PRELIMINARY ENGINEERING REPORT

GN PROJECT NO: 04-4417

PROJECT NAME
Water Supply Improvements

PROJECT ADDRESS

Kugluktuk, NU

PREPARED FOR
Government of Nunavut, Community & Government Services

PREPARED BY
A. D. Williams Engineering Inc.

DATE PREPARED
October 2008

ADWE File No. 13655.

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1.0 INTRODUCTION

The Hamlet of Kugluktuk is located on the Arctic Coastline at 67° 50’ N latitude and 115° 6’ W longitude. Kugluktuk, meaning “place of rapids”, is the second largest community in the Kitikmeot region, with a rapidly increasing population of approximately 1300.

Kugluktuk’s water is pumped from the Coppermine River, treated, placed in storage, and trucked to houses. Raw water often has high levels of turbidity. The turbidity is mostly removed by a series of filters in the water treatment plant. However, treated water turbidity is frequently over the Canadian Drinking Water Quality Guidelines (CDWQG).

The intake site is close to the ocean; approximately 2.5 km upstream from Coronation Gulf. Salt water periodically reaches upstream to the intake site due to the effects of tide and wind. The river has an average width of 570 m at the current intake location. Depths are generally less than 3 m, but can reach up to 8 m in isolated areas.

The water supply intake experiences frequent issues due to sedimentation, which can bury the intake, preventing water flow, and can also cause challenges in filtration. Divers have been retained approximately biennially to clear sand from the intake. In recent years the required frequency has increased to where it is required annually. In addition, the riverbank at the intake site is unstable and recently differential movement has been observed between the intake and the pumphouse.

Design guidelines primarily used for this project are:

- Good Engineering Practice for Northern Water and Sewer Systems, GNWT Public Works and Services, April 2004.
- Water and Sewage Facilities Capital Program: Standards and Criteria, GNWT Department of Municipal and Community Affairs, July 1993.
- Guidelines for Canadian Drinking Water Quality, Health Canada, Federal-Provincial-Territorial Committee on Drinking Water, May 2008.
- Cold Regions Utilities Monograph, 3rd Edition, American Society of Civil Engineers, 1996.

Government of the Northwest Territories (GNWT) design standards were used as no Government of Nunavut (GN) water systems design standards were made available or known to exist.

1.1 CHALLENGES

- Water is frequently turbid during open water seasons and excessively turbid during the freshet;
- Saline water intrudes into the river estuary at lower depths of the river;
- Parts of the river bed near the current intake are deposition areas;
- Intake facilities must be protected from ice;
- River bank is unstable in places;
- Extend filter life in the WTP and lower operating costs;
- Treatment sludge management.

1.2 OBJECTIVES

- Provide a reliable source of raw water to meet the needs of the community of Kugluktuk for the next 20 years;
- Reduce operations costs associated with the intake, notably diving to clean sediment from around the intake;
- Eliminate, or reduce to the extent practical, effects of the intrusion of saline water into the estuary on the water system;
- Upgrade the water treatment system to provide more effective treatment and meet GCDWQ requirements.
- Improve truckfill rate.

1.3 BACKGROUND

The current intake and pumphouse has experienced problems since its original installation in 1970. In brief, these include:

- Salinity intrusion – at certain tide and wind conditions, also influenced by season and river flow, [1]saline water enters the estuary and reaches the intakes. This necessitates shutting off the intake pumps and using an alternate temporary system pumping from near the surface;
- Sedimentation – the intakes are located in an area of deposition where river sediments settle out of the river flow. Divers have been retained approximately biennially to excavate near the intakes to prevent them from being covered with sediments;
- Stability – the intake casings have been noted to be shifting down-gradient in recent years, resulting in differential movement of the pumphouse and bending of the intake casings to the point where recently it has sometimes not been possible to remove the submersible pumps from the casings.

It has been noted in recent years that the intakes have required excavation to clear sediment more frequently. There is also anecdotal evidence that salinity events have been lasting longer over the past few years.

The pumphouse and intake casings now exhibit severe signs of distress due to differential movement, possibly caused by a rotational slump on the riverbank pulling the intake casing away from the pumphouse.

1.3.1 History

The present intake was installed in the late 1970's. It soon became apparent that saline water entered the estuary periodically, apparently depending on several factors including wind direction and river flow. At times saline water would

[1] The worst time is in the months around September and October when the tides are highest, the river is at a low flow, and sometimes the winds are onshore, causing a saline "wedge" to course up-river. Since water with a higher salt content is more dense than fresher water, intakes during these times are often pulling in water that is not fit to drink. Automatic sensors (and actual tasting by water treatment plant crews) cause the pumps to shut down during these times.

enter the intakes. Saline water is denser than fresh water, thus the saline water was in a layer at the river bottom, with fresh water at the surface.

In an attempt to alleviate the salinity problem, floating intakes were added in the early 1980's. These comprised swivel arms on the end of each intake casing complete with buoyancy chambers. The buoyancy chamber of the operating intake was filled with air from a compressor in the pumphouse prior to pump start. This elevated the intake to a level near the surface of the river. At this time the pump started and fresh water was pumped into the system.

This system operated satisfactorily for a short time. However it was found that sedimentation was burying the swivel arms and preventing them from rising. Divers were retained to clear the intake swivel arms, however they were quickly covered in sediment again. Ultimately the floating intakes were removed and replaced with fixed intakes near the river bottom.

However, sedimentation has continued to present a problem with divers retained approximately biennially to excavate sediment from around the intakes.

In recent years it has been noted that there has been differential movement in the pumphouse. During a site visit in September of 2006, what appeared to be tension cracks were noted on the top of the riverbank near the pumphouse. This leads to speculation that movement of the soil in the riverbank is pulling the intake casings. This speculation is reinforced by divers reports that the intake casings are bowing upward in between restraints.

1.3.2 System Improvements

The Government of Nunavut (GN) retained FSC Architects and Engineers in the late 1990's/early 2000's to investigate and design improvements to the water supply and treatment system. The resultant design was a balance achieved within GN financial constraints at the time. Recommendations implemented included:

- Construction of a new pipeline from the intake pumphouse to the water treatment plant;

- Construction of a raw water reservoir with a capacity for approximately 10 days storage, intended to provide fresh raw water during periods of saline water intrusion;

- Installation of cartridge filters to remove turbidity.

The current WTP consists of two parallel trains of four cartridge filtration units each followed by chlorination (the two finest filters operate in parallel, thus there are three filtration stages). The cartridge filtration system is frequently overwhelmed by sedimentation and the output water quality is below that of GCDWQ when this happens.

1.3.3 Previously Investigated Solutions

In April 2006, a desktop study was performed to review existing reports and data. The following reports were obtained from the PW&S library in Yellowknife and CGS archives in Cambridge Bay, NU. They were summarized as follows in the April 2006 Data Gap analysis:

1. *A Pre-design Report on Water Supply Pumphouse and Supply Line for Coppermine, Northwest Territories*, Underwood McLellan (1977) Ltd., October 1978.

   This report investigated the following alternatives for the proposed water supply system:

   - Twin 10” intake lines c/w submersible pumps;
   - Single 10” intake w/ 2 self-priming pumps in the pumphouse;
   - Single 8” intake w/ 2 vertical turbine pumps in a wet well.

   The single intake with self-priming pumps was recommended as having a slightly lower present value than the twin intake with submersible pumps. Servicing the pumphouse with a bombardier, rather than constructing a road, was recommended.

2. *A Study of Salinity in the Vicinity of the Coppermine River Water Intake Structure – Reports 1 and 2*, Northwest Hydraulic Consultants Ltd., A. Babb, P.Eng., August and October, 1981.

   This document comprises two reports dated August and October 1981 that investigate the intrusion of saline water into the water intake in the Coppermine River. The Coppermine River is noted to be a stratified estuary, with low tidal range and river flows large compared to inflow from tidal action. Field tests showed little mixing of fresh and salt water, except at the mouth of the river. The document presents data collected on salinity and ice thickness, analysis and discussion of alternative approaches for improving intake operation.

3. *A Study of Salinity in the Vicinity of the Coppermine River Water Intake*, Northwest Hydraulic Consultants Ltd., A. Babb, P.Eng., August, 1982.

   Discusses mechanism of saline water intrusion and field data collection. Recommends construction of a river bottom intake system, with a through-ice intake for use when saline water intrudes near intake.

4. *Design Brief – Proposed Modifications- Coppermine Water Intake, Coppermine N.W.T.*, Underwood McLellan Ltd., Ben Grieco, P.Eng., March 1984.

   Presents design basis for adjustable level intakes. Recommended that existing 'semi-portable' intake system be retained for emergency back-up use. Recommends a conductivity sensor be incorporated to stop pumps in event of salt-water intrusion in the intakes. Notes that it may be necessary to clean silt from the intakes.

5. *Coppermine Water Intake System – Excavation of Sand Project – September 1988 Diving Report*, Arctic Divers Ltd., Wayne Gzowski, October 1988.

   The introduction of the report provides a brief history of the permanent intakes from 1980 to 1988, and the repairs required between its installation in 1980 and 1988, including the installation of the swing arm intake system in 1984.

6. *Northwest Territories Water Quality Study – Coppermine, N.W.T.*, Roger M. Facey and Daniel W. Smith, July 1991.

   Objective of study was to identify the quality of source water and treated water delivered to consumers.

7. *Coppermine Water System Modifications – Final Planning Report*, Stanley Associates Engineering, May 1995.

Report discusses annual water usage, water supply quality and quantity, issues with the Coppermine River intake, and alternative water sources.

8. *Water Treatment Plant Pre-design Report, Kugluktuk, N.W.T. (2nd submission)*, Ferguson Simek Clark, August 1997.

   Refers to water treatment plant. Does not contain unique information relevant to the intakes.

9. *Water System Modifications, Kugluktuk, N.W.T. – Intake Structure Design Concept Brief (95% draft submission)*, Ferguson Simek Clark, January 1998.

   Discusses condition of pumphouses, reviews riverbed and ice conditions.

10. *Water Treatment Plant Pre-Design Report, Hamlet of Kugluktuk, NU – Final Design Brief*, Ferguson Simek Clark, April 1998.

    Refers to water treatment plant. Does not contain unique information relevant to the intakes.

11. *Water System Improvements – Kugluktuk, NU – Overall Design Brief, Supplementary Submission*, Ferguson Simek Clark, December 1999.

    Reviews improvements and upgrades to existing system. Provides demand forecasts and cost estimates.

12. *Water System Improvements – Kugluktuk, NU, Intake Structure Design Concept Brief, Supplementary Submission*, Ferguson Simek Clark, December 1999.

    Presents a Kepner-Tregoe analysis of various intake alternatives, including modifications to existing intake, various locations for intakes including bridge piers, rock locations, and cantilevers.

13. *Hamlet of Kugluktuk, NU – Water System Improvements – Final Design Brief*, Ferguson Simek Clark, December 1999.

    Similar to Document 11.

14. *Kugluktuk Water Intake System and Screens Inspection & Cleaning Report*, Arctic Divers, August 2002.

Contains a summary of dives from 1998 to 2000, including observed conditions and repairs performed.

15. *Kugluktuk Water Intake System Inspection & Sand Excavation Report*, Arctic Divers, February 2004.

Similar to Document 14.

In brief, the following solutions are considered in these reports:

- New water source; either lakes in the area, or Coronation Gulf, with reverse osmosis desalination;
- Relocating the intakes in the Coppermine River upstream of the saltwater intrusion zone, approximately 8 km, with either trucked or piped transfer to the community;
- Relocating the intakes approximately 100 m downstream of the present location in the Coppermine River to a scour area where currents tend to remove the sediment by either extending the intakes or constructing a new intake and pumphouse;
- Construct a pier in the river with intakes at various levels to obtain raw water below ice and above the saline layer;
- Earthen reservoir for one year storage near the community;
- Short-term (5-7 day) earthen reservoir;
- Raised near-shore intake attached to rock face;
- Raised intake in notch in rock, approximately 200 m downstream from existing intake;
- Unsupported bridge pier, either near shore and accessible via catwalk, or off shore and accessible by boat or ice;
- Relocated submerged intake, extending the existing intake pipes approximately 50 m downstream;
- Cantilevered, adjustable raised intake;

- Two-season system; existing intake in winter, adjustable cantilevered intake in summer.

These alternatives were developed before the stability problems with the current intakes were apparent. Temporary measures have been taken to stabilize the intakes, but as long-term stability must now be considered, alternatives that reuse the existing intakes may be more problematic now than when they were originally considered.

A short-term earthen reservoir was actually constructed near the WTP, which would meet the goals established in the planning study, but would not address the intake stability issues.

The Data Gap analysis concludes by considering four alternatives that would be applicable for future modifications or improvements:

1. Extend existing submarine intake 50 – 100 meters downstream to the scour area. This can only be regarded as a temporary solution until the existing intake pipes are stabilized. The scour area would tend to remove sediment from the intakes, and this solution is likely the least expensive, however it does not address the stability issue or alleviate the salinity issue. There is a possibility the riverbed could change in the future;

2. New intake approximately 8 km upstream in the Coppermine River, with either trucked or piped (submarine or overland) transmission to the community. This option addresses the salinity and stability problems and may lessen turbidity, but is one of the most expensive alternatives;

3. New intake near the rock face 200 meters downstream of the existing intakes. This option addresses the stability and sedimentation problems, but does not address the salinity or turbidity. There is a possibility the riverbed could change in the future;

4. Long-term earthen storage reservoir. Addresses stability problem if temporary pumping is used, reduces turbidity through settling, manages salinity by only pumping once per year, however this option is expensive and requires considerable land and materials.

2.0 DESIGN PARAMETERS

2.1 CLIMATE

Kugluktuk has a harsh arctic climate. Snowfall has been recorded in every month of the year, but generally in trace amounts or zero during July and August. Ice generally forms in early October and persists until early June. Water temperature is generally below 0 °C, reaching 4 °C two months of the year. The average depth of the Coppermine River has been previously determined to be less than 3.0 m, with a maximum recorded ice depth of 2.2 m. Based on Environment Canada data for 1977 – 2007, the mean temperature varies from –27.6 °C in February to 10.7 °C in July. The data shows a trend toward a slight increase in temperature over this time period.

The following climate data for Kugluktuk was obtained from Environment Canada:

Prevailing Winds	May - Sept	E
	Oct - April	SW
Wind Speeds		
mean	16.1 km/hr	
extreme high	93.0 km/hr	
extreme gust	106.0 km/hr	
Air Temperature		
recorded maximum	34.9 °C	
recorded minimum	–47.2 °C	
avg. min. January	–31.9 °C	
yearly avg.	–10.5 °C	
yearly avg. min.	–27.6 °C	
yearly avg. max.	10.7 °C	
Precipitation		
mean annual rainfall	133.4 mm	
mean annual snowfall	165.7 cm	
mean annual precipitation	249.3 mm	

2.2 INTAKE LOCATION

In choosing a location for the intake in the river, several factors must be considered. Preferably, the intake should be positioned to avoid the intake of saline water, it should be in an area of scour rather than deposition both to avoid sedimentation covering the intake and to reduce turbidity, and it should be in a stable location sheltered from ice damage.

An alternative to surface water intake is a groundwater intake in the talik below the river bottom is discussed in section 3.2.

The pumphouse should also be relocated to a more stable location. The pumphouse will continue to require an access road and a power supply. Therefore, if it is moved to a location significantly away from the existing road, a new road and power lines will need to be constructed.

2.3 LOGISTICS

The community of Kugluktuk is remote, and there is no access by road. This impacts the project scheduling, as materials can only be brought in during open-water seasons by barge, or by air at a prohibitive cost.

2.4 WTP OUTPUT

The WTP must be sized to allow 3.0 x the average day use over the design horizon (20-years). Population has been modeled using standard formulas and site-specific data for a 20-year design horizon. The standard formula for predicting total water use (TWU) for communities with a population between 0 and 2000 is:

$$TWU = RWU\ x\left[1.0 + \left(0.00023 x population\right)\right] \qquad \text{Eq 1}$$

where RWU is Residential Water Use.

The RFP reports that water consumption in 1993 was 73 L/person/day and has risen steadily over the years. It is unclear if that is RWU or TWU. The RFP also reports an annual usage for 2006 of 46,400,000 L. For a population of

1,302, this results in a TWU of 97.6 L/person/day. RWU can be calculated by re-arranging Eq 1:

$$RWU = \frac{TWU}{[1.0 + (0.00023 x population]} \qquad \text{Eq 2}$$

which yields measured RWU of 75.1 L/person/day. The water system foreman has reported that during peak consumption (summer) maximum day demands on Mondays and Fridays of approximately 360,000 L. Using a population of 1302 people, the current maximum TWU is 276 L/person/day. This is approximately 2.8 times average TWU and is about what is expected in a system of this nature. This data reaffirms the need to design the plant to handle 3.0 times the daily average.

The RFP suggests the following formula for calculating peak capacity based on MACA standards:

$$PDD_{design\ year} = PDF\ x TDF\ x\ ADD_{design\ year} \qquad \text{Eq 3}$$

where;

$PDD_{\text{design year}}$	= Peak Day Demand in the design year
PDF	= Peak Day Factor = 1.5
TDF	= Truck Delivery Factor
	= 7/5 based on water delivery 5 days per week
$ADD_{\text{design year}}$	= Average Daily Demand in the design year (TWU)

Equation 4 results in a 2.1 peak demand factor. ADWE strongly recommends using a factor of 3.0 as the current plant is already experiencing a 2.8 peak demand factor.

2.4.1 Population and Water Demand Projection

Population growth can be estimated using the following equation:

$$N = N_0 (1 + r)^n \qquad \text{Eq 4}$$

where;

N = estimated population for final year
N_0 = population for start year
r = average annual growth rate
n = number of years

Statistics Canada (Appendix A) reported the population of Kugluktuk to be 1,302 in 2006 and 1,212 in 2001. Equation 4 can be rearranged to calculate the average annual growth rate:

$$r = \left(\frac{N}{N_0} \right)^{1/n} - 1 \qquad \text{Eq 5}$$

This yields an annual growth rate (r) of 1.44% from 2001 to 2006. The estimated population for 2030 would therefore be 1,835 if the average annual growth rate is maintained. 2030 was used for the design horizon as the complete water systems upgrades (intake and treatment) are not anticipated to be completed until 2010.

In calculating water demand for 2030, a design RWU value of 90.0 L/person/day was used as per design guidelines to account for potential changes in water use in the community. The community may see an increase in water use with an increased aesthetic quality of the water and water usage habits may change. Design guidelines indicate that systems can typically expect to reach the 90.0 L/person/day RWU within 5 years. Using this data and the above population projection, demand for 2030 was calculated to be 235,000 L/day. The WTP will be designed for 3.0 x the average day use. Therefore, the system is to be designed to have a peak capacity of 705,000 L/day or 30 m^3/hr (130 USGPM).

2.5 WATER STORAGE

Water storage is an area of current concern for the Kugluktuk Water System. There is a lined raw water holding pond of approximately 800,000 to 1,000,000 L capacity that is currently being used as a settling pond. As the pond was not designed for settling, no provision was made in the design for the removal of sludge. Sludge is removed annually by taking the pond out of service and emptying it. One possible solution would be the installation of tube or plate settlers prior to the storage pond to enhance treatment and prevent excessive sludge build-up within the pond.

In addition to storage of raw water for saline intrusion events, storage of treated water is required for fire storage and equalization storage, as well as dead storage and in-plant use. Water storage is used as a safety factor for the possibility of problems with the water treatment or intake processes. Raw water storage may be of use in the event of saline invasion of the intake, but may not be that useful in case of problems with the WTP.

Treated water storage currently consists of two 178,000 L tanks (356,000 L total) with 45,000 L in each tanks reserved for fire storage (90,000 L total). Therefore, the system currently has a total available treated water storage of 266,000 L.

2.5.1 Fire Storage

For fire protection purposes, MACA guidelines recommend a minimum truckfill rate of 1000 L/min. If this rate cannot be obtained directly from the source, a minimum of 60,000 L of storage should be reserved for fire protection. Sizing the entire system, raw water intake and treatment, for 1000 L/min would eliminate the need for fire water storage. However, 1000 L/min would be a considerable over sizing of the system and therefore the minimum 60,000 L for fire storage is recommended. Alternatively, the system can be designed to allow the treatment process to be bypassed in case of emergency fire demand and the intake pumps sized for 1000 L/min. However, the system would still require a rather large intake pump (fire pump) and there would be sanitary repercussions of introducing raw water into areas of the system designed for treated water only.

2.5.2 Equalization Storage

Equalization storage is used when the supply capacity is limited and cannot meet the peak demand. Per MACA standards, equalization storage is equal to the peak day demand less 8 hours of system production. A peak capacity of 705,000 L/day (29.4 m^3/hr) was calculated in section 2.4.1. The system will therefore be able to produce 235,000 L in an 8 hour period and 470,000 L of equalization storage will be required.

2.5.3 Dead Storage and In-Plant Use

Dead storage is the amount of storage unavailable for use. Dead storage is assumed to be 5% of the overall storage capacity of the system.

An additional 10% of the peak day demand has been allowed for in-plant and facility use; this includes backwash (5% per day for normal use, 7% for spring break-up), daily plant washdown water, and domestic water for toilets, sinks, and laboratory use.

2.5.4 Total Storage

The total storage required for fire protection, equalization storage, dead storage, and in-plant use is estimated to be 624,000 L. Currently, the total tank storage at the plant is 356,000 L and therefore an additional 268,000 L is needed.

2.6 WATER QUALITY

According to available raw water quality data for Kugluktuk, the raw water meets the requirements of the Guidelines for Canadian Drinking Water Quality, with the following exceptions:

- Turbidity of treated water frequently exceeds Health Objective of "less than or equal to 0.3 Nephelometric Turbidity Units (NTU) in at least 95% of the measurements made, or at least 95% of the time each calendar month, and shall not exceed 1.0 NTU at any time". Per the RFP, average monthly levels in the WTP vary from a low of 4 NTU to a high of 26 NTU. In spring, raw water turbidity of 99-130 NTU has been reported. Filtration of this water brought turbidity levels down only to 37-52 NTU in the treated water.

- Seasonal intrusion of salt water leads to total dissolved solids (TDS) concentrations that exceed the Aesthetic Objective of 500 mg/L. When this occurs, an alternate surface intake is used to pump fresh water from above the saline layer. Since the salt water is not pumped, there is little data available for TDS in this situation.

- Iron and manganese levels occasionally exceed the Aesthetic Objectives of 0.3 and 0.05 mg/L

- Available information on natural organic matter (NOM) concentrations is insufficient to determine compliance with regulations for disinfection byproducts (DBP)

2.7 TRUCKFILL RATE

The current truckfill rate has been observed to be between 1200 - 1500 L/min. At this flow rate, it takes approximately 15 minutes to fill a water truck. A fill time of approximately 5 minutes is desirable. In addition, the flow rate worsens as the tanks empty, leading to the slowest flow occurring when fire reserves are in use. 1000 L/min is the required minimum flow rate for fire suppression purposes.

3.0 WORK DONE TO DATE

3.1 SITE VISIT

A site visit was conducted by representatives from ADWE, Hayco, EBA and CH2M HILL from July 31 to August 2, 2007. During this site visit, Hayco conducted a bathymetric survey using a handheld GPS unit with depth sounder to obtain riverbed data. CH2M HILL representatives visited the existing water treatment plant and met with the Senior Administrative Officer (SAO) and plant operators. Reports from Hayco and CH2M HILL are included in Appendices B and C, respectively. Their recommendations are summarized in the following sections.

3.1.1 Hayco Recommendations

The report issued by Hayco following the site visit summarized their findings on water depth and sediment size and provided recommendations on proposed new intake locations and boat speed restrictions.

Based on the bathymetric survey data, Hayco identified a depression in the riverbed approximately 7.0 m deep about 100 m downstream of the existing intake. This appears to be a scour area. To minimize sediment deposit around the intake, Hayco recommended placing the intake in this hole and constructing sandbag skimming walls to divert sediment.

3.1.2 CH2M HILL Recommendations

The report from CH2M HILL discussed the available raw water quality data and recommended that a monitoring program be established to measure raw water turbidity, Total Organic Carbon (TOC), Ultraviolet Transmission (UVT), iron and manganese levels. As recommended, UVT meter was purchased and a water sampling program was implemented.

3.2 GROUNDWATER INVESTIGATION

ADWE worked with Nuna Burnside Engineering and Environmental Ltd. to investigate the possibility of a groundwater intake in the talik beneath the riverbed. The location of a suitable aquifer was not known, and therefore it was not possible to choose drilling locations. Drilling costs would be substantial since many holes would be required, with no assurance of locating an aquifer. As an alternative to drilling, a geophysical survey was performed above the ice during the spring of 2008 (Appendix D). Several potential talik aquifer targets were identified beneath the river. Drilling to investigate these targets was discussed; however, the cost of drilling was believed to be of a similar order of magnitude as the cost of installing a horizontal intake well. A tender was issued for the intake installation in August 2008. The prices received for this tender were significantly higher than anticipated. In addition, there is a risk that the groundwater may not be of suitable quality for a potable water source, or that there may not be a sufficient quantity of water.

Because of the high cost and risks associated with the intake well, ADWE recommended that an investigative drilling program proceed through the ice during the winter of 2009. This drilling program will allow tests of the groundwater quality, as well as providing information on drilling conditions for a potential groundwater intake.

By client request, ADWE is now proceeding with the surface intake design. The surface and groundwater intake designs will occur in parallel.

4.0 DISCUSSIONS AND RECOMMENDATIONS

4.1 RELOCATION OF INTAKE

Before addressing the treatment process, the intake location should be determined, as relocating the intake may affect the raw water quality and change the treatment requirements. Four locations for the surface water intake and pumphouse were examined and are outlined below. Sketches of all four options are available in Appendix E. Suitability of a groundwater intake will be assessed further after the 2009 winter drilling program.

4.1.1 Move pumphouse and intake to new location

During the earlier bathymetric survey of the Coppermine River, a hole approximately 7 m deep was discovered, which appears to be an area of scour. The intake could be located in this hole and the pumphouse relocated to the rock cliff above the hole. This hole would shelter the intake, there would be little sediment and the intake can be located deep enough to avoid the ice. The rock would be a more stable platform than the current riverbank location.

4.1.2 Move intake and run pipe underwater

The deep hole in the river could also be reached by running the pipeline along an existing trench in the river that extends from the current location to the hole. This trench appears to be an area of scour. The trench would shelter the pipeline, protecting it from turbulence. The trench is sufficiently deep to locate the pipe approximately 3 m below the surface of the water, which is deep enough to be below the maximum depth of ice. The pumphouse would be moved back from the river to a more stable sheltered location on rock.

4.1.3 Move intake and run pipe through rock

Similar to the previous option, the intake would be located in the hole, with the pumphouse moved back from the riverbank at the current location, but the hole could be reached by running the pipe along the rock face on the shoreline by hanging the pipe to rock anchors. The pipe would be located high enough to protect it from ice damage. Some drilling/blasting may be required to burry and/or berm over the pipe as it enters the water at the shoreline. The hanging pipe supports could also be built in conjunction with the auxiliary catwalk intake system.

4.1.4 Shorten intake and keep present location

The intake could be kept at the present location, but the pipe could be shortened in order to move the intake closer to shore. This would potentially locate the intake in an area of scour in order to prevent sediment build-up. The pumphouse would again be moved back from the riverbank.

4.2 DISCUSSION OF INTAKE LOCATION OPTIONS

The riverbank at the current location appears to be unstable. Although the pumphouse would be moved back, the movement of the riverbank could still cause differential movement by pulling on the intakes.

Relocating the intake to the hole appears to offer the best solution for stability and shelter from ice and sediment. As the hole is 7 m deep, there is sufficient depth available to locate the intake well below the largest recorded depth of ice.

The reduction in sediment near the intakes will also assist with improving water quality and increasing filter life in the WTP, as the raw water will be much lower in suspended solids. Locating the pump in this scour area should also reduce or eliminate the need to retain divers to clear the intakes. However, periodic inspections would still be required.

Each intake could be located at a different elevation. One would be deep in the hole and the other would be just below the ice line. The higher intake could then be used during times of salt water invasion.

Moving the pumphouse to the location of the hole would require a new road to access the pumphouse. Based on the topography of the area between the location and the WTP, this would require significant blasting. Due to the cost of blasting and the difficulty of bringing in materials, this road would be very expensive.

Running the pipe along the underwater trench is a valid cost-effective option that would shelter the pipe and allow the intake to be located in the hole. The pipe could be further sheltered by a wall of sandbags along the trench if needed, and the entry point into the river can be sheltered against the rock and protected from ice. The pumphouse can be moved onto rock and can still be accessed via the existing road. A disadvantage of this option is it may interfere with an auxiliary intake in that location and the berms may require ongoing maintenance.

Running the pipe along the shoreline and hanging it from the rock is also a valid cost-effective option. This option has the advantage of having less pipe length with need of protection from ice. It may also have less O&M cost as long sections of berms will not need to be inspected and/or repaired. The hanging pipe support could also be constructed with catwalk system.

4.3 INTAKE DESIGN

From previous reports, sediment in the Coppermine River is classified as fine sand, with median grain size (D_{50}) approximately 0.5 mm in the area of the intake. The river is shallow, with an average depth of less than 3 m, and speedboats travel at high speed in the area of the intakes. A combination of wind-driven current, orbital velocity from wind-generated waves, propeller wash from speedboats, and suction velocity through the intake screen easily transports the fine sand toward the shore. The recommended intake location discussed above would assist with reducing sediment around the intakes.

The proposed intake would have two screens, with one available for temporary backup. In accordance with Fisheries and Oceans guidelines, the suction inflow velocity will be 11 cm/s. The screens will be constructed of 1.8 mm diameter wire with 0.38 mm gaps between the wires. This gap is less than the median size of the sand. In order to meet the projected peak water demand of 29.4 m^3/hr, the screen will have a diameter of approximately 324 mm. This screen will be connected to a 300 mm intake pipe and a 25 mm air pipe.

In order to reduce plugging of the intake screens by aquatic life, a copper-nickel alloy will be used. This will also allow for easy removal of animal or vegetable matter by scrubbing or high-pressure washing. The intake screen will be cleaned every 2-3 days by an airburst system, which will force compressed air inside the screen via the 25 mm pipe.

To further reduce sediment around the intake, a skimming wall in front of intakes is suggested. This would have the effect of deflecting the current that carries sediment towards the shore, as well as guiding bed sediment past the intakes. The proposed wall could be a temporary structure built from sandbags.

It is not likely possible that one intake structure can be completely successful in eliminating the salinity problem. Rather, the best result is likely to be minimization of days when an alternate intake must be used. This may be achieved by staggering the intake height. An effective alternate system should be maintained, such as the present portable pumphouse, which could provide water through the ice. Consideration should also be given to providing floatation for this pumphouse; currently, it is used from the ice surface, but recently, salinity events have been occurring before the ice is sufficiently thick to support the weight of the pumphouse. Floatation would allow it to be used when ice is not present.

Alternatively, an auxiliary pump lowered from a partially cantilevered catwalk that is attached to the first rock nose to the east of the intake pumphouse should provide all season back-up supply. The pump's height could be adjusted so that it draws water from above any layer of salinity, and could also be dropped through a hole bored in the winter ice. This intake could also be easily attached to the main intake system.

4.4 TREATMENT PROCESS CHANGES

4.4.1 Turbidity

The primary issue with treatment of water from the Coppermine River is high turbidity. Data on raw water turbidity shows levels from 0.4 to 170 NTU during 1967-2007. Treated water turbidity frequently exceeds the Health Canada guideline of 0.3 NTU and the filters are frequently overwhelmed by sediment.

In addition to any improvement gained by moving the intake, settling of sediment before the filtration stage is recommended. The current method of settling using the holding pond is problematic as there is no way of removing sludge. Annual build-up of sludge and increased demand has reduced the pond’s capacity from the designed 10-day capacity to 7 days. Even with sludge removal in the storage pond, a significant amount of sediment is plugging up the filters. Adding a pre-settling process to the system may remove much of the sediment. Settling can be accomplished by settling tanks, tube settlers, or chemically assisted filtration. The type of settling process would be determined based on the results of water sampling program. Sludge from the settlement process can be removed and taken to the community landfill site to be used as cover material or to the lagoon by sewage trucks. Certain chemicals used in the flocculation step of chemically assisted filtration can enhance phosphate removal in sewage lagoons. An addition to the existing building will be required in order to install the settling process.

4.4.2 TDS

Prevention of saline water intrusion will be covered by the intake design and raw water storage. It will not be dealt with by treatment.

4.4.3 Iron and Manganese

There is insufficient water quality data for process design purposes for iron and manganese. Available data indicates that the levels are typically very low, however previous reports have indicated that concentrations in excess of the Health Canada aesthetic guidelines do occur occasionally. The data does not clearly indicate whether these metals are in dissolved or particulate phase. If it is determined that the water contains significant amounts of dissolved iron and manganese, chemical oxidation and precipitation (greensand filtration, for example) may be required in order to prevent fouling of the filtration process. This would not affect the current cartridge filters, but may be a concern in the future if a more advanced filtration process is used. According to previous reports, the Coppermine River is well aerated, and there have been no reports of fixture staining in Kugluktuk, therefore the iron and manganese are most likely in the oxidized, particulate phase, and are present as turbidity during run-off events. In this form, these metals would not affect treatment process design. Additional sampling is needed to verify the chemical phase of the iron and manganese.

4.4.4 Natural Organic Matter

The hamlet has obtained a UVT meter in order to measure NOM concentrations, and measurements are being performed regularly. Elevated NOM levels can lead to the formation of disinfection byproducts (DBPs) during chlorine disinfection and can also affect the design of clarification processes.

4.5 WATER STORAGE

Preliminary calculations for water storage requirements are shown in section 2.5. Water storage was calculated using an assumed WTP output of the design criteria. Water storage requirements are based on the production capacity of the water treatment plant. Therefore, the water storage requirements will need to be reassessed once the new treatment process has been finalized and the actual plant production capacity is known. Also, a contingency factor is recommended for when sizing water storage tanks to deal with possible uncertainty with population growth projections.

4.6 TRUCKFILL RATE

The option of changing the impellor in the current pump was investigated but, per the manufacturer, this would only provide a slight increase in flowrate. The desired improvement in truckfill rate can be accomplished by replacing the current pump with a larger one that can achieve a 5-minute fill time when the tanks are low.

5.0 CLOSURE

In order to prevent sediment deposition at the intake location and prevent differential movement of the pumphouse, it is recommended that the intake be relocated from the unstable riverbank to the 7-meter-deep hole identified as a scour area in the river. The pumphouse should be moved away from the unstable riverbank. In order to make use of the existing access road and avoid the cost of constructing a new road, the pumphouse would be kept in the same area, but moved back against the rock. To reach the pumphouse, the intake pipe will be run along the rock face by hanging rock anchors. Prior to final design, the location will need to be observed at break-up to ensure that the ice conditions will not affect the intake. In order to prevent the pumping of saline water, intake heights may be staggered. An effective alternate system such as the current portable pumphouse should be maintained.

Following the installation of the new intake and pumphouse, settling tanks should be added to the treatment process to reduce the demand on the filtration cartridges. A building addition will be required in order to accommodate the settlement process. It would be advisable to include extra space in this addition for future replacement or improvement of the filtration system to add capacity in order to meet water usage requirements toward the end of the design period and beyond. Additional treated water storage capacity is also required in order to meet recommended storage volumes for fire protection and equalization storage.

The new intake location should eliminate the need to retain divers to clear the intakes. Additionally, the reduction in sediment in the pumped water combined with the removal of sediment by the settling tanks will reduce clogging and wear on the filter cartridges.

Monitoring of raw water turbidity, TOC, UVT, iron and manganese levels should continue.

Replacement of the pump at the truckfill station with a larger pump will enable the station to meet the required flowrate and fill time.

A P P E N D I X   A

STATISTICS CANADA COMMUNITY PROFILE
KUGLUKTUK, NUNAVUT

Print Close

Statistics Canada Statistique Canada

Canada

Population and dwelling counts	Kugluktuk Nunavut (Hamlet) — Kugluktuk, Hamlet Total	Male	Female	Nunavut (Territory) — Nunavut Total	Male	Female
Population in 2006[1]	1,302			29,474		
Population in 2001[1]	1,212			26,745		
2001 to 2006 population change (%)	7.4			10.2		
Total private dwellings[2]	407			9,041		
Private dwellings occupied by usual residents[3]	359			7,855		
Population density per square kilometre	2.4			0.0		
Land area (square km)	549.61			1,932,254.97		

Notes:

1. 2006 and 2001 population based on 100% data

   Statistics Canada is taking additional measures to protect the privacy of all Canadians and the confidentiality of the data they provide to us. Starting with the 2001 Census, some population counts are adjusted in order to ensure confidentiality.

2. Total private dwellings

   For the 2006 Census, a private dwelling is defined as: A set of living quarters designed for or converted for human habitation in which a person or group of persons reside or could reside. In addition, a private dwelling must have a source of heat or power and must be an enclosed space that provides shelter from the elements, as evidenced by complete and enclosed walls and roof and by doors and windows that provide protection from wind, rain and snow.
   Private dwellings

3. Private dwellings occupied by usual residents

   A separate set of living quarters which has a private entrance either directly from outside or from a common hall, lobby, vestibule or stairway leading to the outside, and in which a person or a group of persons live permanently.
   Private dwellings occupied by usual residents

4. Age - 100% data

   Refers to the age at last birthday (as of the census reference date, May 16, 2006). This variable is derived from date of birth.

5. Median age

   The median age is an age 'x', such that exactly one half of the population is older than 'x' and the other half is younger than 'x'.

6. Common-law status - 100% data

   Refers to persons who live together as a couple but who are not legally married to each other. These persons can be of the opposite sex or of the same sex.

7. Legal marital status - 100% data

   Refers to the legal conjugal status of a person.

8. Never legally married (single)

   Persons who have never married (including all persons less than 15 years of age) and persons whose marriage has been annulled and who have not remarried.

9. Legally married (and not separated)

A P P E N D I X B

HAYCO BATHYMETRY AND INTAKE DESIGN REPORT

November 27, 2007 Hayco File: V13201030

A.D. Williams Engineering Inc.
P O Box 1529
4903-47 Street
Yellowknife, NT X1A 2P2

Attention: Mr. John Clark, P.Eng.

Dear Mr. Clark:

Subject: Coppermine River Water Intake

1.0 INTRODUCTION

Thank you for contacting Hay & Company Consultants (Hayco), a division of EBA Engineering Consultants Ltd. (EBA) with regard to intake design in the Coppermine River at Kugluktuk. Kugluktuk is located about 67° 49' 13" N and 115° 5' 4" W, about 450 km southwest of Cambridge Bay and approximately 1000 air kilometres north of Yellowknife. It is one of the largest communities in the Kitikmeot Region, with a population of approximately 1,500.

Kugluktuk draws its water from the Coppermine River through an intake pump-house and trucks supply water to the houses. The intake site is fairly close to the ocean, being about 2.5 km upstream from the Coronation Gulf. The river estuary extends approximately 7 to 10 km from its mouth to an area of rapids. It has an average width of 570 m; depths reach up to 8 m in isolated areas, but generally are less than 3 m.

The existing intake system, located on the west bank of the Coppermine River, has two parallel, connected intake screens. This system is about 25 years old, and over the last couple of years has experienced many problems. One of the major issues is sand build-up around the intake screens and the consequent disruption to the rate of water discharge. To address this problem, divers drag about one metre around these intake screens once every two years.

A site visit was conducted by John Clark, P.Eng (A. D. Williams Engineering Inc.), Justin Hazenberg (A. D. Williams Engineering Inc.), Dr. Shamsul Chowdhury, P.Eng (Hayco), and Sarah Freeman (EBA), from August 31, to September 2, 2007. During this site visit, a bathymetric survey was conducted using a Trimble GeoXT handheld GPS unit with SeaMax depth sounder. The data was post-processed using GPS Pathfinder Office

3.10 software. This equipment was installed on a boat, and a survey area was selected about 300 m along the shore from the existing intake and 300 m perpendicular to the shore. The sounding information has been collected with a high resolution grid spacing within this area. We also collected sounding information for a couple of river cross-sections. From our visual inspection, we found that the water depth in the Coppermine River is less than one metre in some places and averages about two to three metres.

The Government of Nunavut, Department of Community and Government, has been requested to install a better system, which can meet the anticipated demands over the next twenty years.

2.0 DESIGN CRITERIA

2.1 POPULATION

We reviewed the document "Nunavut: Community Population Projects 2000-2020" published by Nunavut Bureau of Statistics. The population for Kugluktuk is shown in the following Table 1:

TABLE 1: COMMUNITY POPULATION FOR KUGLUKTUK

Year	2000	2005	2010	2015	2020
Population	1,389	1,556	1,720	1,893	2,076

The design of this water intake will be based on the anticipated water demand for the next twenty years. The population for the year of 2027 has been estimated by the following equation:

$$N = N_o (1+r)^n$$

where N = estimated population for 2027

N_o = population for 2000

r = average annual growth rate

n = number of years

The average annual growth rate for the period 2000 to 2020 has been calculated to be about 2.03%. The estimated population would, therefore, be about 2,400 by 2027.

2.2 WATER DEMAND

In 1993, the estimated use of water in Kugluktuk was 73 litres per capita per day. Water demand per capita has increased over the years. In our design, we have, therefore, estimated the water demand by 2027 will be 100 litres per capita per day. The estimated total demand of water by that year, therefore, would be 240,000 litres per day. For our design purpose, we have used 250,000 litres per day.

2.3 TIDE LEVELS, WIND SPEED AND ICE THICKNESS

Tidal fluctuations in the Coppermine estuary can be computed from the Canadian Tide & Current Tables (Volume 4), published by the Canadian Hydrographic Service, which is provided in the following Table 2:

TABLE 2: TIDE ELEVATION FOR KUGLUKTUK

Description	Tide Elevation
Higher High Water Level, Large Tide (HHWL)	0.4 m
High Water Level, Mean Tide (HWL)	0.4 m
Mean Water Level (MWL)	0.3 m
Low Water Level, Mean Tide (LWL)	0.2 m
Lower Low Water Level, Large Tide (LLWL)	0.2 m

Note: Tide elevations refer to Chart Datum

Wind speed data recorded for the period 1978 to 2007 has been collected for the closest wind station (Kugluktuk Airport) from the Meteorological Service of Canada. Wind speed data has been analyzed and calibrated with the wind speed data from another independent source. The wind speeds were calibrated to pressures from the National Building Code of Canada (NBCC, 1995). The scaled wind speed for eight compass directions are summarized in Table 3.

TABLE 3: WIND SPEEDS FROM EIGHT DIRECTIONS

Directions	1 Year (kph)	1:10 Year (kph)	1:50 Year (kph)
NE	54.4	71.6	83.6
E	75.4	98.2	114.2
SE	52.7	73.5	88.8
S	69.3	94.0	111.2
SW	78.7	100.5	115.8
W	82.3	105.5	121.8
NW	83.7	108.9	126.5
N	82.3	107.5	125.2

High wind speeds from the east, northwest and north directions may raise water level about 0.6 m onshore.

Ice generally forms over the Coppermine estuary in early October and stays until early June. The thickness of the ice varies with the severity of the winter. Based on the documents reviewed, the recorded maximum thickness of the ice in the Coppermine River in the spring is about 2.2 m.

2.4 SEDIMENT SIZE

From our field observations, we conclude the average water depth for the Coppermine River is shallow (less than 3 m) and speedboats travel at a high speed. It is reported that sand grain sizes close to the government dock area about 1.5 km downstream of the intake are D_{90}=1.2 mm, D_{50}=0.5 mm and D_{35}=0.4 mm. In 1997, AGRA Earth & Environmental Ltd. (Yellowknife) carried out a sediment study 50 m downstream of the existing intake screen. They reported that most of the sand sample grain sizes ranged from 1.18 mm to 0.30 mm, which is classified as fine sand according to the unified soil classification (USC). The median size of sand (D_{50}) around the intake screen area is about 0.5 mm.

3.0 PROPOSED NEW INTAKES

The average water depth for the Coppermine River is less than 3.0 m within a couple of kilometres of the existing intake screen. The wind driven current, orbital velocity developed by wind generated waves, propeller wash, and suction velocity through the intake screen can easy transport this fine sand towards the shore. From our sounding survey, we have found a hole about 6.0 m deep, about 100 m downstream of the existing intake. We consider that this may be the optimum location to install the intake screens. Two intake screens are proposed in this area, with one available for temporary backup. The suction inflow velocity is calculated at about 11 cm/s to minimize sediment transport. The proposed intake screen is made from 1.8 mm diameter wire with gaps between the wires of about 0.38 mm, which is less than the median size of the sand. The required size of the intake screen is estimated at about 315 mm diameter and the length of the screen is 1.5 m making it capable of supplying 250,000 litres/day. This intake screen will be connected to a 250 mm (10 in) intake pipe and a 25 mm (1 in) pipe.

Intake screens are subject to fouling and plugging by vegetation or aquatic life, which can include zebra mussels. To date, 100% prevention of plugging by mussels is not possible; however, a copper-nickel alloy coating will aid in minimizing the problem and allow for the easy removal of mussels by physical scrubbing or high pressure cleaning. An airburst system will be installed to clean the intake screen once every two or three days. This will be done by forcing compressed air inside the screen through the 25 mm pipe.

Sediment build-up in front of the intakes is a common problem for thermal power plants that withdraw water from relatively small rivers or shallow rivers. To address this problem, skimming walls with vane arrays along the intake entrance or submerged guide walls have been installed in front of the intakes of thermal plants. The skimming walls guide bed sediment past the intake while forcing the intake to draw water from elevations substantially above the riverbed. The skimming walls eliminate the sediment-entraining action of eddies shed from the upstream and downstream shoulders of the intake.

A skimming wall is proposed to deflect the sand movement in front of the intake screen due to the wind driven current, orbital velocity due to wind generated waves, propeller wash, waves generated by speedboats, and river current. To avoid building a permanent structure for this skimming wall in front of intake screens, we propose a temporary structure, which may be built by stacking sand bags.

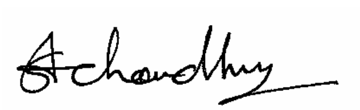
The proposed location and configuration of the intakes are shown in Drawing No. D101.

4.0 RECOMMENDATION REGARDING BOAT SPEED

The average water depth in the Coppermine River in front of the intake screen area is about 3 m and the water depth is less than 1 m deep in some places. Since the maximum ice thickness in winter is about 2.2 m, it would not be possible to raise the intake screen much from the river bottom. It was observed during our site visit that motorboats travel in front of the intake area at a high speed. The Coppermine riverbed consists of mostly fine sand; this class of sand will be moved by the propeller wash and waves generated by motorboats. It is recommended, therefore, that the speed of motorboats around the intake area be reduced.

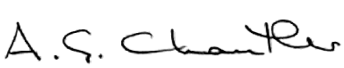
We trust the information provided in this report meets your requirements. Should you have any questions or comments, please contact the undersigned at your convenience.

Sincerely,
Hay & Company Consultants
(a division of EBA Engineering Consultants Ltd.)



Dr. Shamsul Chowdhury, P.Eng.
Senior Hydraulic Engineer

Reviewed by:



Dr. Adrian Chantler, P.Eng.
Principal

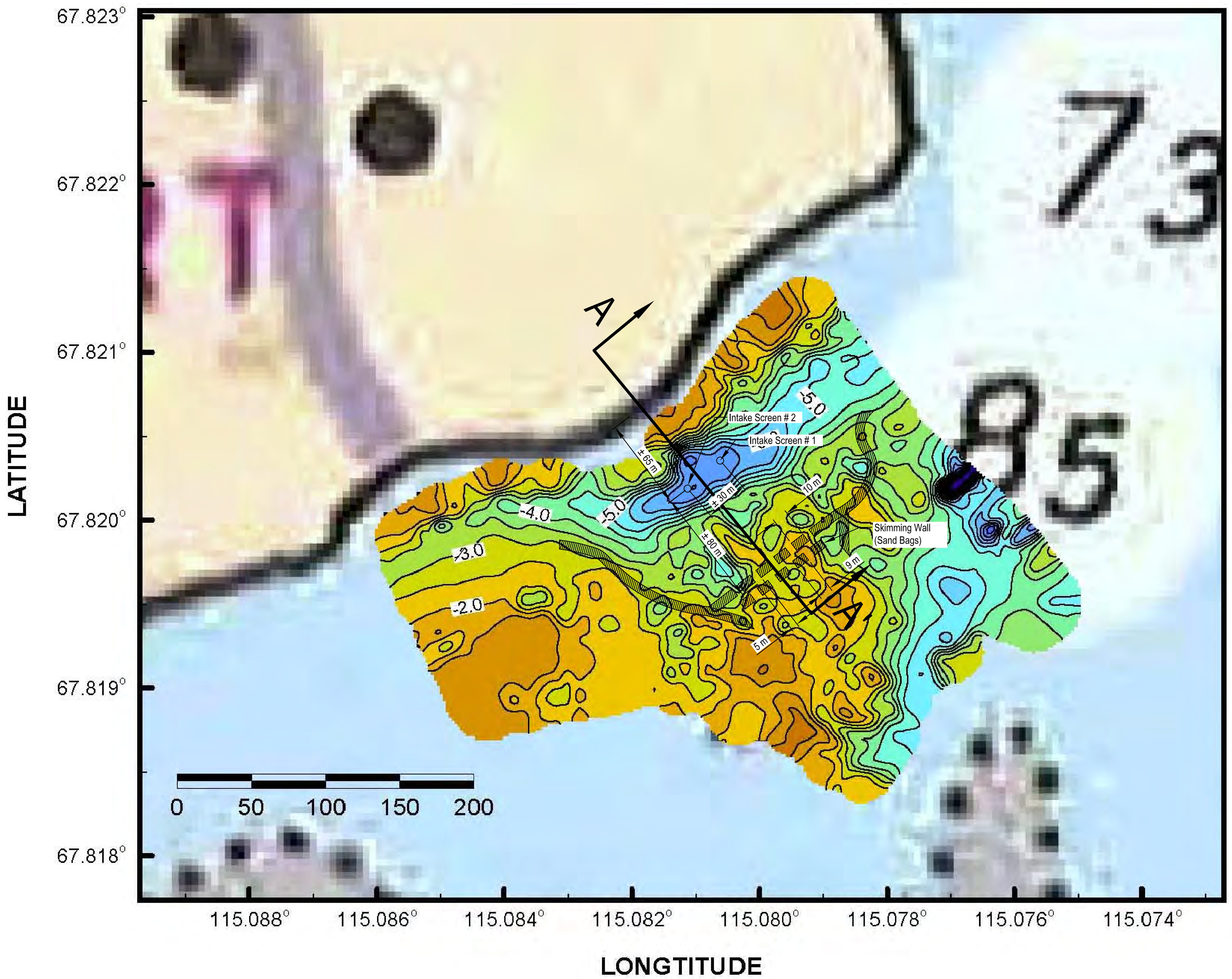
REFERENCES

Journal of Hydraulic Engineering (ASCE), May 2006. Case Study: Sediment Control at Water Intake for Large Thermal-Power Station on a Small River, 440 – 449.

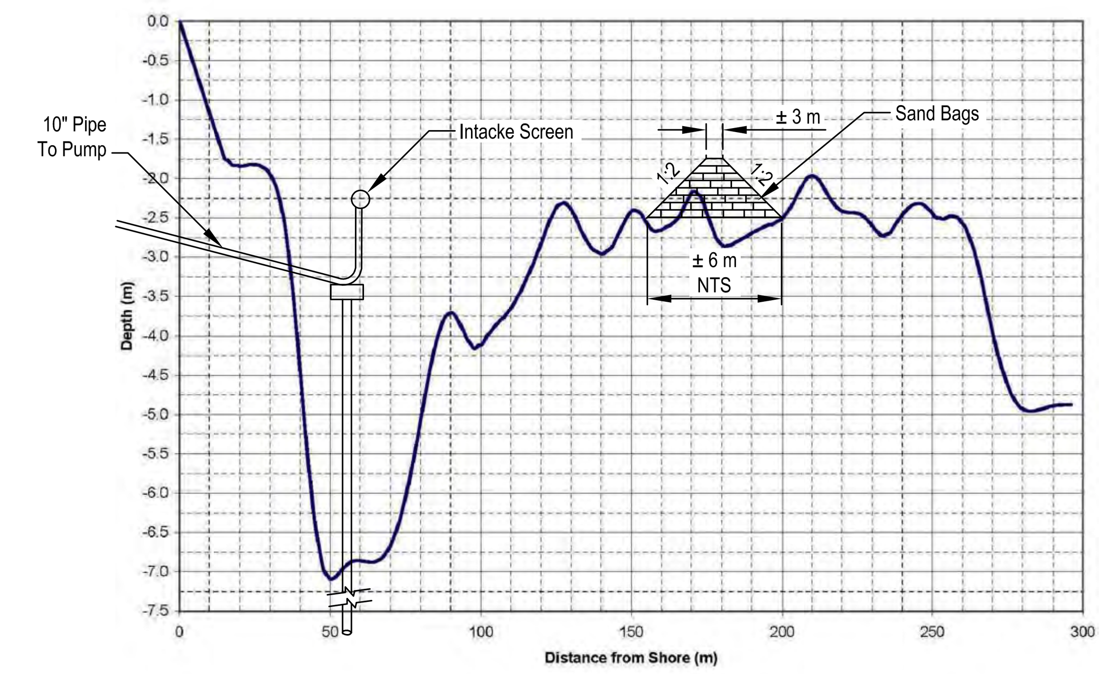
Nunavut Bureau of Statistics, 2000. Nunavut: Community Population Projections 2000 – 2020.

Journal of Hydraulic Engineering (ASCE), June 1998. Sediment Control at Water Intakes Along Sand-Bed Rivers.

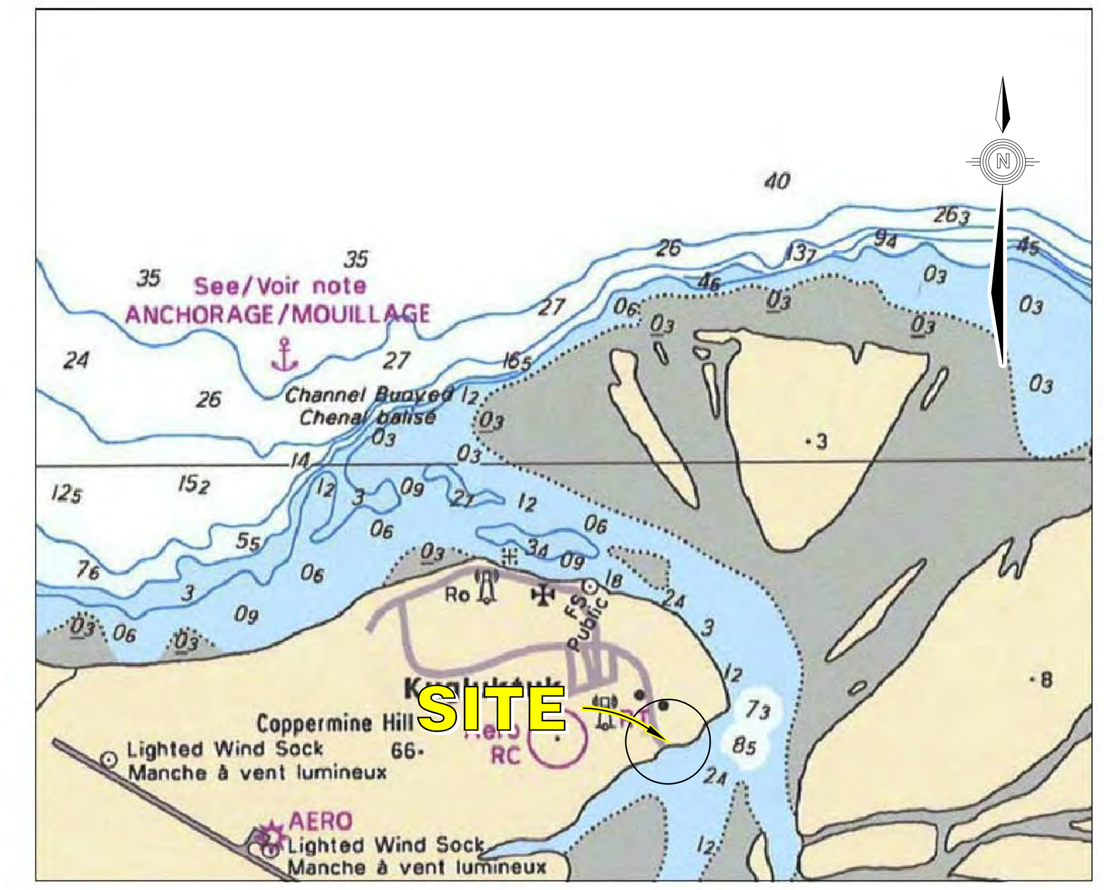
FIGURE



PLAN

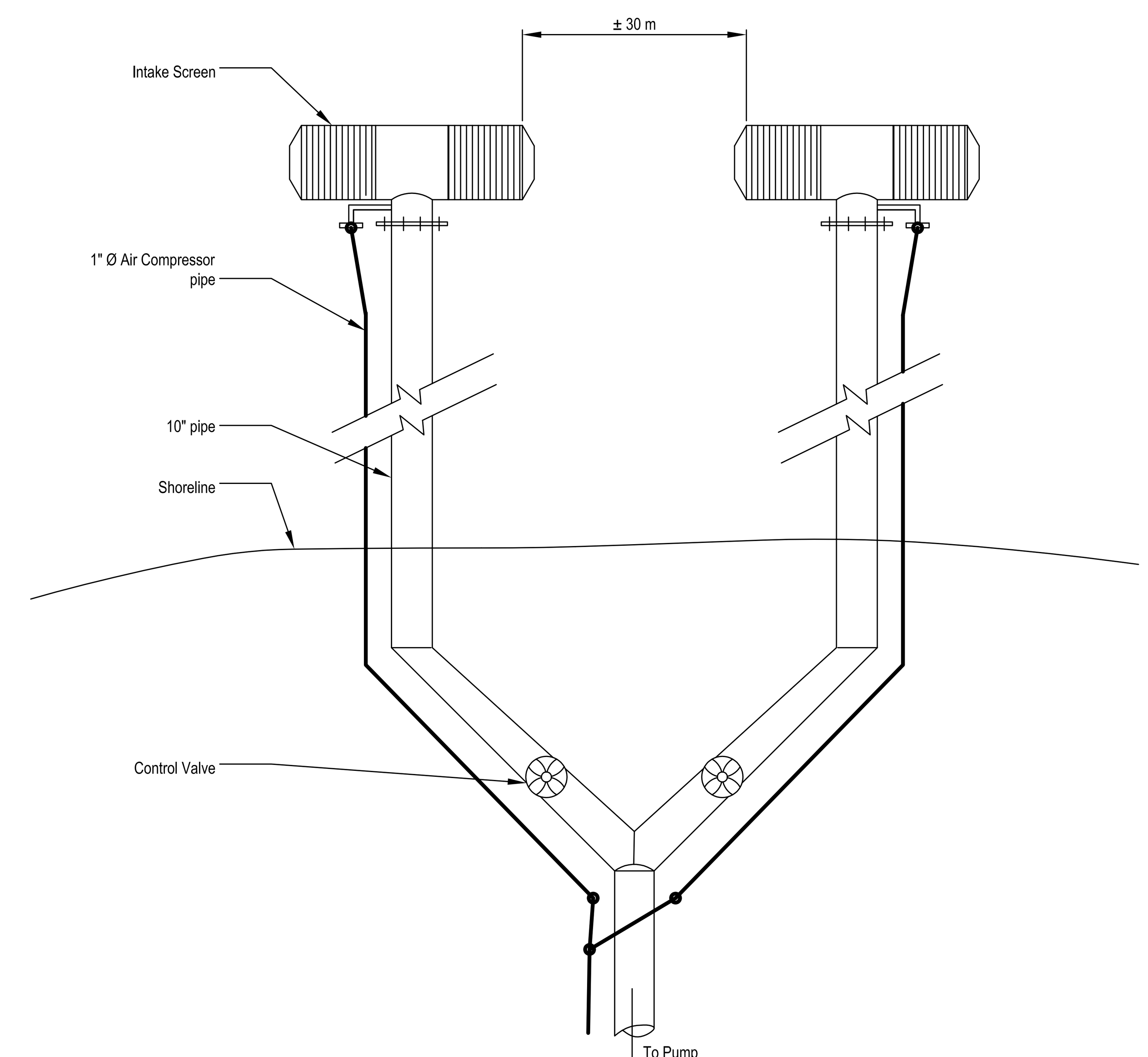


SECTION A-A'



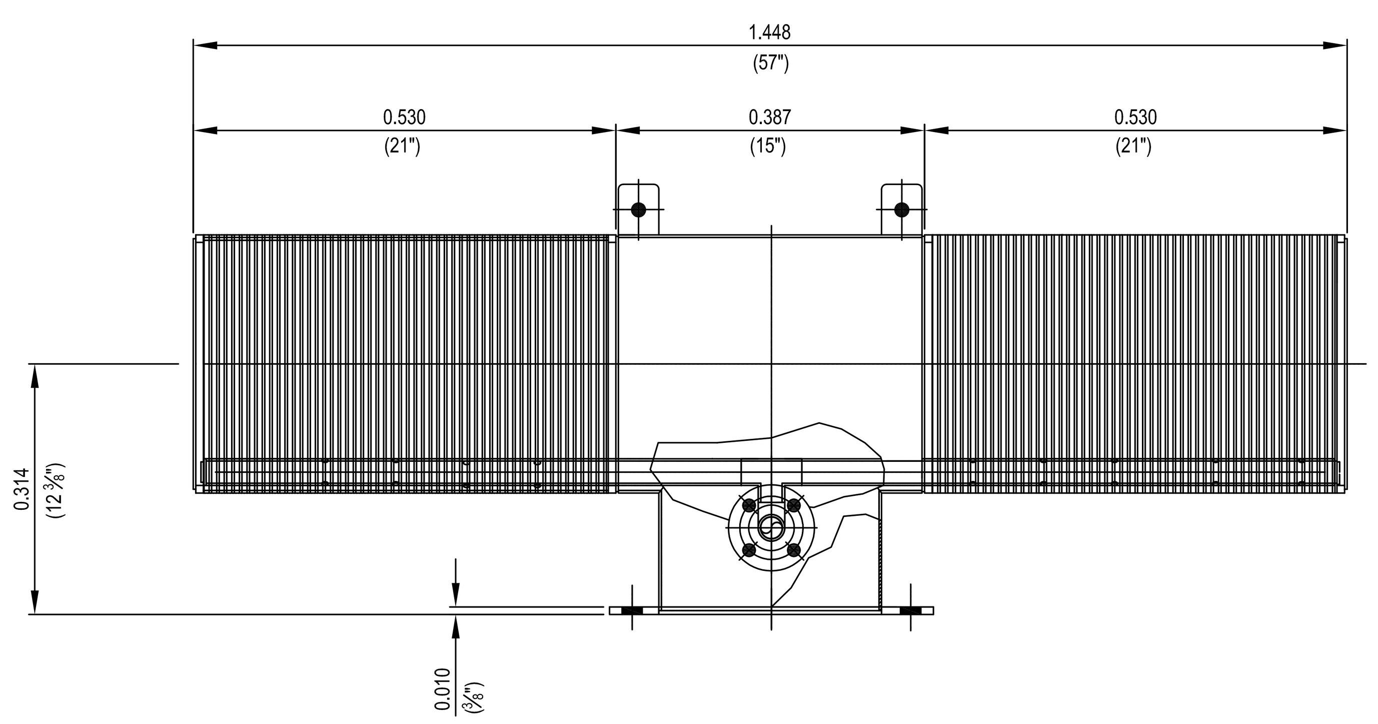
KEY MAP

SCALE: NTS



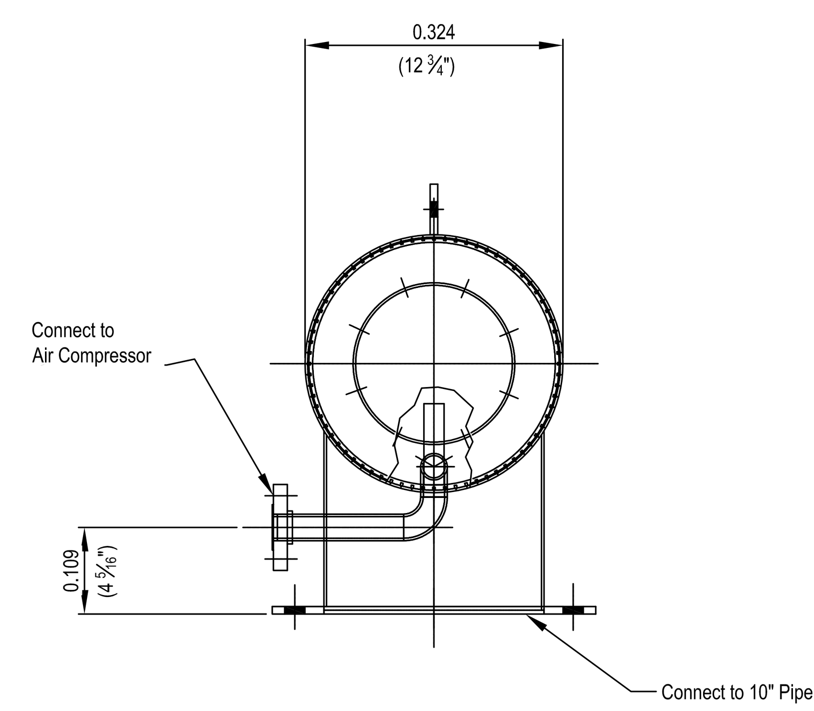
INTAKE SCREEN PLAN

SCALE: 1:30



T - INTAKE SCREEN ASSEMBLY

SCALE: 1:7.5



SIDE VIEW OF SCREEN

SCALE: 1:7.5

NOTES

1. All dimensions shown are in metres, unless noted otherwise.
2. "T-Intake Screen 12 3/4" O.D. Assembly & Details", Drawing No. 111607, provided by 'Hendrick Screen Co.", dated Novemver 16, 2007.

SCALE 1:200

STATUS	DATE	DWN	CKD	APR	DESCRIPTION
A	Nov/20/2007	SM	SC		Issued for review

REVISION	DATE	DWN	CKD	APR	DESCRIPTION

PROFESSIONAL SEAL

CLIENT

A. D. Williams Engineering Inc.

HAY & COMPANY CONSULTANTS A DIVISION OF EBA

COPPERMINE RIVER WATER INTAKE
KUGLUKTUK, NUNAVUT

PLAN AND CROSS SECTION FOR WATER INTAKE

PROJECT NO. V13201030 | DES SC | CKD SC | REVISION 0 | DRAWING NO. D101

SHEET NO. 1 OF 1 | DWN SM | APP | STATUS A

OFFICE EBA-VANC | DATE November 20, 2007

APPENDIX C

CH2M HILL TECHNICAL MEMO

Kugluktuk Water System Upgrades: Preliminary Review of Water Quality Data and Recommended Raw Water Monitoring Program

PREPARED FOR: Sudhir Kumar Khan – Government of Nunavut

PREPARED BY: David Pernitsky - CH2M HILL

John Clark – A.D. Williams Engineering

DATE: September 7, 2007

The Hamlet of Kugluktuk obtains raw water from the Coppermine River. This Technical Memorandum (TM) reviews the available water quality data for the Coppermine River and compares it to the current Guidelines for Canadian Drinking Water Quality (Health Canada, 2007), and the requirements for treatment process selection. Additional raw water quality monitoring recommendations are also included.

Review of Raw Water Quality

Raw water quality data from previous studies has been consolidated and summarized in Table 1. Good records exist for the main physical / chemical water quality parameters such as turbidity, total dissolved solids (TDS), pH, alkalinity, and hardness. Based on the available data, the raw water meets the requirements of the Guidelines for Canadian Drinking Water Quality, with the following exceptions:

- Treated water turbidity is frequently greater than the Health Canada guideline of 0.3 NTU.
- Seasonal salt water intrusion is experienced, leading to total dissolved solids (TDS) concentrations in excess of the Health Canada Aesthetic Objective of 500 mg/L
- Iron and manganese levels in excess of the Health Canada Aesthetic Objective of 0.3 and 0.05 mg/L, respectively
- Insufficient information is available on natural organic matter (NOM) concentrations to determine compliance with disinfection byproduct (DBP) regulations.

Turbidity: Treated water turbidity is controlled by the existing cartridge filtration equipment. Elevated river turbidities frequently challenge the filtration capacity of this equipment. Treated water turbidity is measured online at the water treatment plant (WTP). Raw water turbidity is not routinely measured at the plant. Treatment process improvements to address filtered water turbidity will be discussed in a separate TM.

TDS: Measures to limit salt water intrusion are focused on the raw water intake design, and are not discussed in this TM.

Iron and Manganese: The available water quality data for iron and manganese is insufficient for process design purposes. The available data indicate that iron and manganese levels are typically very low. However, previous reports have noted that concentrations in excess of the Health Canada aesthetic objectives are seen periodically. The chemical phase of these metals (dissolved versus particulate) is not clearly indicated in the data. If significant concentrations of dissolved iron and manganese are present, chemical oxidation and precipitation (for example with greensand filtration) may be required to prevent fouling of filtration processes. This is not a concern with the current cartridge filtration system, but would be of concern if a more advanced filtration process was added in the future. Based on the fact that the Coppermine River is well aerated, and fixture staining in Kugluktuk has not been reported, it is believed that the iron and manganese spikes seen in the data are most likely in the oxidized, particulate-form, and present as turbidity during runoff events. Iron and Manganese in this form would not impact treatment process selection or design. This should be verified with additional sampling.

NOM: Additionally, insufficient water quality data exists on the levels of natural organic matter (NOM) in the Coppermine River. NOM concentrations are typically measured as colour, total organic carbon (TOC), or ultraviolet transmittance (UVT). Elevated NOM concentrations can lead to the formation of disinfection byproducts (DBPs) during chlorine disinfection and can have design impacts for clarification processes. NOM concentrations can be quickly and easily measured using simple bench-top UV transmittance measurements. It is recommended that Kugluktuk obtain a UV spectrophotometer for this purpose.

Additional Raw Water Quality Monitoring

In summary, it is recommended that a monitoring program be established to measure raw water turbidity, TOC, UVT, iron, and manganese levels, as shown in Table 2.

TABLE 2
Recommended Water Quality Sampling Plan For Kugluktuk

Parameter	Sample Location	Frequency	Measurement Type
Turbidity	Raw Water	Daily	Bench-Top Instrument at WTP
UV Transmittance at 254 nm (UVT)	Raw Water	Weekly	Bench-Top Instrument at WTP
Total Organic Carbon	Raw Water	Monthly	Commercial Lab
Dissolved Iron	Raw Water	Monthly	Commercial Lab
Dissolved Manganese	Raw Water	Monthly	Commercial Lab

Table 1: Summary of Available Raw Water Quality Data for Coppermine River at Kugluktuk

Date		1967-1973	11/15/1990	10/25/1993	5/30/1994	8/29/1994	9/27/1994	11/7/1994	3/5/1997	4/5/1997	6/16/1997	8/8/1997	10/23/1997	12/18/1997	1/22/1998	2/20/1998	8/2/2007
Reference		1a	1	2	2	2	2	2	3	3	3	3	3	3	3	3	4
Parameter	**Units**																
Turbidity	NTU	0.4 to 45	10	4.8	18.5	16.7	5.5	3	6.3	10.1	170	6.7	7.5	2.9	6.7	2.7	13.7
Total Suspended Solids (TSS)	mg/L	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Total Dissolved Solids (TDS)	mg/L	4 to 8169	<29	-	-	-	-	-	103	-	61	28	102	31	9	33	54
pH	pH units	6.4 to 8.3	7.4	7.4	7.27	7.02	7.64	7.63	7.48	7.42	7.91	7.58	7.62	7.52	7.36	7.45	7.8
Alkalinity	mg/L as CaCO3	2 to 47	27	27.2	21.6	32.1	38.4	31.6	21.4	23.6	37.3	25.8	29.7	23.7	24.6	26.2	46
Total Hardness	mg/L as CaCO3	4.7 to 1559	16.6	29	24	25.1	49.3	37.3	24.4	26.6	65.2	24.4	32	25.2	26.7	27.94	47.5
Fe	mg/L	0.01 to 0.05	0.3	0.374	0.766	7.04	0.21	0.062	0.315	0.159	8.33	0.216	0.417	0.364	0.442	0.141	<0.06
Mn	mg/L	-	<0.003	-	-	-	-	-	0.01	0.007	0.164	0.006	0.013	0.008	0.008	0.006	<0.004
Total Organic Carbon (TOC)	mg/L	1.0 to 9.5	2.3	-	-	-	-	-	-	-	3.4 (DOC)	2.6 (DOC)	-	2.4 (DOC)	5.1 (DOC)	1.1 (DOC)	3
Colour	CU	< 5 to 50	-	12	10	17	9	8	5	<5	30	<5	5	<5	-	<5	-

References:
1: Daniel W. Smith and Associates (1991) *Northwest Territories Water Quality Study: Coppermine N.W.T. Kitikmeot Region*
1a: Daniel W. Smith and Associates (1991) quoting: Inland Waters Directorate, Western and Northern Region, Water Quality Branch, Regina, Saskatchewan (1986). *Detailed Surface Water Quality Data (Station 00NW10PC001)*
2: Stanley Associates (1995) *Coppermine Water System Modifications Final Planning Report*
3: FSC Engineers and Architects (1998) *Water Treatment Plant Pre-Design Report, Hamlet of Kugluktuk, NWT, Third Submission*
4: Samples taken Aug. 2, 2007

APPENDIX D

NUNA BURNSIDE GEOPHYSICAL INVESTIGATION

GEOPHYSICAL INVESTIGATION FOR WATER SYSTEM UPGRADES AT KUGLUKTUK, NUNAVUT

Presented to:
The Hamlet of Kugluktuk
c/o
Nuna Burnside Engineering and Environmental Ltd.
15 Townline,
Orangeville, Ontario,
L8W 3R4

Presented by:
Geophysics GPR International Inc.
6741 Columbus Road, Unit 103
Mississauga, Ontario
L5T 2G9

June 2008 T08070

GEOPHYSICAL INVESTIGATION FOR WATER SYSTEMS UPGRADE AT KUGLUKTUK, NUNAVUT

Presented to:
THE HAMLET OF KUGLUKTUK
c/o
Nuna Burnside Engineering and Environmental Ltd.
15 Townline,
Orangeville, Ontario,
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Presented by:
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June 2008 T08070

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1. Introduction

Geophysics GPR International Inc. was requested by Nuna Burnside Engineering and Environmental Ltd. to carry a geophysical survey for the Hamlet of Kugluktuk, Nunavut (Figure 1).

The purpose of the investigation was to produce depth to bedrock profiles and overburden profiles to aid in the selection of drill locations for water sourcing.

Data were collected May 3rd through 7th, 2008.

The TISAR *(Testing & Imaging using Seismic Acoustic Resonance)* and seismic refraction methods were applied to collect the data along three profiles on the Coppermine River.

This report deals with the various aspects of the survey including field techniques, interpretation techniques, and finally an interpretation in the form of depth to bedrock profiles.

2. Basic Data

2.0. Investigation Site

The survey area was on the Coppermine River adjacent to the hamlet of Kugluktuk, NU, approximately 600km north of Yellowknife, NWT. Figure 1 indicates the approximate site location. Access to the survey area was by snowmobile.

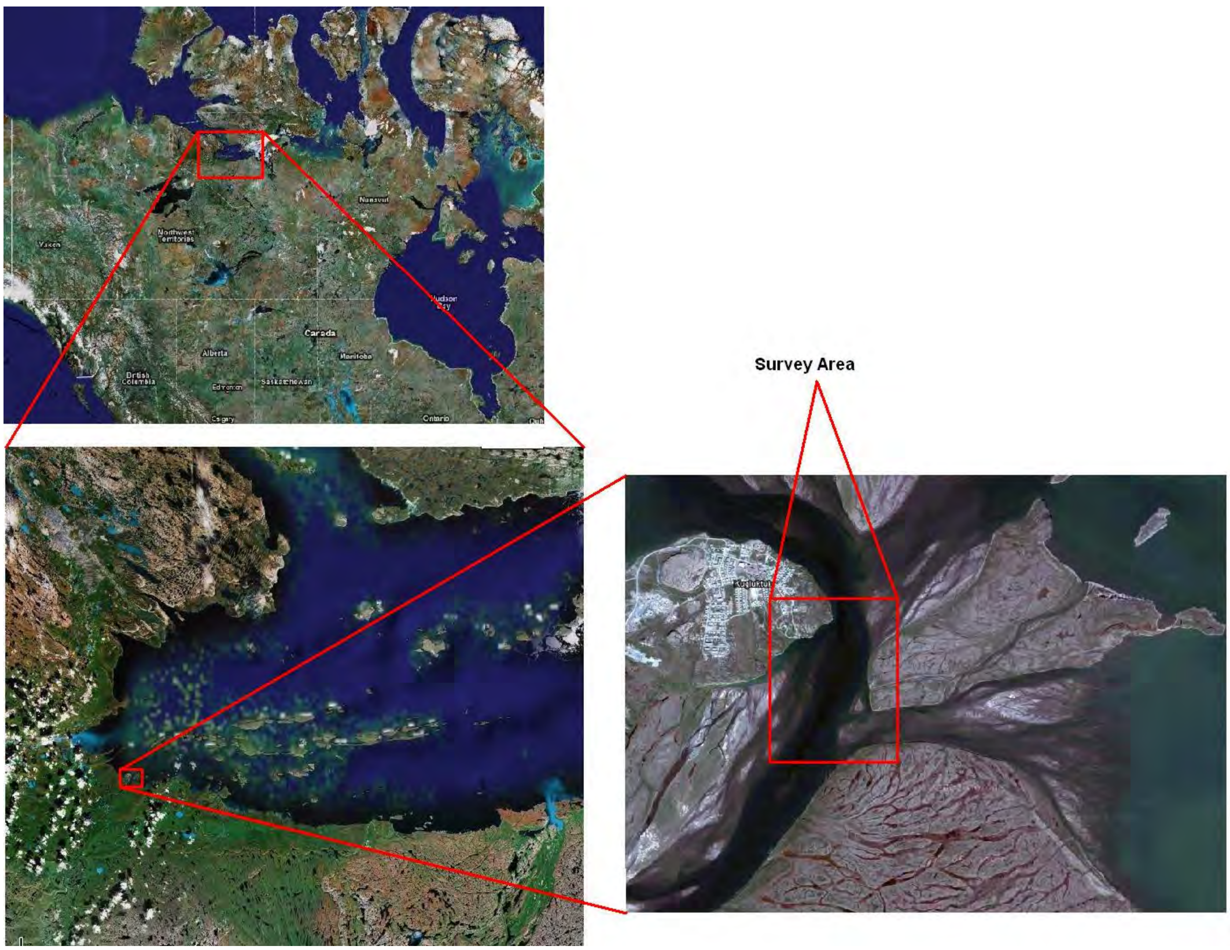


Figure 1: Survey site. Kugluktuk Water Intake Area, Kugluktuk, NU

2.1. Mobilization

A Geophysics GPR personnel was mobilized on May 1st and met with local helpers in Kugluktuk on May 3rd. The survey was performed May 3rd to May 7th.

2.2. Personnel and Equipment

The personnel involved in the this project and the dates they were on-site are outlined below:

Employee	**Title**	**Dates On-Site**
Ben McClement	Geophysicist	May 3 to May 7
Freddy Havioyak	Helper	May 3 to May 7
Joe Niltak	Helper	May 3 to May 4
Shane Oniak	Helper	May 3 to May 7
Beatrice Oniak	Helper	May 3 to May 4
Chris Ipakohak	Helper	May 5 to May 7

The main geophysical equipment used for the seismic survey consisted of an ABEM Terraloc Mark 6, 24channel seismograph. The seismic source was a combination of buffalo gun but mostly sledge hammer. A detailed description of the equipment is presented in Appendix B.

3. Methodology

3.1. Positioning, Topography and Units of Measurement

The location of the seismic profile was chosen to run approximately perpendicular to the trend of the surficial valleys.

The approximate locations of the seismic lines were predetermined on a site plan and adjusted slightly once on-site to avoid large snow berms and areas of heavy snowmobile traffic. Since the site was free of visible obstacles it was relatively simple to maintain transects with a combination of markers across the river. GPS readings were taken along the profile alignment with a hand-held GPS unit. The coordinates are in the UTM Coordinate System and should be accurate to within +/- 5m.

Topography was also simple because the ice surface was assumed to be very close to flat. The ice surface was measured to be at sea level with the use of repeated readings with the GPS.

All geophysical measurements were collected in SI units.

3.2. Seismic Methods

3.2.1. Seismic Resonance (*TISAR*)

Basic Theory

The seismic resonance, or *TISAR (Testing & Imaging using Seismic Acoustic Resonance),* method is based on the frequency analysis of seismic records. It considers the seismic resonance within the signal. The method was originally developed for geological sub-surface profiling (1 to 15m deep); however it has been shown to be effective for ranges smaller than 0.1m for testing of concrete/asphalt structures, as well as for deep (100m) geological investigations.

The method uses the information from an induced seismic signal in the frequency domain instead of the direct time domain as with classic seismic reflection. For both methods, however, the principal physical parameter involved remains the acoustic impedance contrast, which is the product of the seismic velocity and the volumetric mass of the investigated materials. At the interface between two materials with different acoustic impedance, the seismic signal is partially reflected back to the surface. Under specific conditions, the repetition of such reflections leads to the build-up of a resonance signal, whose frequency is related to the depth of the interface and the seismic velocity of the upper material. The resonance frequency is inversely proportional to the reflection time. The first advantage of the use of frequencies instead of reflection times is the amplitude and the repetitive signal, which is less sensitive to the ambient noise and produces a resolution that increases with shallow depths. The second advantage of using resonance frequencies is the ability to resolve very thin layers (contrary to standard reflection).

Survey Design

A seismic spread typically consists of 24 vibration monitoring devices (geophones) connected in line (spread) to a seismograph (ABEM Terraloc Mark 6) by two 12-connector cables. Seismic pulses (shots) are then generated at various locations with respect to the spread. Spacing between geophone at this particular site was 6.25m. The resonance testing involved hammering a metal plate at 12.5m intervals along the length of the profile and at various distances off both ends of the profiles.

A sledgehammer was used as the primary energy source. A sledgehammer is an ideal energy source for resonance surveys.

Interpretation Method and Accuracy of Results

The seismic resonance method requires adequate geological models and seismic velocities. These parameters were derived from the seismic refraction measurements discussed below. The accuracy of the depths of reflectors is related to the accuracy of the geological model, in particular, the input velocities. It may be possible that velocities vary by approximately 10% resulting in a similar variation in depth to a given reflector. Resonance has the advantage of a vertical resolution that cannot be obtained from conventional seismic methods.

Interpretation involves identifying trends in the amplitude of reflectors. TISAR reflectors could be from geologic contacts, fractures or voids. As with seismic reflection, the true nature/source of the reflection cannot be certain.

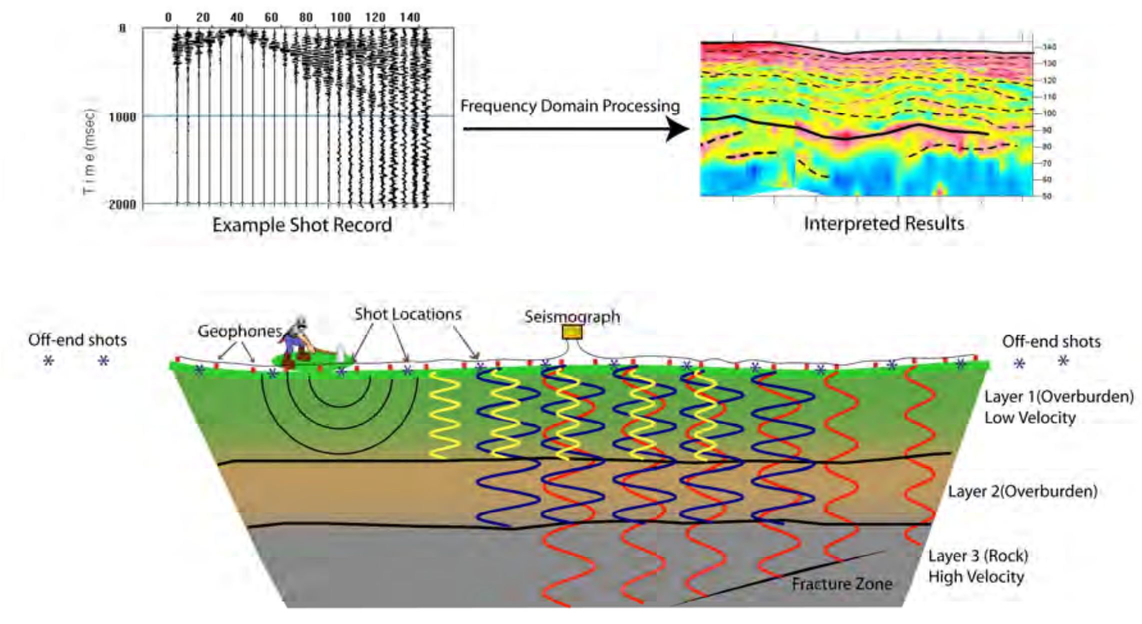


Figure 2: Seismic Resonance Operating Principle.

3.2.2. Seismic Refraction

Basic Theory

The seismic refraction method relies on measuring the transit time of the wave that takes the shortest time to travel from the shot-point to each geophone. The fastest seismic waves are the compressional (P) or acoustic waves, where displaced particles oscillate in the direction of wave propagation. The energy that follows this first arrival (including reflected waves, transverse (S) waves and resonance) is not considered under routine seismic refraction interpretation. Figure 3 illustrates the basic operating principle for refraction surveys.

Survey Design

The seismic refraction survey was carried-out with the same set-up as the seismic resonance investigations. Five to seven shots were executed for each spread to obtain the lateral velocity variation in the overburden and clear signal arrivals from the bedrock.

The energy sources used for this investigation were blank shotgun shells along with a large sledgehammer. Ideally explosives are used as the seismic energy source wherever possible as it produces excellent signal and recordings of high quality; however, at this particular site explosives were not a practical option. The buffalo gun had limited use because it was very difficult to auger holes in the ice. The ice thickness was anywhere from 5 to 7 feet but more restrictive was the existence of sand within or just beneath the ice. This was a problem because it ruined the ice blades of the auger.

Interpretation Method and Accuracy of Results

Typically the accuracy of a refraction surveys is +/- 1m for depths less than 10m and +/- 20% for depths greater than 10m; however, the depth to bedrock at this particular site was near the limit for accurate mapping as the sledgehammer was barely adequate for the site conditions. The refraction records are also used to measure the overburden velocities to develop a starting model for the resonance analysis.

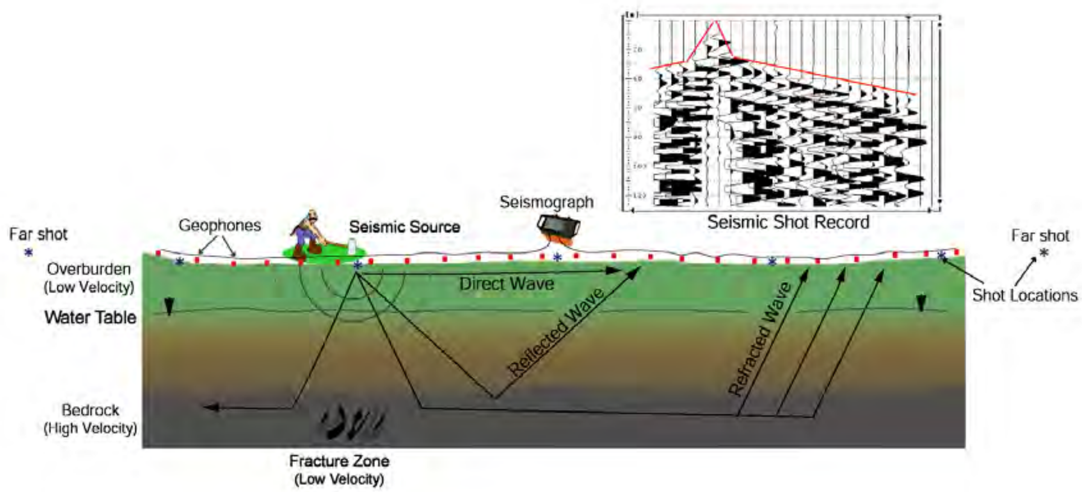


Figure 3: Seismic Refraction Operating Principle

4. Results

The combined results of the seismic refraction and resonance interpretation are presented in the form of an interpreted cross-section in drawing T08070-A1. The quality of the TISAR data was very good. The outcome was a pleasant surprise considering that the application on ice over water over overburden was experimental. The refraction data was adequate enough to resolve bedrock given the depth involved and the seismic source that was used.

The profile coordinates were recorded by Geophysics GPR International personnel and presented in Table 1. The coordinates are expressed in metres with the projection U.T.M. (NAD-83, Zone 11), and the elevations are relative to the Mean Sea Level. The topography was assumed to be flat given the entire survey was conducted on the ice and the ice surface is given as 0.0 m.a.s.l. This number was obtained from repeated GPS measurements.

Table 1: Profile Line Coordinates

Profile #	Northing	Easting
1 @ 0+00	7524078	580831
1 @ 5+50	7523780	581300
2 @ 0+00	7523973	580572
2 @ 6+90	7523667	581191
3 @ 0+00	7523840	580833
3 @ 1+40	7523921	580952

The bedrock elevations based on the seismic refraction results ranged from approximately –16 to greater than –30 m.a.s.l.

If we disregard the ice and the water the general structural model consists of a two-layer case. The upper most layer has a velocity of 1500 m/s to 1700 m/s. This layer can be composed of a variety of material types from clay to gravels that are not densely packed. This layer has been created in a river depositional environment. The material is not frozen and is saturated. The third layer has a velocity range of 3400 to 4400 m/s. This velocity range is typical for competent shale rock. There is no evidence of a fracture zone but there may be a dip in the bedrock at a few locations.

The TISAR images are colour contoured. The red signifies a contact or series of contacts with a strong contrast. The blue zones signify very weak contrast or no contacts at all.

5. Conclusions

A seismic resonance (TISAR) and seismic refraction survey was undertaken to aid in the water-sourcing project of Nuna Burnside Engineering and Environmental Ltd. at Kugluktuk, Nunavut. Seismic data were collected along three profiles on the Coppermine River for a total of approximately 1380 m of seismic profiles.

The quality of the TISAR data was very good and the refraction was adequate to discern the top of rock.

Seismic refraction is the preferred seismic method for accurately mapping bedrock; however, without the use of explosives the depths of investigation are typically limited to less than 20 to 30 meters.

Seismic resonance (TISAR) is a method developed by Geophysics GPR International that has the advantage of providing greater depths of investigation from a sledge hammer energy source, higher resolution data on overburden layers and in some cases features within the bedrock (e.g. fractures). The disadvantages of the resonance method is that the depths will typical not be as accurate as with the refraction method. The method highlights highly contrasting contacts by colour contouring the relative strength.

The combined results of the seismic surveys are presented in the enclosed drawing T08070-A1. Table 2 summarizes suggested drilling locations with an explanation. Each target had a dip in the bedrock. The TISAR images suggest some strongly contrasting contacts within the overburden that are identified by the red shading. The top two ranking targets have strong contrasting contacts.

Table 2: Potential Targets for Drilling

Target Description	Rank	Profile #	Chainage	Interpreted Bedrock Depth	Coordinates
Slight dip in bedrock topography and multiple strong TISAR reflectors	1	2	1+10	22 to 29m	7523926N 580668E
Slight dip in bedrock topography and multiple strong TISAR reflectors	2	2	2+50	25 to 29m	7523874 580773
Slight dip in bedrock topography	3	1	1+50	22 to 24m	7524013 580934

Processing and interpretation of the seismic data was performed by Ben McClement and Jean-Luc Arsenault. This report has been written by Ben McClement, P.Eng and reviewed by Milan Situm, P.Geo.

Ben McClement, P.Eng. Geophysicist	Milan Situm, P.Geo. Manager

APPENDIX A

SEISMIC EQUIPMENT AND METHODOLOGY FACT SHEETS

TERRALOC MK6 FEATURES

Great features in a small seismograph

The Terraloc mark 6 is a high resolution multi-channel seismograph with an 18-bit A/D converter and 3-bit instantaneous floating point (IFP) amplifier. Overall resolution is thus 21 bits. Its dynamic range, 126 dB, eliminates all gain setting hassles and satisfies the most stringent shallow reflection requirements.

7,8" full colour daylight-visible backlit display with VGA resolution
Armoured glass LCD protection
Sealed, Rugged aluminium case protects against weather and rough handling
sealed 1.44 MB 3.5" floppy drive
Numeric keyboard
Command keyboard

Added Terraloc advantages:

Great for tomography thanks to high sampling rates starting at 25 µs.

Usable with various energy sources (even mini-vabrators) thanks to long record lenghts, auxiliary source signature channel input and built-in correlation software.

provides sophisticated automation. Aversatile digital (TTL) interface (trigger IN/OUT,arming IN/OUT signals) makes it easy to connect several Terralocs and supports handshaking with vibrators and marine seismic energy sources.

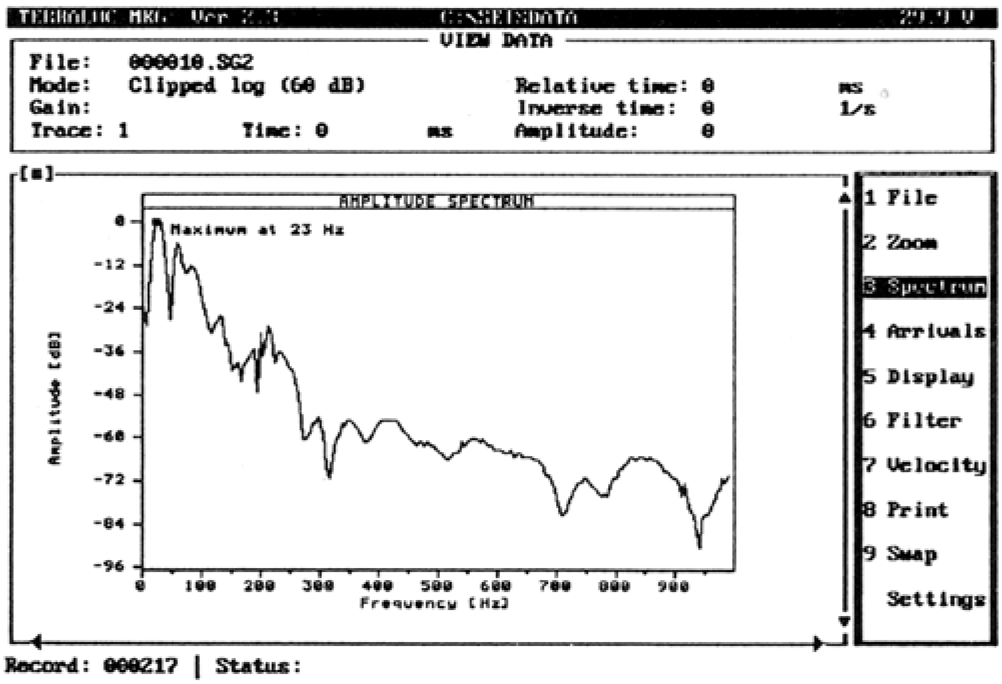
Ideal for refraction as well as shallow reflection seismics thanks to built-in roll-along function and a broad spectrum of analog and digital filters

In-field quality control. On-site geophone testing, cable testing and noise monitoring. Wide choice of multi- or single-trace view modes and frequency spectrum analysis (FFT)

Powerful computer

Fully compatible with your office computer thanks to MS-DOS 6.0 or higher, an internal hard disk, a built-in 1.44mb floppy disk, and compliance with the international SEG-2 format for storing of seismic traces and header information.

Interpretation software can be installed and run right in your Terraloc field unit.



Spectrum analysis helps you select the right filter, and it can also reveal soil properties

Lightweight and easy to use

The compact, lightweight Terraloc mark6 weighs only 16kg (24-channel version) and is less than half the size of its predecessor the popular Terraloc mark 3.

Carefully prepared, logically arranged documentation includes a copies of the operators manual (one for the field, and one to keep in the office), a user's manual for the computer , a complete description of the SEG-2 format and a service manual loaded with detailed technical information and schematics. Also included are a DOS manual and practice records to get you started.

Broad range of viewing provisions.

Scroll through records
Change display settings as desired
Select different time-scales
Select display mode
Select trace mode
Select AGC window length and set time and amplitude scale factors
Analyse single-trace frequency content (FFT)
Calculate refractor velocities
Analyse ground noise
Re-Scale traces individually
Create a geophone test report
Enlarge traces individually (Zoom)

Broad Printer support

The terraloc mark 6 supports a wide range of printers through dynamic link libraries (DLLs) via either the parallel or serial port and new printers can be added easily if required in the future.

Roll-along optimum offset

You can type in numerical values for roll-along start-trace, end-trace and step, you can roll along part of your receiver spread a step at a time . This feature is used in reflection surveys that include CDP stacking.

Expand your system

Two or more Mark 6's can easily be linked together to form a larger system. The print-out below is from a 96channel survey in which four 24-channel Terraloc's were connected

Technical Specifications for the Terraloc

- Number of channels (smaller unit)................. 4-24 in steps of 4
- Number of channels (larger unit).................... 4-48 in steps of 4
- Additional channels....................................... Easily obtained by linking two or more units together
- Up-hole channel.. Yes
- Sampling rate (selectable).............................. 25, 50, 100, 200, 500,1000 & 2000 µs
- Record length (selectable).............................. 128, 256, 512, 1024, 2048,4096, 8192 or 16384 samples per trace equivalent to: 3.2 ms - 32.7 s
- Pre-trig record (selectable)............................. 0-100 % of record length
- Pre stack correlation..................................... Yes, cross correlation with reference or any other channel
- Delay time .... Related to sampling rate May be set (for example) from: 0-0.8 s at 25 ps ,sampling rate 0-131 s at 2 ms sampling rate
- Stacking... 32 bits, up to 999 impacts
- Unstack.. Remove last shot from stack
- First-arrivals picking.................................... Automatic or manual. Times can be saved with record
- Trigger inputs... Trigger coil, make/brake, geophone, TTL
- A/D converter resolution............................. 21 bits (18 bits plus 3-bit IFP)
- Dynamic range (theoretical/measured).......... 126 / 114 dB
- Max input signal.. 500 mV p-p
- Frequency range.. 1 - 4000 Hz (at 25 ps sampling rate)
- Total harmonic distortion............................. - 80 dB
- Crosstalk... - 86 dB
- Input impedance.. 3 k
- Noise monitor.. Amplitude or full waveform display available on-line

Analog filters

- Low cut (selectable)... 12 or 24 dB/octave 16 steps from 12 to 240 Hz
- Notch.. 50 or 60 Hz specify when ordering
- Anti-aliasing.. set automatically based on sampling rate

Digital filters

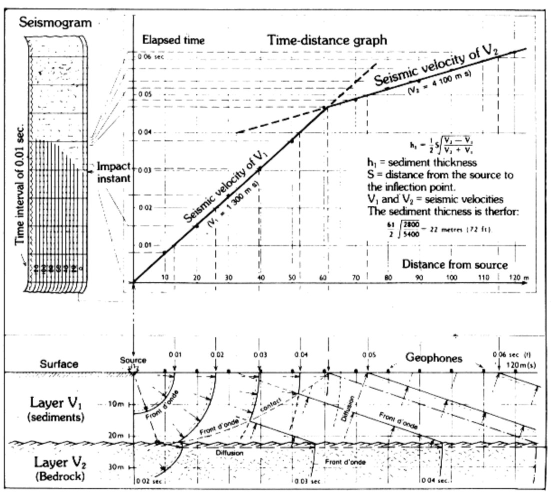
Bandpass, low-cut, high-cut, bandreject, alpha-beta and remove DC offset Spectrum analysis...... Any single trace

GEOPHYSICS G P R INTERNATIONAL INC.

SEISMIC REFRACTION

Seismic refraction consists of recording the length of time taken for an artificially provoked surface vibration to propagate through the earth. By processing the data, the seismic velocities and depths of the underlying rock layers can be determined. These velocities are characteristic of the nature and quality of the bedrock; a fissured, fractured or sheared rock will be characterized by reduced seismic velocities.

The method is generally used to obtain a better geological analysis of the sub-surface and to determine the following characteristics: the quality, profile and depth of bedrock, its nature, degree of alteration and any other physical contrasts. Seismic refraction ensures that maximum information may be gained from geological field work, and that direct investment costs (drilling, excavation), will be reduced.



PRINCIPLE OF SEISMIC REFRACTION

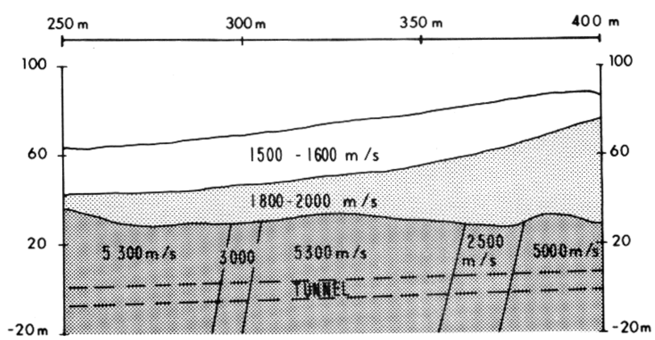
FEATURES

- Precise determination of soil thickness .
- Precise determination of the seismic velocities (rock type and quality).
- Localization and identification of geological units.
- Detailed analysis of soil.
- Year-round use.
- Sea and land surveys (above and below ground).
- Great accessibility possible to rough terrain and remote regions.

AREAS OF APPLICATION

Civil Engineering/Mining Exploration - Exploitation/Petroleum and Gas Sectors/ Geotechnology/Geology/ Hydrology.

- Identification of faults, fractures, shear zones.
- Detection of rock differences (veins, dykes, cavities, etc.).
- Determination of rock topography.
- Evaluation of volume of soil present or to be excavated.
- Excellent complement to geological mapping.
- Recognition of geophysical anomalies such as VLF, gravimetry, etc.
- Drill site selection, better target identification.
- Evaluation of the size, thickness and condition of surface shafts (mining exploitation).
- Mass Rock Quality Determination (MRQD).
- Detection of rock irregularities and breaks.
- Hydrogeology (detection of water tables, veins, reservoirs).
- Excellent complement to any geological analysis.

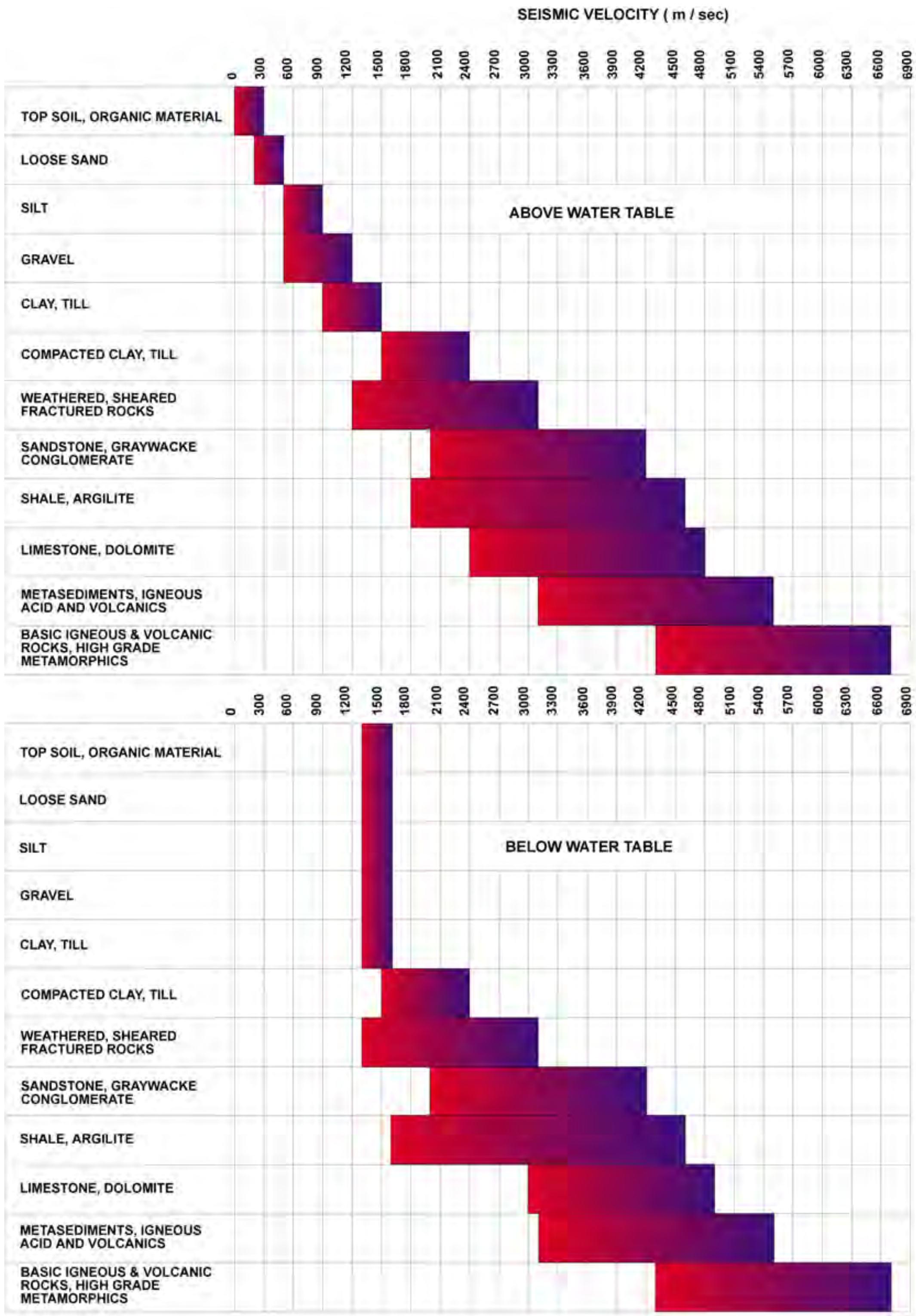


Interpretation results of a seismic profile

ADDITIONAL REMARKS

Geophysics GPR International Inc. has been recognized for the past fifteen years as a leader in both the application and the development of seismic methods. Seismic refraction is currently used in both civil and mining engineering; the use of lighter high-performance equipment and better tomographical interpretation of the results have contributed to its growing popularity.

GEOPHYSICS G P R INTERNATIONAL INC.



SOIL AND ROCK CLASSIFICATION BASED ON SEISMIC VELOCITIES

APPENDIX B

SITE PHOTOS

Photo 1: Seismic Profile 1, looking west towards 0+00

Photo 2: Hammering along seismic profile 1

Photo 3: Using the ice auger

Photo 4: Installation of the geophones and cables

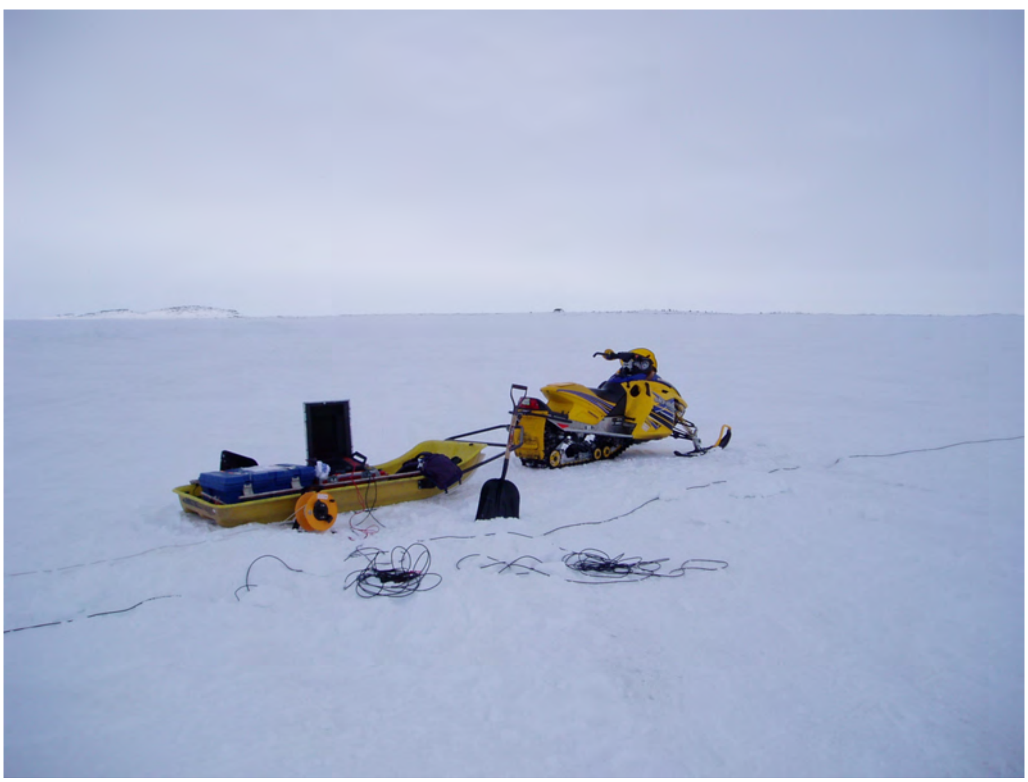


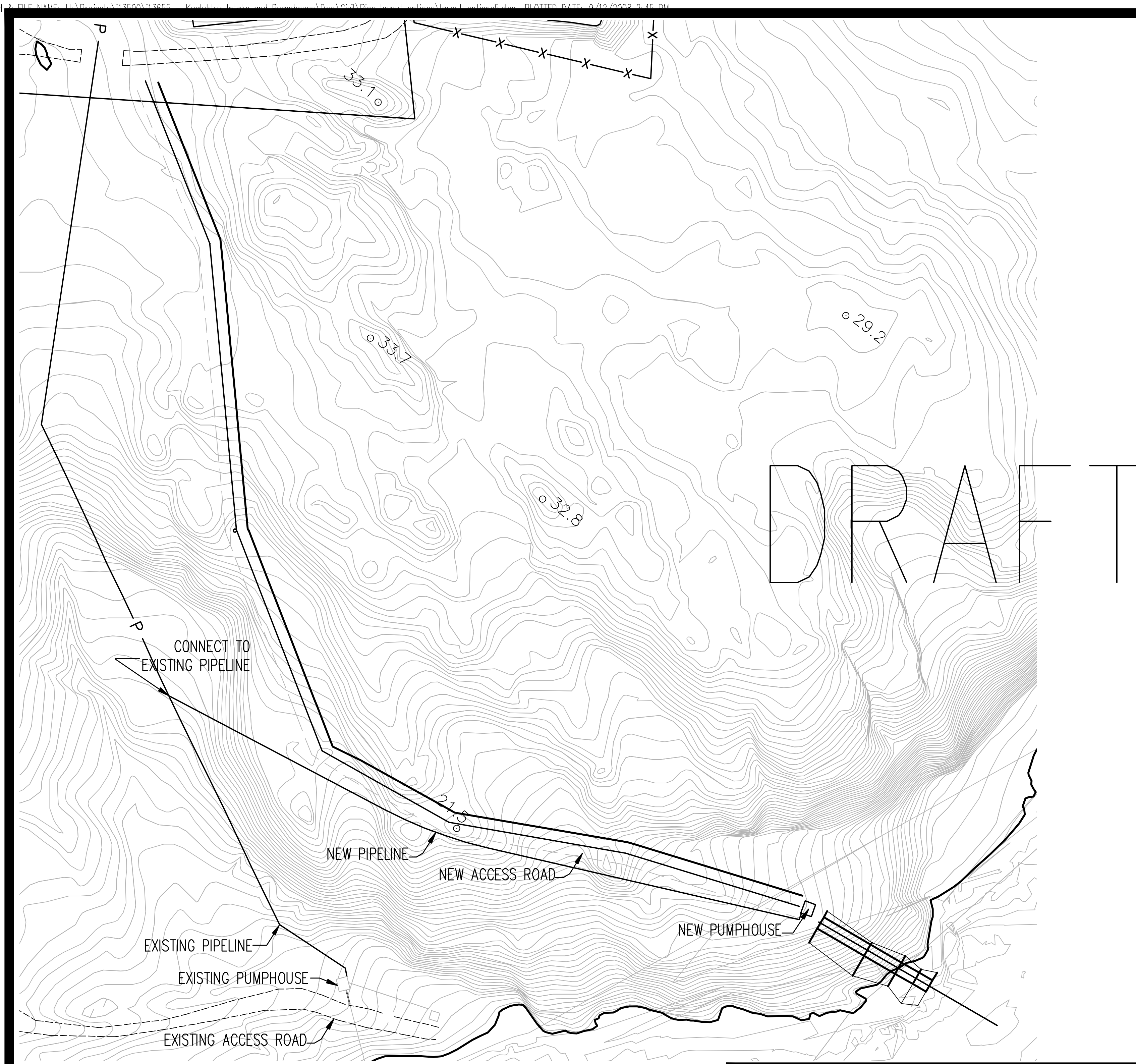
Photo 5: Seismic equipment set-up

APPENDIX C

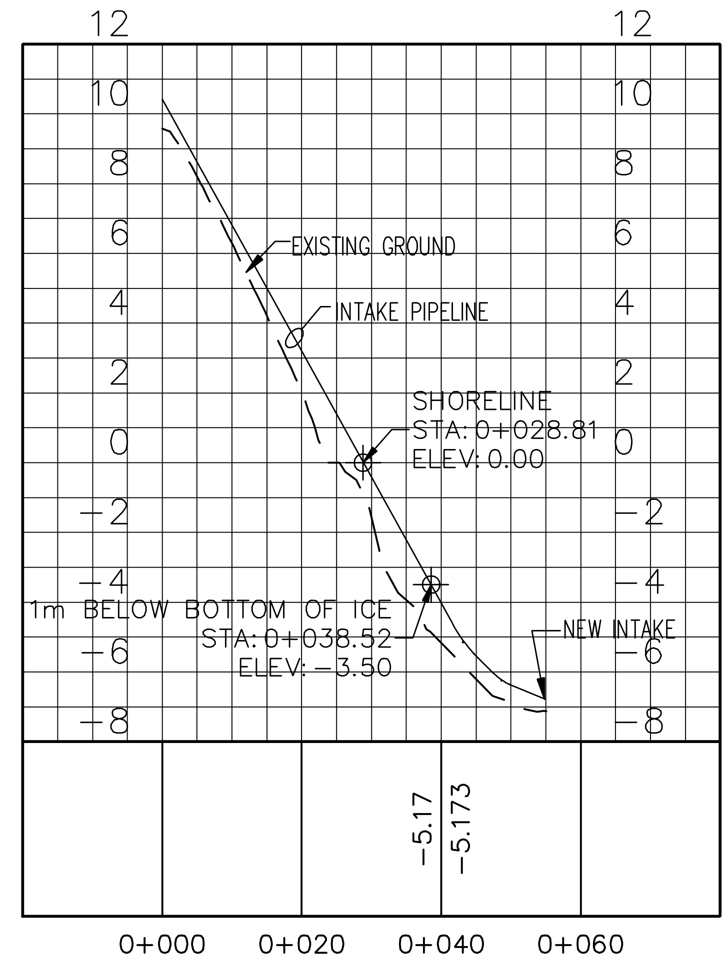
DRAWING T08070-A1

A P P E N D I X E

INTAKE LOCATIONS SKETCHES



OPTION 1 INTAKE PIPELINE PROFILE



PRELIMINARY ONLY
NOT FOR CONSTRUCTION
DATE (YYYY MM DD): 2008.09.09

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JOB. TITLE: WATER SUPPLY IMPROVEMENTS PH 1 NEW INTAKE & PUMPHOUSE KUGLUKTUK, NU	DWN. BY: JG	DES. BY: JC	PROJ. MGR.: JC
	PEER REVIEW: JH	DATE: (YY-MM-DD) 2008.09.09	SCALE: NTS
DWG. TITLE: INTAKE LOCATIONS OPTION 1	CLIENT PROJ. #: –		ADWE PROJ. #: 13655
	DWG #: 13655-SK1	OF: –	REV #: A

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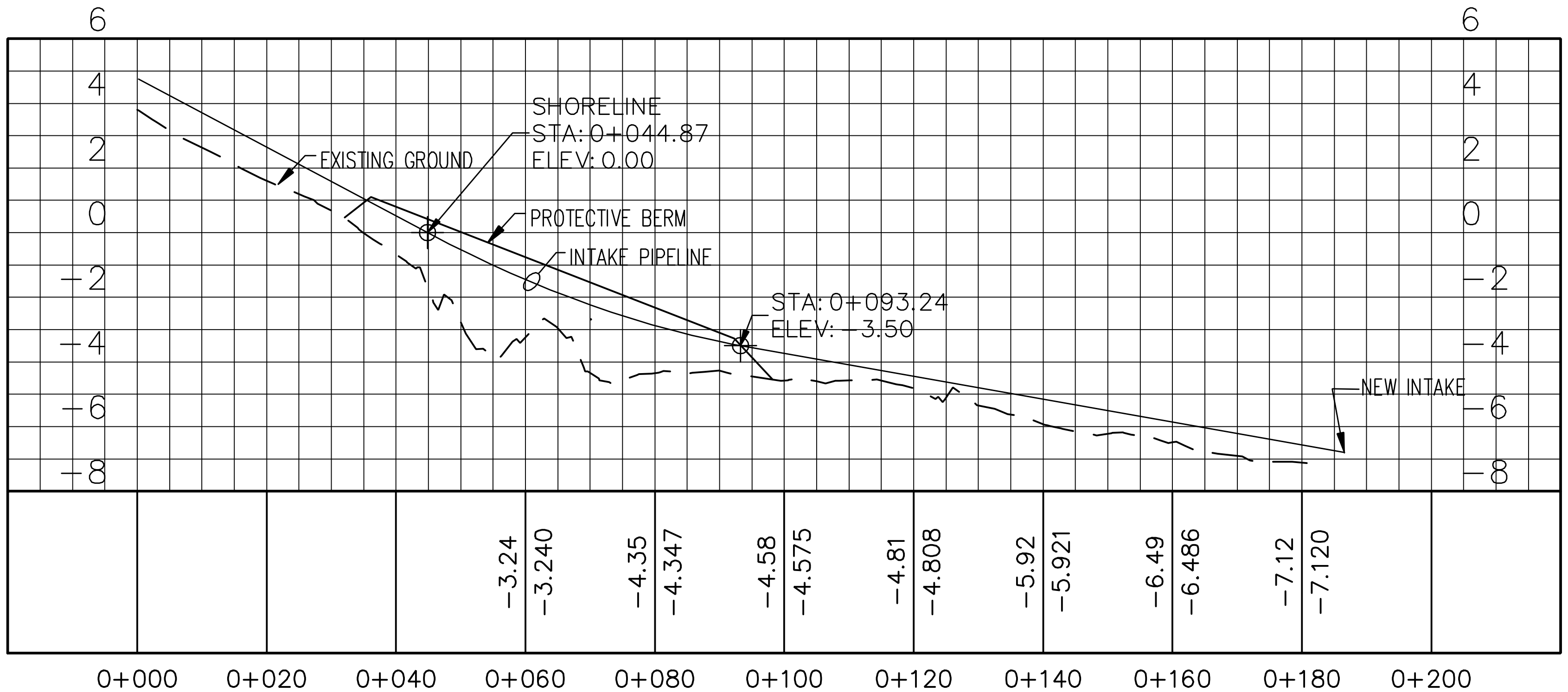
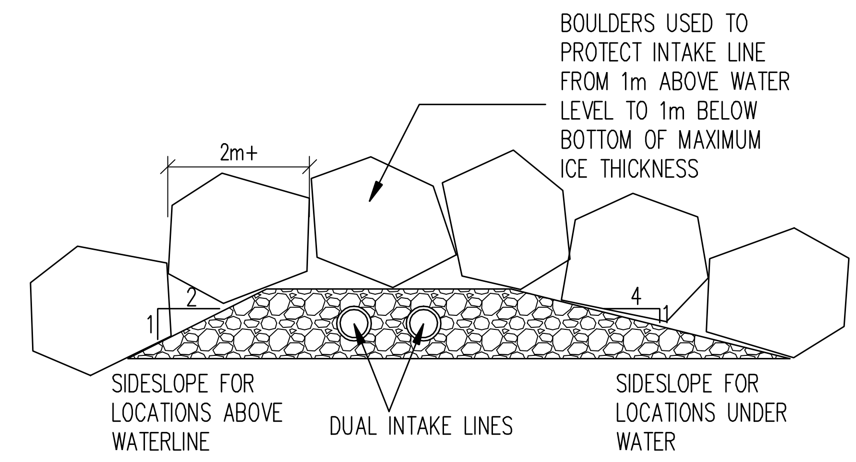
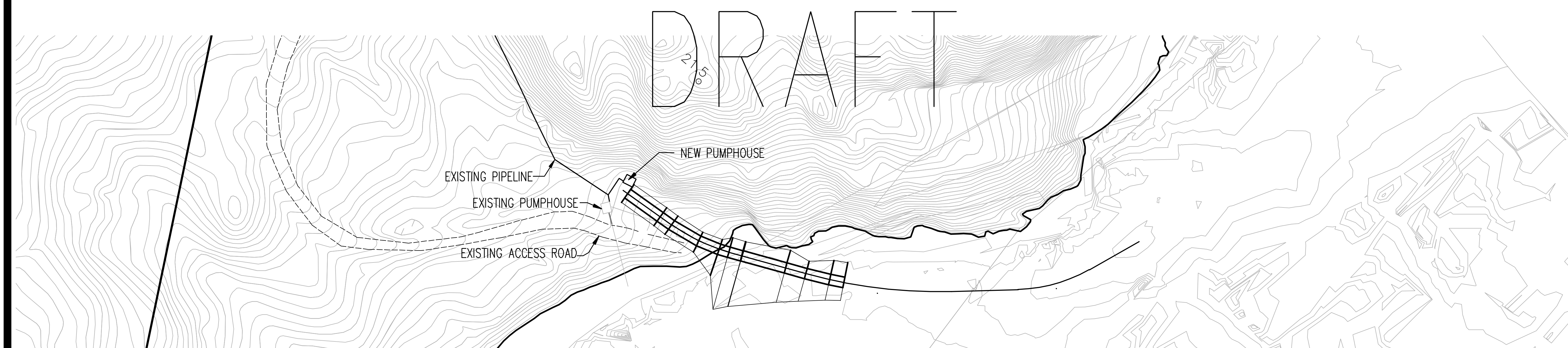
OPTION 2 INTAKE PIPELINE PROFILE





A
C1
BERM OVER INTAKE LINE
NTS



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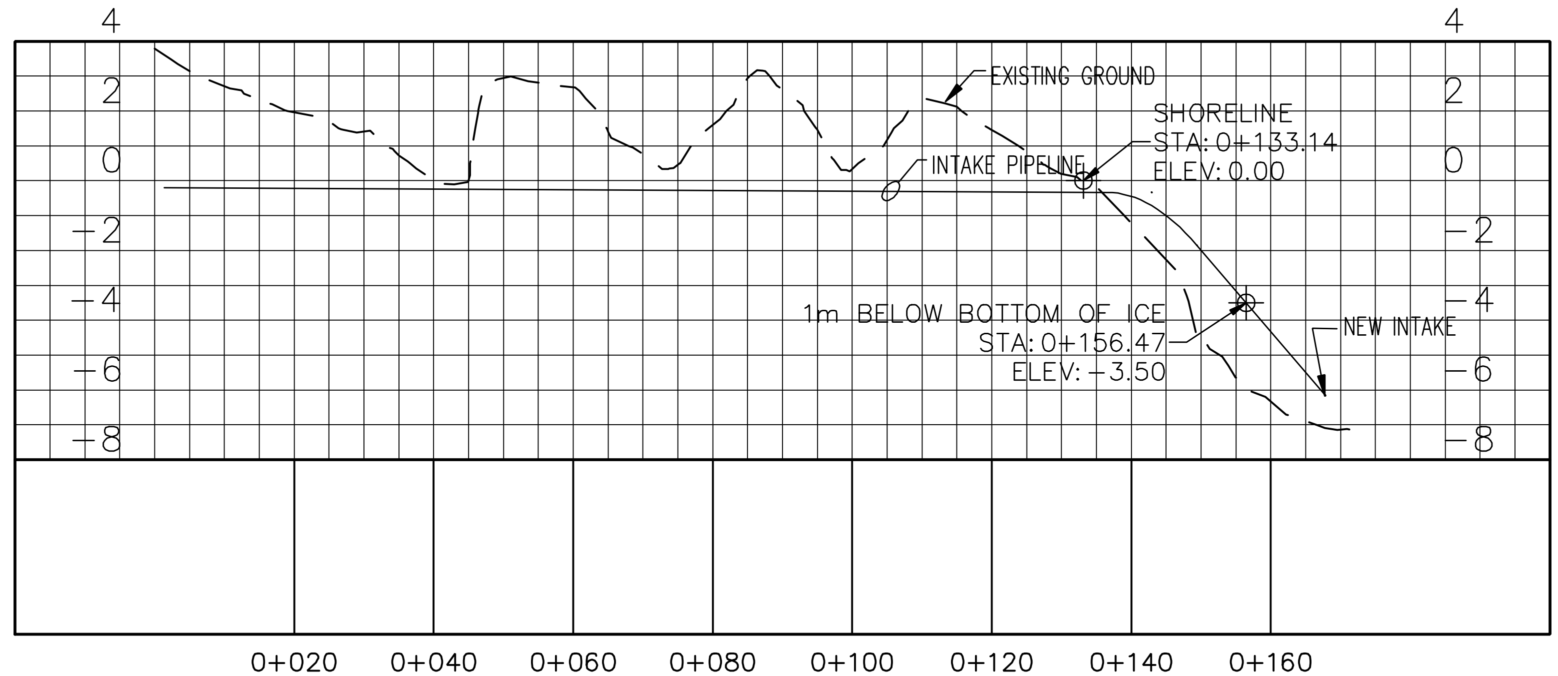
PH 1 NEW INTAKE & PUMPHOUSE
KUGLUKTUK, NU

DWG. TITLE: INTAKE LOCATIONS
OPTION 2

DWN. BY: JG	DES. BY: JC	PROJ. MGR.: JC
PEER REVIEW: JH	DATE: (YY-MM-DD) 2008.09.09	SCALE: NTS
CLIENT PROJ. #: –		ADWE PROJ. #: 13655
DWG #: 13655-SK2	OF: –	REV #: A

OPTION 3 INTAKE PIPELINE PROFILE



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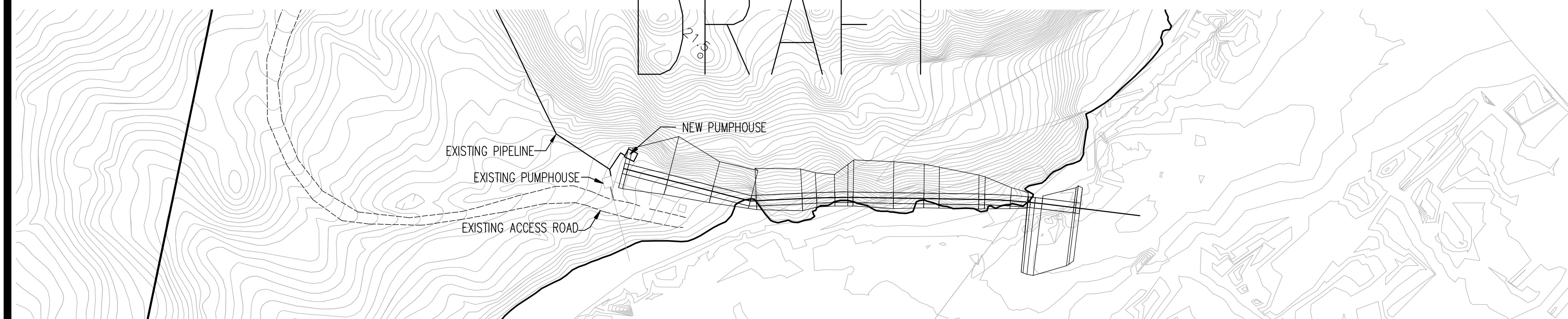

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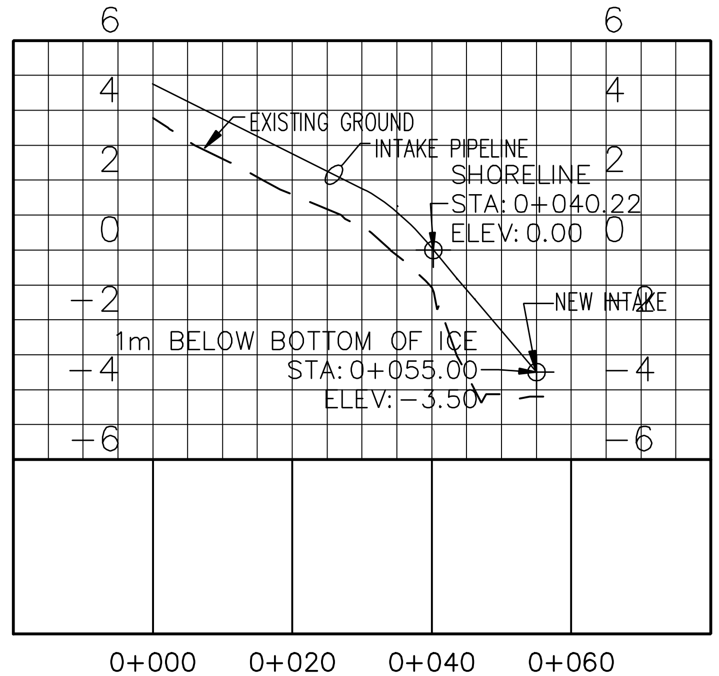
JOB TITLE: WATER SUPPLY IMPROVEMENTS PH 1 NEW INTAKE & PUMPHOUSE KUGLUKTUK, NU	DWN. BY: JG	DES. BY: JC	PROJ. MGR.: JC
	PEER REVIEW: JH	DATE: (YY-MM-DD) 2008.09.09	SCALE: NTS
DWG. TITLE: INTAKE LOCATIONS OPTION 3	CLIENT PROJ. #: –		ADWE PROJ. #: 13655
	DWG #: 13655-SK3	OF: –	REV #: A

OPTION 4 INTAKE PIPELINE PROFILE



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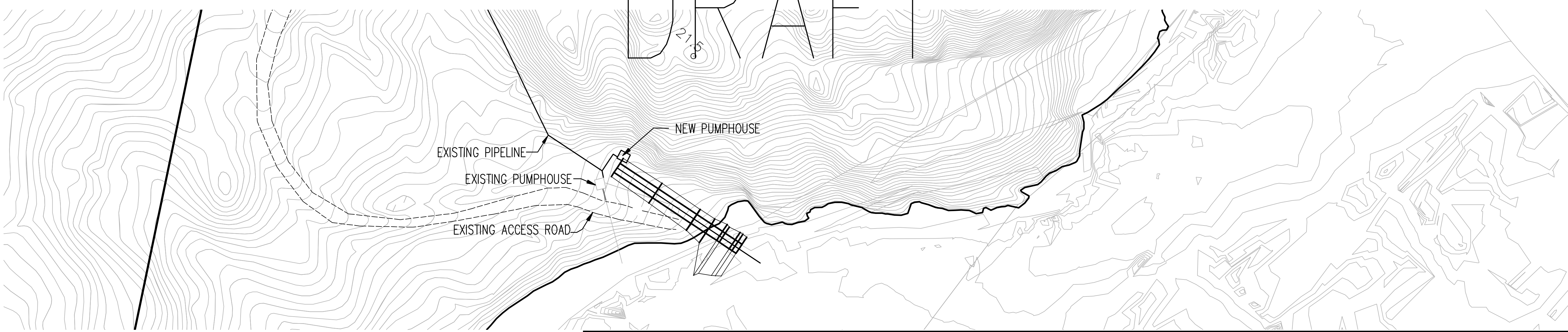

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JOB. TITLE: WATER SUPPLY IMPROVEMENTS PH 1 NEW INTAKE & PUMPHOUSE KUGLUKTUK, NU

DWG. TITLE: INTAKE LOCATIONS OPTION 4

DWN. BY: JG	DES. BY: JC	PROJ. MGR.: JC
PEER REVIEW: JH	DATE: (YY-MM-DD) 2008.09.09	SCALE: NTS
CLIENT PROJ. #: –		ADWE PROJ. #: 13655
DWG #: 13655-SK4	OF: –	REV #: A