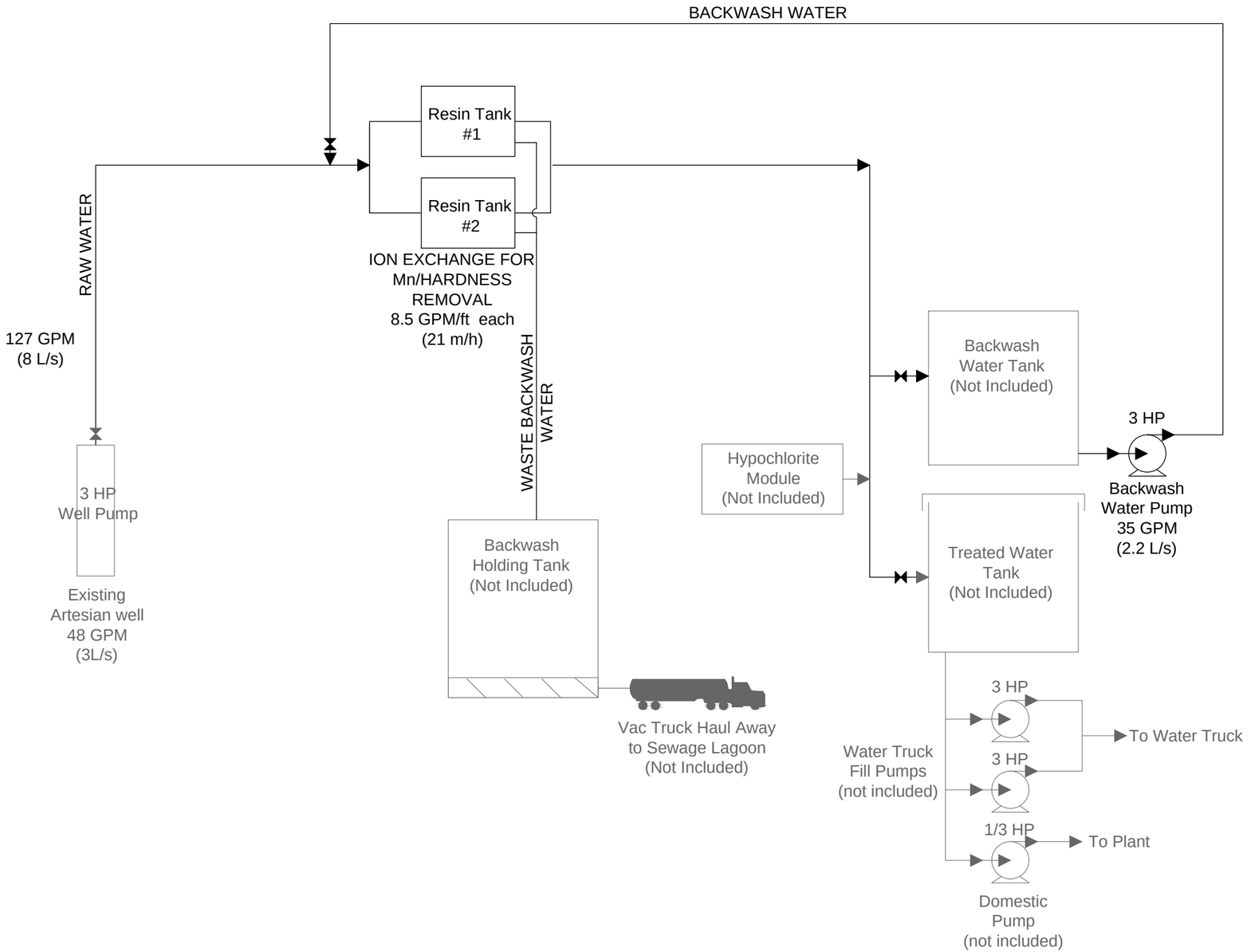
This proposal is valid for acceptance within for 60 days.

Optional Equipment:

- A larger salt storage / brine tank with a 3500 pound capacity can be ordered.

Physical Parameters of System

Tank Diameters	36”	
Overall Height	86”	
Footprint	12’ (W) x 4’ (D)	
Vessel Wt (MT)	100 lb. (Each)	
Vessel Wt (With Media)	Data to Follow	
Inlet Size	2” x FNPT	
Outlet Size	2” x FNPT	
Salt Consumption	9 pounds / cubic foot to provide 400,000 grains capacity	
Estimated salt consumption	4, 680 pounds per month (Total for both units)	
Salt Tank	39” x 48”	
	1,800 pound capacity	
Regeneration Frequency	Every 2.3 days	
	(13 Regenerations per month based on 23,000 USGPD)	
Backwash rate	35 USGPM	
Backwash Duration	8 Minutes	
Rinse Rate	7 USGPM	
Rinse Duration	60 Minutes	
Fast Rinse	25 USGPM	
Fast Rinse Duration	8 Minutes	
Water used	900 Gallons per Regeneration	
Electrical Requirements		
- Controls	115 / 230 Volt / 1 Ph / 60 Hz	N.A.



LEGEND:

YUKON ENGINEERING SERVICES

REVISIONS:

NO.	DATE	ENG.	SUBJECT
0A	17/05/10	VS	FOR INFO

PROJECT:

OLD CROW
WATER TREATMENT
PLANT

DRAWING TITLE:

PROPOSED CONCEPT
PROCESS FLOW DIAGRAM
WEST COAST FILTERS

DATE: 2010

DRAWN: RSC

DESIGN: VS

CHECKED: LF

APPROVED: VS

PROJECT: E10003

SHEET 4 of 5

LAYOUT: Process Flow - West Coast Filters PLOT DATE: Jul 07, 2010 FILENAME: S:\JOBS\E10003\Proposed Concept.dwg

3726 E. Miraloma Ave., Anaheim, California 92806
Phone: (714)-630-5040 Fax: (714)-630-1160
www.filtronics.com

March 19, 2010

Yukon Engineering Services
1-151 Industrial Rd.
Whitehorse, YT Y1A 2V3

Attn: Ms. Virginia Sarrazin

QUOTATION NO.: 100319-2
OUR REF: 1003Oldcro.pro
PROJECT: **Old Crow WTP**

Dear Ms. Sarrazin:

We are pleased to offer our proposal covering the following filtration system:

APPLICATION: **IRON & MANGANESE REMOVAL**

The system is designed for a maximum flow of 110 gpm at 60 psi pressure, having a maximum iron content of 2.0 mg/l, manganese content of 1.0 mg/l, hydrogen sulfide/dissolved sulfide content of 0.1 mg/l and total organic carbon content of <0.1 mg/l, in the raw water supply. The filtered water will be in accordance with applicable State Health Department Standards for these elements/compounds.

One each, **Filtronics Model FV-06, *Electromedia*® I Automatic Filter Station** designed according to the following specifications utilizing ANSI 60/61 materials as applicable:

FILTER VESSEL

The filter vessel shall be 48" diameter x 54" straight sideshell, ends fitted with torispherical and flanged heads. Tank shall be fabricated from carbon steel according to ASME code procedures for unfired pressure vessels, stamped and shall have a working pressure of 60 psig and test pressure of 78 psig. Ports and connections shall be according to drawing S-110 enclosed and as follows:

Inlet and Outlet:	4" flanged
Access Handholes:	One each, 12" x 16" oval type in top
Drain:	4" victaulic, equipped with media drain screen and valve
Air Vent:	1½" flanged
Supporting:	Structural steel angle legs

FILTER INTERNALS

Filter internal equipment shall consist of upper and lower manifold assemblies of Schedule 80 PVC-1 pipe, ABS upper manifold distribution heads, and PVC collector tubes specifically designed for each vessel size and hydraulically tested at the factory to ensure near uniform distribution of water. Couplings, support braces and hardware to be stainless steel and epoxy coated.

REACTION VESSELS

Two each, **Filtronics Model V-100 Reaction Vessels** shall be 24" diameter x 62" straight sideshell, ends fitted with torispherical and flanged heads. Tanks shall be fabricated from carbon steel according to ASME code procedures for unfired pressure vessels, and shall have a working pressure of 60 psig and test pressure of 78 psig.

Interior and exterior finishes shall be the same as for filter vessel. Each reaction vessel provided with air vent valve, stainless steel body and stainless steel internals.

LINING AND PAINTING

The filter vessel shall be internally cleaned and finished to remove all weld splatter or surface irregularities and provide a minimum 1/8" radius. All contaminants shall be removed by solvent washing or steam cleaning per SSPC-SP-1.

All wetted surfaces shall be sandblasted to a shadow free white metal surface per SSPC-SP-5 and shall have an angular profile of 2 to 4 mils. The white metal shall be per pictorial standard Vis-1. The coating shall be factory-applied within eight hours of sandblasting under controlled conditions of humidity and temperature. An oven of sufficient size to contain the vessel shall be available for curing the coating.

The coating shall consist of Keysite 740, 100% solids epoxy applied in a cross-spray application of 6 to 8 mils per coat. The second coat shall not be applied until the first coat has achieved a dry tack-free surface. Each coat will be tested for a holiday free surface and proper thickness with a Tinkor and Razor 67 volt holiday detector and Nordson dry film thickness gauge calibrated prior to each test.

Exterior surfaces shall be commercial blasted to SSPC-SP-6 and one shop coat of Tnemec Series 69 primer applied.

PIPE, VALVES, FITTINGS

Face piping and valve assembly will be provided to complete the system for normal filtration, backwash and purge operations. Piping shall be 4" Schedule 40 steel pipe with 150# forged steel flanged connections. Fittings shall be 125# cast iron flanged. Pipe 2" and smaller shall be standard galvanized iron threaded with galvanized iron 150# fittings.

Five each, 4" wafer type butterfly valves shall be of the wafer body design for installation between 125# flat face or 150# raised face flanges. The valve shall be non-directional and of the dry stem journal design, providing bubble-tight shut off at 200 psi differential pressure.

Valve bodies shall be gray iron to ASTM-A-48 class 20. Valve stems shall be 416 stainless steel of the non-wetted two piece design with the lower stem acting as a trunnion for the valve disc and the upper stem being the drive shaft.

The valve disc shall be of a high flow design of ASTM B148 aluminum bronze alloy.

The valve disc to stem engagement shall have no mechanical fasteners, allowing the valve disc to float to a perfect seal in the valve seat. The valve seat shall have a rigid phenolic backup ring with Buna-N elastomer bonded to it, rendering the valve seat suitable for pressure or vacuum service. The valve seat shall incorporate its own flange seals and they shall mate with full face or raised face flanges.

The valve body shall incorporate O-ring secondary seals to maintain lubricant in the stem journals and eliminate exterior moisture from the stem journals.

The butterfly valve actuators shall be of the pneumatic, double rack and pinion, double acting design, close coupled to the butterfly valve top plate. The pneumatic actuator shall be constructed of aluminum with replaceable steel rack, and steel pinion output shaft. The actuator shall have fiberglass/carbon guide bands that maintain clearance between the piston and cylinder walls, and O-ring piston seals. The pneumatic actuators shall be sized for an 80 psi minimum supply air pressure and shall have an output torque greater than the required operating seating and unseating torque of the butterfly valve. Butterfly valve torque used for sizing purposes shall be the wet torque as published by the butterfly valve manufacturer.

Air vent valve to be cast iron body and stainless steel internals. Pressure gauges to be 0 to 100 psig.

One each, **4" Filtronics Model 8366-8R,** hydraulically operated diaphragm backwash flow control valve, 125# class, ASTM-A-126-CL-B, stainless steel stem and spring, guided stem assembly top and bottom, brass trim, brass pilot valve, copper tubing with Y-strainer, flow limiter and set at 250 gpm.

One each, **2½" Filtronics Model 8366-8R,** hydraulically operated diaphragm effluent flow control valve, 125# class, ASTM-A-126-CL-B, stainless steel stem and spring, guided stem assembly top and bottom, brass trim, brass pilot valve, copper tubing with Y-strainer, and set at 110 gpm.

One each, **4" Filtronics Tube Meter,** designed to meet AWWA standard C704, flanged 150# AWWA class D flat face steel, straightening vanes, and fusion epoxy coated internally and externally, shall be provided to be installed in the backwash inlet line to accurately measure backwash rate.

One each, **3" Filtronics Tube Meter,** designed to meet AWWA standard C704, flanged 150# AWWA class D flat face steel, straightening vanes, and fusion epoxy coated internally and externally, shall be provided to be installed in the effluent line to accurately measure effluent rate.

Nuts, bolts and gaskets for mated flanges only.

AUTOMATION

Automatic controls for full, unattended operation shall be provided. Controls shall be housed in a NEMA 12 steel cabinet mounted on the filter or optional remote mounting as specified:

The controls shall include the following features:

- Allen-Bradley programmable controller
- Remote access modem connection for maintenance/troubleshooting
- Automatic reset timers for each filter cycle
- Time delayed process start signal
- Filtronics Series 7000 recorder/controller, seven day, 120 VAC pen drive, input 4 to 20 milliamps DC, with high/low alarm contacts
- NEMA 13 oil tight pilot lights and switches
- Status lights for each filter mode
- Low air alarm/push to test pilot light
- Power status pilot light
- Cabinet mounted adjustable differential pressure switch
- Adjustable low air pressure switch monitor
- 4-way electro-pneumatic solenoid valves with manual override
- Air filter and air lubricator for pneumatic system
- Inlet and outlet pressure gauges for monitoring differential pressure

- o Interlocking control relays for chemical treatment equipment/associated pumps
- o Plug-in components for easy servicing and troubleshooting
- o Cabinet factory wired and completely tested for function prior to shipment
- o 2 hp, 1/60/115-230 compressor for instrument air including V-belt, guard, motor, drive and air tank
- o 500 feet of 1/4 inch black poly tubing
- o UL 508 Certified

CHEMICAL PRETREATMENT

One system of chemical pretreatment equipment, manually set and automatically operated, consisting of the following:

CHEMICAL FEED: SODIUM HYPOCHLORITE

One each, **Filtronics Model CF-10** chemical feed system including the following equipment:

One each — 100 gallon polyethylene tank, solution level indication, hinged cover, pump suction piping with PVC foot valve strainer, ½ inch diameter drain valve, back pressure valve, and pressure relief valve.

One each — Chemical feed pump shall have chemical resistant wetted parts, capacity of 6 gallons per day at 60 psig, micrometer dial for flow adjustment, and motor.

One each — **Filtronics Model CC-8000 System Process Analyzer** for monitoring and accurate adjustment of chemical dosages, including carbon dioxide buffer feed regulator, rotometer, and rate valve (bottle not included).

CHEMICAL FEED: SODIUM BISULFITE

One each, **Filtronics Model CF-5** chemical feed system including the following equipment:

One each — 50 gallon polyethylene tank, solution level indication, hinged cover, pump suction piping with PVC foot valve strainer, ½ inch diameter drain valve, back pressure valve, and pressure relief valve.

One each — Mixer and steel mounting bracket. Mixer shall have steel coupling and stainless steel shaft and propeller. Mixer shall be ¼ hp 1/60/115 TENV/TEFC.

One each Chemical feed pump shall have chemical resistant wetted parts, capacity of 6 gallons per day at 60 psig, micrometer dial for flow adjustment, and motor.

MEDIA

One complete ***Electromedia*®** **I** load, ANSI 60/61 approved, including support layers, shall be provided. **Installation of media shall be by others.**

RECLAIM EQUIPMENT

One each, backwash reclaim system designed for **Filtronics Model FV-06** at a working pressure of 60 psig and shall include the following equipment:

Two each Normally open float switches to be mounted in the stilling well in the backwash reclaim tank for reclaim start and low suction pump protection.

One each 3/60/230-460 TEFC reclaim pump capable of delivering 11 gpm at 60 psig, under flooded suction conditions.

One each 1" reclaim flow control valve, fixed rate, variable orifice, cast iron body, stainless steel internals, set at 11 gpm.

One lot Automatic reclaim control logic and hardware incorporated in the filter control panel.

Two each Double acting pneumatic butterfly valves, 2" for reclaim return, and 2" tank drain.

One each 1" wafer check valve cast iron body, Buna-N seal, stainless steel internals.

One each 1-1/2" floating suction strainer with non-floating hose.

CUSTOMER TO FURNISH

Single phase power to terminal strips located on control enclosure.

THIS PROPOSAL DOES NOT INCLUDE

1. **Installation**
2. **Exterior plumbing**

3. **Exterior wiring, magnetic starters, disconnect switches, or overload protection**
4. **Concrete or concrete design**
5. **Any other item not specifically mentioned in this proposal**
6. **Freight**

THIS PROPOSAL DOES INCLUDE

1. **Four sets of filtration system drawings, and four sets of submittal data**
2. **Up to five days of assistance to contractor/owner to place system in operation**
3. **Three sets of operation and maintenance manuals**

TERMS

- To approved credit accounts
  - * 10% with order, Net 15 days
  - * 20% with drawings, Net 15 days
  - * 60% upon shipment, or available on our dock for shipment
  - * 10% with start-up or net 90 days, whichever comes first
- F.O.B. Anaheim, California
- Price does not include any applicable taxes
- This proposal valid for thirty (30) days

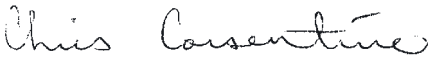
SHIPMENT

- 10 - 12 weeks **after approval of all drawings.**
- Approximate shipping weight: 9,300 lbs.
- Partial shipments accepted

BUDGET PRICE----------$225,378.00 USD

Very truly yours,

FILTRONICS, INC.



Chris Corsentino
Regional Sales Manager

ACCEPTED: Yukon Engineering Services

PROJECT: Old Crow WTP

By: _____

Title: _____

Date: _____

Enclosures: Drawings S-110, S-170, S-200

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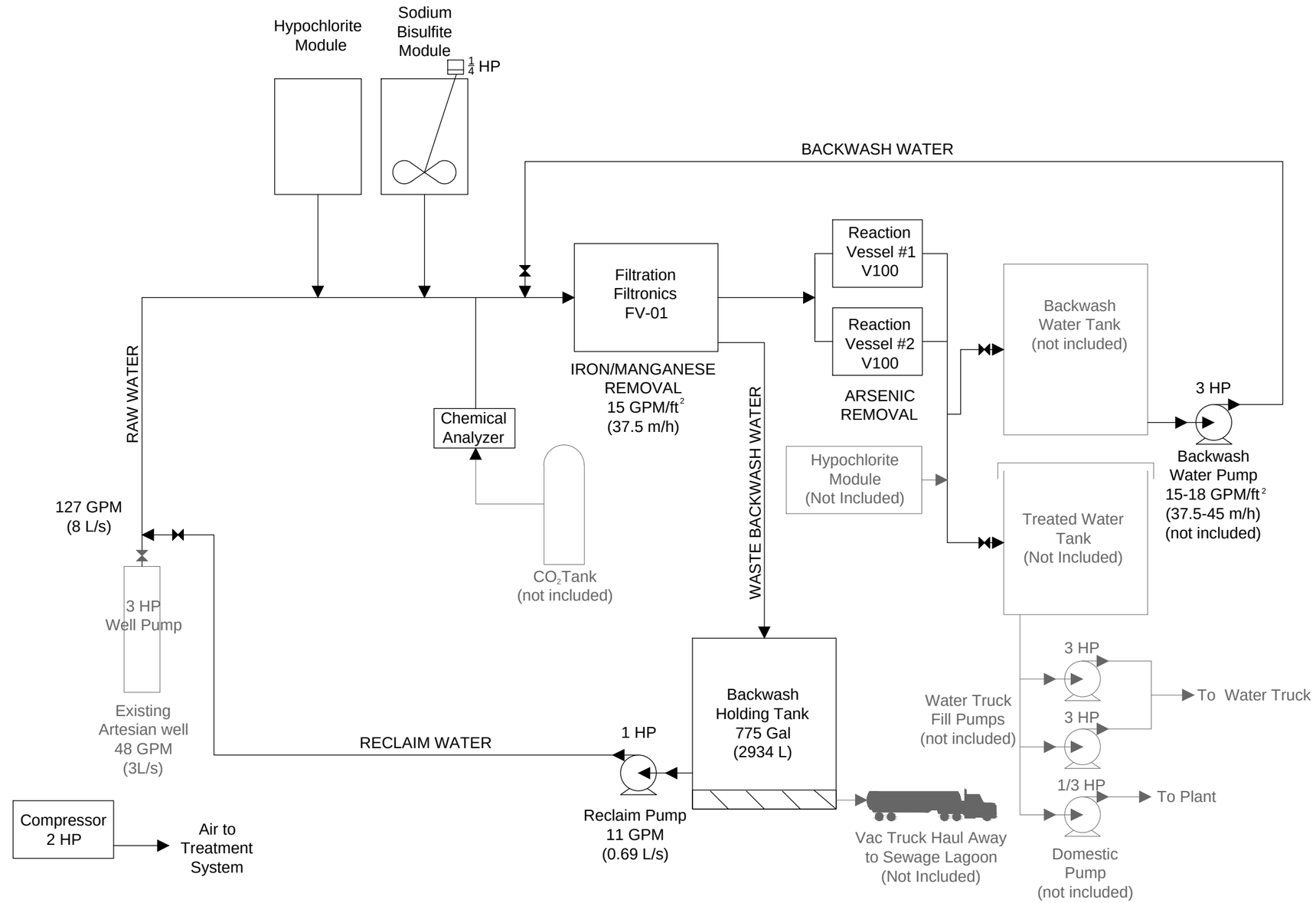
GENERAL TERMS OF SALE

Filtronics, Inc. hereinafter “Seller” is an original equipment manufacturer. The equipment sold contains proprietary, trade secrets of Seller and shall not be disclosed.

1. **Terms of Payment:** All invoices are due and payable fifteen (15) days from the date of the invoice. No discounts are authorized, unless otherwise specified.
2. **Shipping Point:** All prices are F.O.B. Seller’s plant in Anaheim, California, unless otherwise expressly provided in this contract.
3. **Delivery:** The shipping dates as specified above are approximate; are subject to the Seller’s prompt receipt from the Buyer of all necessary information and are subject to the Seller’s current production schedules. Seller shall not be liable in any respect for failure to ship or for delay in shipment where such failure or delay shall be due in whole or in part to shortage or curtailment of materials, labor, transportation or utility services, or due to any labor or production difficulty in Seller’s plant or those of its suppliers, or to any cause beyond Seller’s control.
4. **Failure to Reject:** Before the materials covered hereby are used and within five (5) days of receipt of shipment, the Buyer shall notify the Seller, in writing, of any defects or omissions. Failure to so notify the Seller shall constitute an irrevocable acceptance of the goods.
5. **Taxes:** Sales, use, excise, property or similar taxes arising out of or relating to this order or the goods delivered are not included in the price, except as otherwise specifically stated in the invoice. All such taxes are the responsibility of the Buyer. The Seller shall have the right at any time to separately bill the Buyer for any such tax which the Seller may be called upon to pay, and the Buyer shall be obligated to pay Seller such amount.
6. **Force Majeure:** Neither party shall be liable for any failure or delay in performance under this Agreement (other than for delay in the payment of money due and payable hereunder) to the extent said failures or delays are proximately caused by causes beyond that party’s reasonable control and occurring without its fault or negligence, including, without limitation, failure of suppliers, subcontractors, and carriers, or party to substantially meet its performance obligations under this Agreement, provided that, as a condition to the claim of non-liability, the party experiencing the difficulty shall give the other prompt written notice, with full details following the occurrence of the cause relied upon. Dates by which performance obligations are scheduled to be met will be extended for a period of time equal to the time lost due to any delay so caused.
7. **Warranty:** Seller guarantees equipment of its own manufacture to be free from defects in material and workmanship for a period of 18 months from the invoice date or 12 months from the date of installation, whichever is sooner, and when the equipment is paid for, properly operated and maintained. No warranty if given for products or components which have been subject to misuse, improper installation, corrosion, or which have been disassembled, modified, or repaired by unauthorized persons. No other express or implied warranty is given and THE SELLER MAKE NO WARRANTY OF MERCHANTABILITY AND THERE ARE NO WARRANTIES WHICH EXTEND BEYOND THE DESCRIPTION ON THE FACE HEREOF.

8. Seller's liability, if any, shall be limited to the value of the product as supplied to the Buyer. The Seller at its option may repair or replace any equipment found to be defective. All shipping and field warranty inspection costs shall be paid by the Buyer. It is expressly agreed that the remedy provided in this section shall be the exclusive remedy against the Seller for all such claims of any kind. In no event, whether as a result of breach of contract or warranty or alleged negligence, or of any other claim or any other kind shall the Seller be liable for special or consequential damages including, but not limited to loss of profits or revenue, loss of use of the equipment or any associated equipment, cost of capital, cost of substitute equipment, facilities or services, down time costs, or claims of customers of the purchasers for such damages. The Buyer assumes all responsibility for loss or damages resulting from the handling or use of the material or goods covered hereby.
9. **Technical Advice:** Seller, upon Buyer's request, may furnish technical advice with reference to the use of the material sold hereunder, if and to such extent as Seller has such advice conveniently available; but it is expressly agreed that there is no obligation to furnish any such advice, and that if any advice or assistance is furnished, which will be without charge, it shall be given and accepted at Buyer's risk, and Seller shall not be responsible or liable for the advice or assistance given or results thereof.
10. **Entire Contract:** This Agreement constitutes the entire contract of sale and purchase of the goods named herein. No modification hereof shall be of any force or effect unless in writing and signed by the party claimed to be bound thereof.
11. **Waiver:** The failure of the Seller to insist, in any one instance or more, upon the performance of any of the covenants or conditions of this contract, or to exercise any right or privilege herein conferred, shall not be construed as thereafter waiving any such covenants, conditions, rights or privileges, but the same shall continue and remain in full force and effect.
12. **Financial Responsibility:** If payment is not made in accordance with the terms of this agreement, or if the Seller shall have any doubt at any time of Buyer's financial responsibility, Seller may withhold delivery of goods or services called for hereunder.
13. **Risk of Loss:** The risk of loss of the goods shall pass to Buyer as soon as the goods are delivered to Buyer at Seller's plant.
14. **Attorney's Fees:** The Buyer shall pay for the Seller's costs of collection of Buyer's debt hereunder, including attorney's fees.
15. **Applicable Law:** This agreement shall be governed by the laws of the State of California and any claim arising hereunder shall, at the Seller's election, be prosecuted in the appropriate court of Orange County, California. The Buyer hereby attorns to the jurisdiction and judgement of the courts of the County of Orange, State of California, and agrees that a judgement of an Orange County, California court shall be enforceable in the jurisdiction in which the Buyer is located.
16. **Late Charges:** Overdue accounts shall bear interest at the rate of one and one half percent (1 ½%) per month until paid.
17. **Acceptance of Shipment:** Acceptance of shipment constitutes acceptance of above terms and conditions.



LEGEND:

YUKON ENGINEERING SERVICES

REVISIONS:

NO.	DATE	ENG.	SUBJECT
0A	17/05/10	VS	FOR INFO

PROJECT:

OLD CROW
WATER TREATMENT
PLANT

DRAWING TITLE:

PROPOSED CONCEPT
PROCESS FLOW DIAGRAM
FILTRONICS

DATE: 2010

DRAWN: RSC

DESIGN: VS

CHECKED: LF

APPROVED: VS

PROJECT: E10003

SHEET 2 of 5

LAYOUT: Process Flow – Filtronics PLOT DATE: Jul 07, 2010 FILENAME: S:\JOBS\E10003\Proposed Concept.dwg

Virginia Sarrazin

From: Pardini, James J. [JPardini@MEIchem.com]
Sent: May 13, 2010 9:26 AM
To: 'vsarrazin@yes-group.ca'
Subject: Old Crow Treatment Proposal
Attachments: Old Crow Flow Diagram.xls

Virginia - I have to apologize since this project fell into a crack and I forgot about it. However I did get all the information and the proposal is presented below.

The flow diagram for the proposed treatment system is attached. It includes the following:

1. Chlorination
2. Iron/Manganese Removal System with backwash recovery
3. Water Softening System

As with the Tagish proposal, I am assuming that chlorination already exists.

The iron/manganese removal system is a three-vessel system where all three vessels operate in parallel. Each vessel is 42" in diameter and 72" high. Each vessel has an individual backwash timer/control valve. Backwashing of iron/manganese systems typically must be done at a flow rate 1.5 times the normal service flow rate. In order to keep the backwash flow rate to a manageable value, the system is divided into three vessels so that each can be backwashed separately at a lower flowrate than would be needed for a single large vessel. The backwash flowrate for each vessel is 100 gpm. Each backwash is followed by a 50 gpm rinse. Each backwash/rinse cycle generates 2,500 gal. of backwash water.

For backwash recovery, I've included an 7,000 gallon plastic storage tank and a backwash recovery pump.

For the iron/manganese removal system we will supply the following:

- Three fiberglass vessels, 42" diameter by 72" high.
- All associated media and internal downcomer pipes for the three vessels
- Three, Fleck 3900 backwash timer/control valves
- One, backwash supply pump

The price for this equipment is $54,240, FOB Flemington NJ

For the backwash recovery system we will supply the following:

- One, 7,000 polyethylene storage tank
- One, 20 gpm backwash recovery pump

The price for this equipment is $22,000, FOB Flemington NJ

The softening system is a two-vessel system where both vessels operate in parallel. Each vessel is 24" in diameter and 72" high. Each vessel has an individual regeneration timer/control valve. Softeners must be backwashed just line the iron/manganese

system. However since softeners do not precipitate any solids that have to be removed, backwash rates are much lower. Each backwash/regeneration cycle involves a backwash at 10 gpm for about 10 minutes followed by regeneration/rinse with a brine solution at 7 gpm for 60 minutes. Figure each backwash/regeneration cycle generates about 520 gallons of waste water. As we have discussed, this wastewater cannot be recovered so the site will have to find a way of dealing with it.

For the softening system we will supply the following:

- Two fiberglass vessels, 24" diameter by 72" high
- All associated media and internal downcomer pipes for the three vessels
- Two Clack, WS-3 meter assemblies/timer
- One, 100 gallon brine tank

The price for this equipment is $16,800, FOB Flemington NJ

On-site technical service for start-up and training is available at $800 per man-day (including travel time) plus expenses.

Our standard terms are as follows:

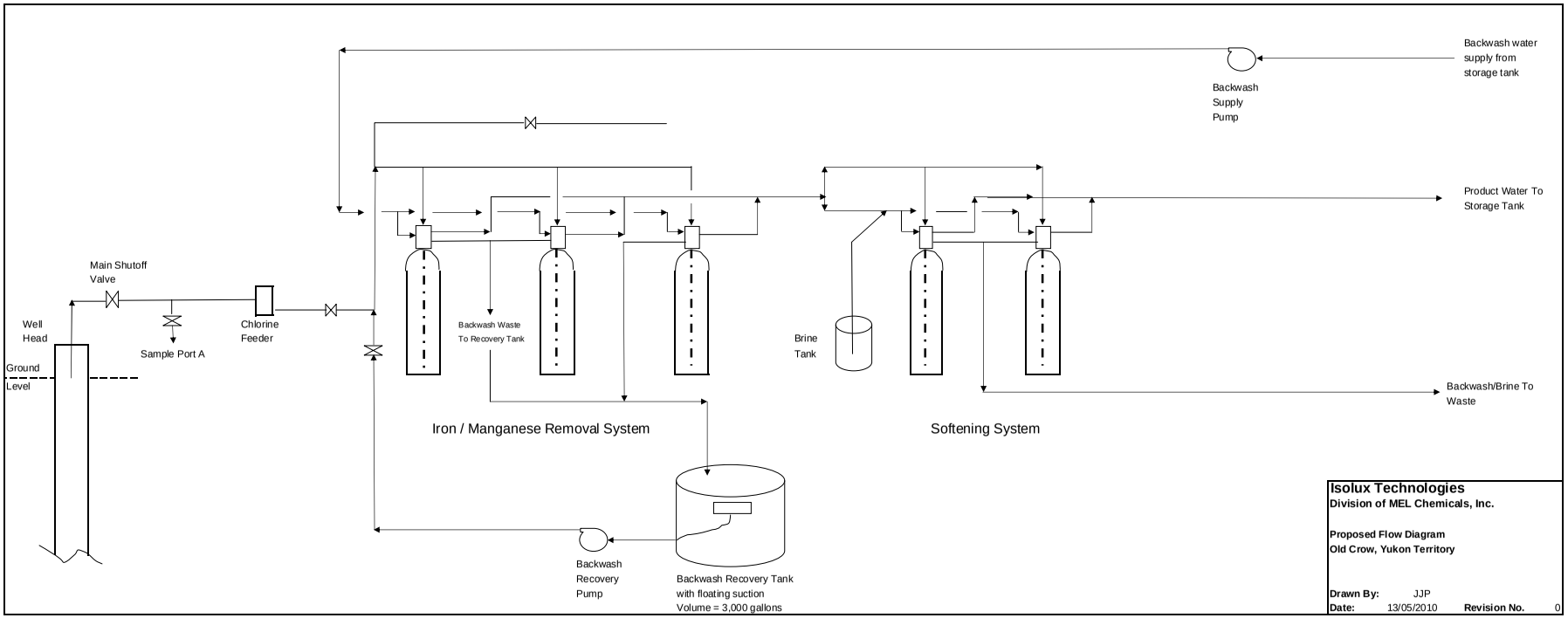
30% with order
60% upon shipment
10% upon successful start-up but no later than 90 days after shipment

Prices are valid until September 30, 2010.

I think this covers everything, but feel free to call or e-mail me. I will be out of the office from May 17, returning June 2. I will have access to my cell phone and e-mail, but response may be slow.

Jim Pardini

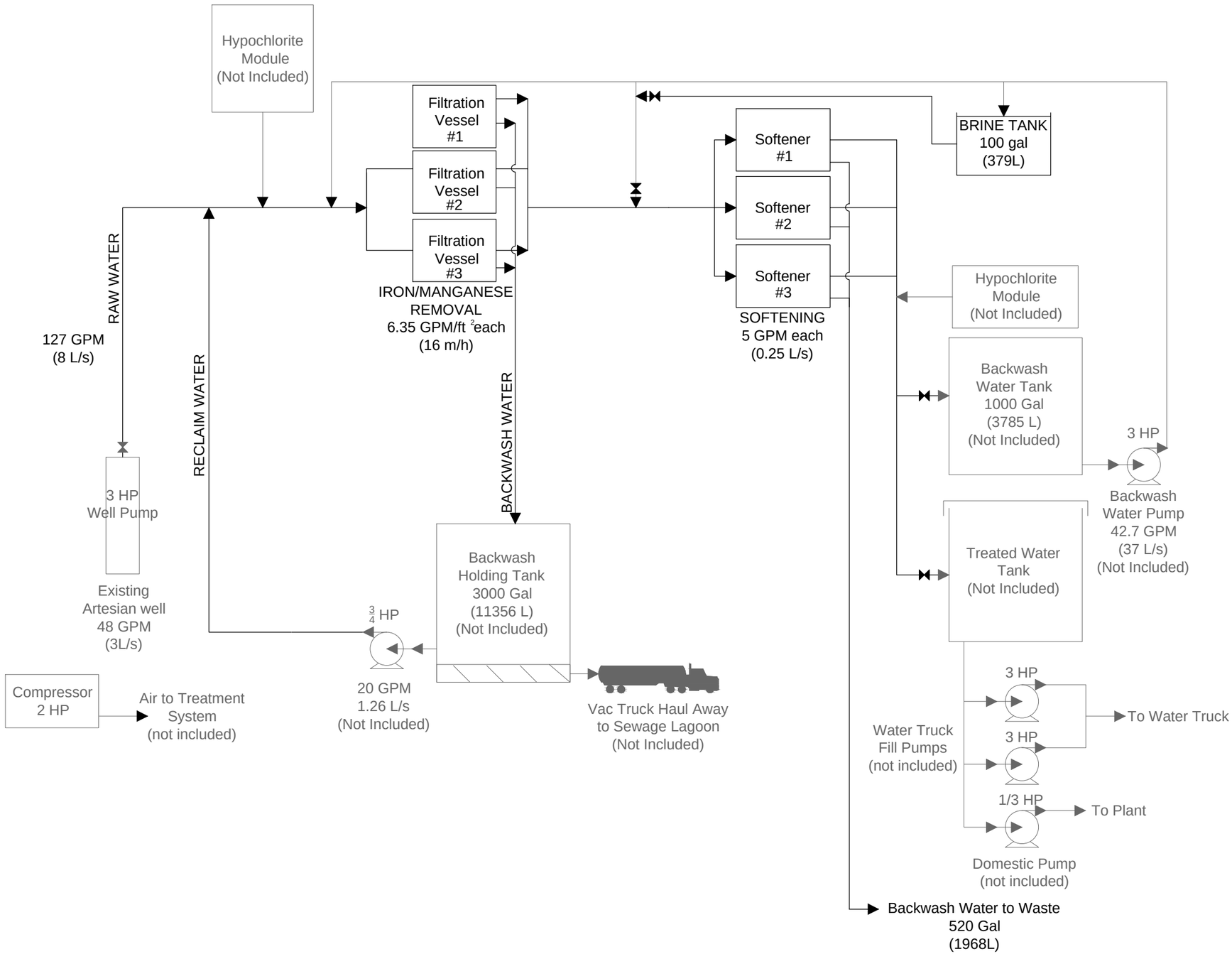
James J. Pardini PE, CPE
Isolux Business Manager
MEL Chemicals, Inc.
500 Barbertown-Point Breeze Rd.
Flemington, NJ 08822
908-782-5800, x1200
jpardini@meichem,com



Isolux Technologies
Division of MEL Chemicals, Inc.

Proposed Flow Diagram
Old Crow, Yukon Territory

Drawn By: JJP
Date: 13/05/2010 **Revision No.** 0



LEGEND:

YUKON ENGINEERING SERVICES

REVISIONS:

NO.	DATE	ENG.	SUBJECT
0A	17/05/10	VS	FOR INFO

PROJECT:

OLD CROW WATER TREATMENT PLANT

DRAWING TITLE:

PROPOSED CONCEPT PROCESS FLOW DIAGRAM ISOLUX

DATE: 2010

DRAWN: RSC

DESIGN: VS

CHECKED: LF

APPROVED: VS

PROJECT: E10003 | SHEET 3 of 5

LAYOUT: Process Flow - Isolux PLOT DATE: Jul 07, 2010 FILENAME: S:\Obs\E10003\Proposed Concept.dwg

Old Crow, Yukon

Client Contacts

Virginia Sarrazin
Yukon Engineering Services Whitehorse

Equipment

Manganese Greensand Filtration
and Softener System

Contact

Anne Bridgman, P. Eng
Water Process Engineer
Phone: 403-537-8473

Sapphire Group
1410 – 530 8th Avenue SW
Calgary, Alberta, Canada

Office: 403.537.8470
Fax: 403.537.8479
sapphire-group.ca

Wednesday, July 07, 2010

TABLE OF CONTENTS

INTRODUCTION TO THE SAPPHIRE GROUP

The Sapphire Group is a private company headquartered in Calgary, Alberta. Sapphire, with the financial backing and management strength of the Mancal Group, has assembled a group of businesses and people with over 50 years of combined experience in water and wastewater management. From this base, Sapphire has attracted Canadian, American and European water and wastewater treatment equipment providers (and their respective engineering and research capabilities) as part of the Sapphire portfolio. The result is that Sapphire is established as one of the premier integrated water and wastewater treatment solutions companies in Canada.

Sapphire Group offers our customers a complete range of high quality and reliable water and wastewater systems, with innovative technologies for municipal and industrial applications. In addition to our standard municipal and industrial clients, we also have extensive experience with private real estate clients, remote installations and first nations groups. Sapphire provides all customers with complete package water and wastewater systems or custom solutions vetted by a highly qualified internal Technical Support Services Group and manufactured to meet unique requirements at a competitive price. In addition to the Calgary head office, Sapphire has branch offices in British Columbia, Saskatchewan and Manitoba.

In addition to representing fifteen world-leading manufacturers of water and wastewater equipment and technology, including Aqua-Aerobic Systems, Inc., Brentwood Industries, Calgon Carbon Corporation, Franklin Miller, Inc., Huber Technology, and WesTech Engineering, Inc, the Sapphire Group also has two of its own manufacturing divisions: Sapphire Water and Sapphire Automation.

Sapphire Water designs, manufactures and services Membrane Treatment Equipment and specializes in Reverse Osmosis and Nanofiltration units from 100 to 1,000,000 gallons per day. These have proven to be the leading technologies for reduction and elimination of hardness, dissolved solids, sulphate, sodium, arsenic and nitrates in the water supply.

Sapphire Automation is a reliable source for expertise in process control, SCADA Systems, PLC programming, information systems, instrumentation, measurement, wireless communication and control centers. As a CSA certified Control Panel Manufacturer, Sapphire Automation designs, manufactures, programs and installs Control Panels in Commercial and Industrial facilities of all capacities. The focus has been on water and wastewater process systems for the last 15 years. Sapphire Automation's experienced technicians are capable of remotely monitoring water or wastewater systems to ensure systems are running at peak performance. Sapphire Automation operates out of Humboldt, Saskatchewan.

PROCESS DESCRIPTION

The proposed source of water for the community of Old Crow in the Yukon is a well which is able to produce 110 gpm. This water is ground water, and not under the influence of surface water. However the water contains high levels of iron and hardness.

In order to remove the iron and hardness to below the recommended levels a manganese greensand system followed by a softener is proposed. The raw water from the well (assumed to be pressurized) is first treated with potassium permanganate in order to oxidize iron, and any manganese. A detention tank provides 30 minutes of reaction time ahead of the manganese greensand filters.

The manganese greensand filters are sized at a loading of 2.5 gpm/ft2 or 6.1 m/hr. Two duty filters are provided, with a third standby. A layer of anthracite aids in removing particulate iron and manganese, while the greensand media removes any remaining material. The Magnum valve on top of each filter allows the operator to set up backwashing based on a fixed time interval, or to initiate them manually. Pressure gauges and pressure transmitters upstream and downstream of each filter allow for observation of the pressure drop across each filter. A flowmeter, turbidity meter, and on-line chlorine monitor are provided. A PLC, and operator interface are provided for simple monitoring. The PLC is equipped with an Ethernet port for future connection to a SCADA system.

A sodium hypochlorite injection system is included in order to provide a chlorine residual in the potable water. The contact/storage tank is by others.

SAPPHIRE SCOPE OF SUPPLY

Potassium Permanganate Pretreatment:

In order to oxidize any remaining iron and manganese a potassium permanganate dosing system with duty pump, one spare, and accessories is proposed.

Potassium Permanganate Dosing Pump	Alldos Chemical Metering Pump
Model	DDI 2.2-16 AR
Spare	1 pump
Accessories	Calibration Column, Day Tank, foot valve, injection quill

Detention Tank:

A 3300 gallon/ 12 490 L detention tank provides 30 minutes of reaction time for the water. A standard plastic tank is proposed; complete with level switches, inlet and outlet ports.

Feed Pump:

Manufacturer	Goulds
Model	TBD
Quantity	2 (one installed, one spare)
Flowrate	110 gpm
Head	160 ft/ 48.8 m

Manganese Greensand System: Two 100% trains of manganese greensand filters are proposed, with a third providing redundancy. A layer of anthracite on top of the manganese media provides extra particulate filtration. The units are triplexed together in order to provide sequential backwashing.

Vessels	42" diameter x 72 " sidewall height
Valve	Clack 2" metered valves with MAV locks outs
Quantity	3
Manganese Greensand Media	25 ft3/ 0.57 m3 with gravel bed
Pressure Transmitters	6- Wika
Pressure Gauges	6

Softening System: Two 100% trains of softeners are proposed, with a third providing redundancy. The units are triplexed together in order to provide sequential regeneration.

Vessels	42" diameter x 72 " sidewall height
Valve	Clack 2" metered valves with MAV locks outs
Quantity	3
Softener Media	25 ft3/ 0.57 m3
Brine Tanks	3x 39 x 48 brine tanks with safety
Pressure Gauges	3

Sodium Hypochlorite Dosing: A chlorine residual is provided in the potable water by a sodium hypochlorite dosing system.

Sodium Hypochlorite Dosing Pump	Alldos Chemical Metering Pump
Model	DDI 2.2-16 AR
Spare	1 pump
Accessories	Calibration Column, Day Tank, foot valve, injection quill
	1 On-line Hach Cl-17 Chlorine Monitor
	1 1720E Hach Turbidimeter with SC100 Controller
	1 flow meter

Control System:

An Allen Bradley PLC is provided, complete with a PanelView Human Machine Interface. This PLC contains an Ethernet port, making it SCADA compatible.

Commissioning/Training: One trip and 5 days have been included in order to commission the equipment and train an operator. Additional time may be purchased at a daily rate of $875.

PRICING

Total Price: **$139 800 CAD**

15% upon final review of drawings
10% upon issuance of notice to manufacture and deliver
65% upon receipt of equipment on-site
10% upon date of issuance of the Certificate of Substantial Performance

This price does not include:
field installation and wiring
neutralization of waste products
chlorine contact tank

SAPPHIRE WATER INTERNATIONAL CORPORATION

WARRANTY

Equipment manufactured and sold by Sapphire Water International Corporation (hereinafter called the "Sapphire"), once paid for in full, is backed by the following warranty:

For the benefit of the original end-user (the **"Purchaser"**), Sapphire warrants all new equipment manufactured and sold by the Sapphire to be free from defects in material and workmanship, and will replace or, at Sapphire's option, repair, F.O.B. its facilities or other location designated by it, any part or parts returned to it which Sapphire's examination shall show to have failed under normal use and service by the Purchaser within one (1) year following initial start-up, or eighteen (18) months from shipment to the Purchaser, whichever occurs first. Such repair or replacement shall be free of charge for all items except for those items such as resin, filter media and the like that are consumable and normally replaced during maintenance, with respect to which, repair or replacement shall be subject to a pro-rata charge based upon Sapphire's estimate of the percentage of normal service life realized from the part. Sapphire's obligation under this warranty is conditioned upon its receiving prompt notice of claimed defects, which shall in no event be later than thirty (30) days following expiration of the warranty period, and is limited to repair or replacement as aforesaid.

THIS WARRANTY IS EXPRESSLY MADE BY SAPPHIRE AND ACCEPTED BY PURCHASER IN LIEU OF ALL OTHER WARRANTIES, WHETHER WRITTEN, ORAL, EXPRESS, IMPLIED, OR STATUTORY, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. SAPPHIRE NEITHER ASSUMES NOR AUTHORIZES ANY OTHER PERSON TO ASSUME FOR IT ANY OTHER LIABILITY WITH RESPECT TO ITS EQUIPMENT. SAPPHIRE SHALL NOT BE LIABLE FOR NORMAL WEAR AND TEAR, CORROSION, OR ANY CONTINGENT, INCIDENTAL, OR CONSEQUENTIAL DAMAGE OR EXPENSE DUE TO PARTIAL OR COMPLETE INOPERABILITY OF ITS EQUIPMENT FOR ANY REASON WHATSOEVER.

This warranty shall not apply to, and Sapphire shall not be liable for, (i) equipment or parts thereof which have been altered, changed, serviced or repaired outside of a Sapphire facility; or (ii) equipment that has been damaged by improper installation, application, or maintenance, or subjected to misuse, abuse, neglect, accident, or incomplete adherence to all manufacturer's requirements, including, but not limited to, Operations & Maintenance Manual guidelines and procedures. Warranty service hereunder shall not operate to extend the original warranty period. The warranty excludes damage incurred in shipment to or from Sapphire.

This warranty applies only to equipment manufactured and sold by Sapphire. For equipment sold by Sapphire but manufactured by a third-party other than Sapphire, Sapphire shall extend to the Purchaser, to the extent permitted, any and all applicable warranty provisions provided to Sapphire by the third-party manufacturer. The extension of any and all applicable third-party manufacturer warranty provisions shall be an exception to this warranty and represents Sapphire's sole responsibility with respect to such equipment.

GENERAL TERMS & CONDITIONS

Terms and Conditions appearing in any purchase order based on this proposal which are inconsistent herewith shall not be binding on Sapphire Water International Corporation (hereinafter called "Sapphire"). The sale and purchase of equipment described herein shall be governed exclusively by the foregoing proposal and the following provisions:

1. SPECIFICATIONS: Sapphire is furnishing its standard equipment as outlined in the proposal and as will be covered by final approved drawings. The equipment may not be in strict compliance with the Engineer's / Owner's plans, specifications, or addenda as there may be deviations. The equipment will, however, meet the general intention of the mechanical specifications of these documents.

2. ITEMS INCLUDED: This proposal includes only the equipment specified herein and does not include erection, installation, accessory, or associated materials such as controls, piping, etc., unless specifically listed.

3. PARTIES TO CONTRACT: Sapphire is not a party to or bound by the terms of any contract between Sapphire's customer and any other party. Sapphire's undertakings are limited to those defined in the contract between Sapphire and its direct customers.

4. PRICE AND DELIVERY: All selling prices quoted are subject to change without notice after 30 days from the date of this proposal unless specified otherwise. Unless otherwise stated, all prices are F.O.B. Sapphire or its supplier's shipping points. All claims for damage, delay or shortage arising from the shipping of such equipment shall be made by Purchaser directly against the carrier. When shipments are quoted F.O.B. job site or other designation, Purchaser shall inspect the equipment shipped, notifying Sapphire of any damage or shortage within forty-eight hours of receipt, and failure to so notify Sapphire shall constitute acceptance by Purchaser, relieving Sapphire of any liability for shipping damages or shortages.

5. PAYMENTS: All invoices are net 30 days, unless specified otherwise. Delinquencies are subject to a 1.5 percent service charge per month or the maximum permitted by law, whichever is less on all past due accounts. Pro rata payments are due as shipments are made. If shipments are delayed by the Purchaser, invoices shall be sent on the date when Sapphire is prepared to make shipment and payment shall become due under standard invoicing terms. If the work to be performed hereunder is delayed by the Purchaser, payments shall be based on the purchase price and percentage of completion. Products held for the Purchaser shall be at the risk and expense of the Purchaser. Unless specifically stated otherwise, prices quoted are for equipment only. These terms are independent of and not contingent upon the time and manner in which the Purchaser receives payment from the owner.

6. PAYMENT TERMS: Credit is subject to acceptance by Sapphire's Credit Department. If the financial condition of the Purchaser at any time is such as to give Sapphire, in its judgment, doubt concerning the Purchaser's ability to pay, Sapphire may require full or partial payment in advance, may request security from the Purchaser to support the payment, or may suspend any further deliveries or continuance of the work to be performed by Sapphire until such payment has been received. If Purchaser defaults in any payment when due hereunder, Sapphire may, without incurring any liability therefore to Purchaser or Purchaser's customers, declare all payments immediately due and payable with maximum legal interest thereon from due date of said payment, and at its option, stop all further work and shipments until all past due payments have been made, and / or require that any further deliveries be paid for prior to shipment.

7. ESCALATION: If shipment is, for any reason, deferred by the Purchaser beyond the normal shipment date, or if material price increases are greater than 5% from proposal date to material procurement date, stated prices set forth herein are subject to escalation. The escalation shall be based upon increases in labor and materials and other costs to Sapphire that occur in the time period between quotation and shipment by Sapphire Purchaser agrees to this potential escalation regardless of contradicting terms in the contract, except when an agreed upon escalation adder is included in the price.

8. APPROVAL: If approval of equipment submittals by Purchaser or others is required, a condition precedent to Sapphire supplying any equipment shall be such complete approval.

9. INSTALLATION SUPERVISION: Prices quoted for equipment do not include installation supervision, unless indicated. Sapphire recommends and will, upon request, make available, at Sapphire's then current rate, an experienced installation supervisor to act as the Purchaser's agent to supervise installation of the equipment. Purchaser shall at its sole expense furnish all necessary labor equipment, and materials needed for installation. Responsibility for the proper operation of equipment if not installed by Sapphire or installed in accordance with Sapphire's instructions, and inspected and accepted in writing by Sapphire, rests entirely with Purchaser; and any work performed by Sapphire personnel in making adjustments or changes must be paid for at Sapphire's then current per diem rates plus living and traveling

expenses. Sapphire will supply the safety devices described in this proposal or shown in Sapphire's drawings furnished as part of this order but excepting these, Sapphire shall not be required to supply or install any safety devices whether required by law or otherwise. The Purchaser hereby agrees to indemnify and hold harmless Sapphire from any claims or losses arising due to alleged insufficiency or inadequacy or the safety devices offered or supplied hereunder, whether specified by Sapphire or Purchaser, and from any damage resulting from use of equipment and supplied hereunder.

10. ACCEPTANCE OF PRODUCTS: Products will be deemed accepted without any claim by Purchaser unless written notice of non-acceptance is received by Sapphire within 30 days of delivery if shipped F.O.B. point of shipment, or 48 hours of delivery if shipped F.O.B. point of destination. Such written notice shall not be considered received by Sapphire unless it is accompanied by all freight bills for said shipment, with Purchaser's notations as to damages, shortages and conditions of equipment, containers, and seals. Non-accepted products are subject to return policy stated below.

11. TAXES: Any federal, provincial, or local sales, use or other taxes applicable to this transaction, unless specifically included in the price shall be for Purchaser's account.

12. TITLE: The equipment specified herein, and any replacements or substitutes therefore shall, regardless of the manner in which affixed to or used in connection with realty, remain the sole and personal property of Sapphire until the full purchase price has been paid. Purchaser agrees to do all things necessary to protect and maintain Sapphire's title and interest in and to such equipment; and upon Purchaser's default, Sapphire may retain as liquidated damages any and all partial payments made and shall be free to enter the premises where such equipment is located and remove the same as its property without prejudice to any further claims on account of damages or loss which Sapphire may suffer from any cause.

13. INSURANCE: From date of shipment until the invoice is paid in full, Purchaser agrees to provide and maintain at its expense, but for Sapphire's benefit, adequate insurance including, but not limited to risk insurance on the equipment against any loss of any nature whatsoever. Purchaser agrees to provide Sapphire with evidence of such insurance upon request.

14. SHIPMENTS: Any shipment or delivery dates recited represent Sapphire's best estimate but no liability, direct or indirect, is assumed by Sapphire for failure to ship or deliver on such dates. Sapphire have the right to make partial shipments; and invoices covering the same shall be due and payable by Purchaser in accordance with the payment terms thereof. If Purchaser requests postponements of shipments, the purchase price shall be due and payable upon notice from Sapphire that the equipment is ready for shipment; and thereafter any storage or other charge Sapphire incurs on account of the equipment shall be for the Purchaser's account.

If delivery is specified at a point other than Sapphire or its supplier's shipping points, and delivery is postponed or prevented by strike, accident, embargo, or other cause beyond Sapphire's reasonable control and occurring at a location other than Sapphire or its supplier's shipping points, Sapphire assumes no liability in delivery delay. If Purchaser refuses such delivery, Sapphire may store the equipment at Purchaser's expense. For all purposes of this agreement such tender of delivery or storage shall constitute delivery.

15. WARRANTY: SAPPHIRE WARRANTS EQUIPMENT IT MANUFACTURES AND SELLS ONLY IN ACCORDANCE WITH THE WARRANTY PROVISIONS EXPRESSED IN THE ATTACHED COPY OF "SAPPHIRE WATER INTERNATIONAL CORPORATION WARRANTY" WHICH IS MADE A PART HEREOF. SUCH WARRANTY IS IN LIEU OF ALL OTHER WARRANTIES , WHETHER WRITTEN, ORAL, EXPRESS, IMPLIED, OR STATUTORY, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABLILITY AND FITNESS FOR A PARTICULAR PURPOSE.

16. PATENTS: Sapphire agrees that it will, at its own expense, defend all suits or proceedings instituted against Purchaser and pay any award of damages assessed against it in such suits or proceedings, so far as the same are based on any claim that the said equipment or any part thereof constitutes an infringement of any apparatus patent of Canada issued at the date of this Agreement, provided Sapphire is given prompt notice in writing of the institution or threatened institution of any suit or proceeding and is given full control of the defense, settlement, or compromise of any such action; and Purchaser agrees to give Sapphire needed information, assistance, and authority to enable Sapphire so to do. In the event said equipment is held or conceded to infringe such a patent, Sapphire shall have the right at its sole option and expense to a) modify the equipment to be non-infringing, b) obtain for Purchaser the license to continue using said equipment, or c) accept return of the equipment and refund to the Purchaser the purchase price thereof less a reasonable charge for the use thereof. Sapphire will reimburse Purchaser for actual out-of-pocket expenses, exclusive of legal fees incurred in preparing such information and rendering such assistance at Sapphire's request. The foregoing states the entire liability of Sapphire, with respect to patent infringement; and except as otherwise agreed to in writing, Sapphire assumes no responsibility for process patent infringement.

17. SURFACE PREPARATION AND PAINTING: If furnished, shop primer paint is intended to serve only as minimal protective finish. Sapphire will not be responsible for the condition of primed or finished painted surfaces after equipment leaves its shops. Purchasers are invited to inspect paint in shops for proper preparation and application prior to shipment. Sapphire assumes no responsibility for field surface preparation or touch up of shipping damages to paint. Painting of fasteners and other touch-up to painted surfaces will be by Purchaser's painting contractor after mechanism installation.

Motors, gear motors, and other components not manufactured by Sapphire will be painted with that manufacturer's standard paint system. It is Sapphire's intention to ship major steel components as soon as fabricated, often before drive, motors, and other manufactured components. Unless Purchaser can ensure that shop primed steel shall be field painted within thirty (30) days after arrival at the jobsite, Sapphire encourages the Purchaser to order these components without primer.

Sapphire's prices are based on paints and surface preparations as outlined in the main body of this proposal. In the event that an alternate paint system is selected, Sapphire requests that Purchaser's order advise of the paint selection. Sapphire will then either adjust the price as may be necessary to comply or ship the material unpainted if compliance is not possible due to application problems or environmental controls.

18. CANCELLATION, SUSPENSION, OR DELAY: After acceptance by Sapphire, the proposal, or Purchaser's order based on this proposal, shall be a firm agreement and is not subject to cancellation, suspension, or delay except upon payment by Purchaser of appropriate charges which shall include all costs incurred by Sapphire to date of cancellation, suspension, or delay plus a reasonable profit. Additionally, all charges related to storage and / or resumption of work, at Sapphire's plant or elsewhere, shall be for Purchaser's sole account; and all risks incidental to storage shall be assumed by Purchaser.

19. RETURN OF PRODUCTS: No product may be returned to Sapphire without Sapphire's prior written permission. Said permission may be withheld by Sapphire at its sole discretion.

20. BACKCHARGES: Sapphire will not approve or accept back charges for labor, materials, or other costs incurred by Purchaser or others in modification, adjustment, service, or repair of Sapphire-furnished materials unless such back charge has been authorized in advance in writing by a Sapphire employee, by a Sapphire purchase order, or work requisition signed by Sapphire.

21. INDEMNIFICATIONS: Purchaser agrees to indemnify Sapphire from all costs incurred, including but not limited to court costs and reasonable attorney fees, by Sapphire relating to this contract, including but not limited to breach of contract by Purchaser or costs incurred in collecting monies owed on this contract.

22. ENTIRE AGREEMENT: This proposal expresses the entire agreement between the parties hereto superseding any prior understandings, and is not subject to modification except by a writing signed by an authorized officer of each party.

23. MOTORS AND MOTOR DRIVES: In order to avoid shipment delays of our equipment, the motor drives may be sent directly to the job site for installation by the equipment installer. Minor fit-up may be required.

24. EXTENDED STORAGE: Extended storage instructions will be part of information provided to shipment. If equipment installation and start-up is delayed more than 30 days, the provisions of the storage instructions must be followed to keep WARRANTY in force.

25. LIABILITY: Professional liability insurance, including but not limited to errors and omissions insurance, is not included. In any event, liability for errors and omissions shall be limited to the lesser of $100,000.00 CDN or the value of the particular piece of equipment (not the value of the entire order) supplied by Sapphire against which a claim is sought.

ACCEPTED BY PURCHASER

BY _____

TITLE _____

DATE _____/_____/_____