

**RESOURCE ASSESSMENT FOR HEAT
POTENTIAL STUDY**

HAINES JUNCTION, YT

Submitted to:

Lessoway Moir Partners

By:

EBA Engineering Consultants Ltd.

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1 **EXECUTIVE SUMMARY**

In the fall of 2002, a new water supply well was completed for the Village of Haines Junction (the Village) in a deep artesian aquifer bearing warm water. Recognizing the prospective economic and environmental benefit to the Village of Haines Junction, the Village has entered into a joint venture agreement with Energy Solutions Centre (ESC) to promote, study, and determine the feasibility of utilizing heat energy from groundwater for space heating in the Haines Junction as a means of reducing/displacing fossil fuel use.

The project team consisting of Lessoway Moir and Partners, EBA Engineering Consultants (EBA) and Quest Engineering Group were contracted by the Joint Venture to provide engineering and hydrogeology services to study and determine the feasibility of utilizing heat energy from this new water supply well (Well #5). EBA's role on the project team was to provide hydrogeological and geotechnical expertise for the resource assessment component of this project. Resource assessment work completed by EBA consisted of the following:

- **Data Collection and Review:** EBA collected and reviewed reports, maps, aerial and satellite photos and other relevant information to estimate the lithology and stratigraphy in the valley near Haines Junction.
- **Aquifer Testing:** EBA coordinated two short "step tests" followed by a long term pumping test. EBA also interpreted pertinent data collected by the Village of Haines Junction during the use of the supply well. The purpose of the aquifer testing was to provide information on:
 - the estimated long term capacity (sustainable pumping rate) of the well;
 - presence of aquifer boundaries (impermeable or recharge boundaries);
 - water temperature variation versus time (may be indicative of temperature gradient in the aquifer); and
- variation in water quality versus time, if any.
- **Preliminary Aquifer Characterization:** EBA compiled the information collected during the previous tasks and built a conceptual model of the spatial distribution of both geologic structure and groundwater in the subsurface.
- **Preliminary Assessment of Subsurface Temperature:** EBA studied the vertical and spatial distribution of water temperature by using a field instrument to

log water temperature at varying depths at several of the water wells in the area to obtain information on the geothermal gradient.

- **Identification of Operation and Maintenance Issues:** EBA gathered information to assess how the long-term use of Well # 5 may affect the observed artesian conditions. A preliminary conceptual hydrogeology and geothermal model was developed to estimate how the groundwater and energy conditions may vary due to the proposed extraction and potential re-injection of groundwater. EBA also developed a program to monitor the risk associated with bacterial growth.

Based on the interpretation of the available information, the following can be concluded:

- Boundary conditions (either indicative of an impermeable barrier or of a recharge boundary) have not been identified;
- The aquifer behaves as a "leaky" aquifer with hydraulic conductivity in the order of 1×10^{-5} m/s, assuming an aquifer thickness of 40 m. If Well #5 is pumped exclusively (no well interference), the estimated safe yield is 25.8 L/s.
- The various parameters monitored on the water flow, the water chemistry and the water temperature have indicated relatively constant conditions. The high flow rates used during the pumping test have not resulted in an apparent stress of the aquifer;
- The water chemistry and isotope analysis indicate that the water is low to moderately mineralized, of meteorological origin and has been resident in the subsurface for more than 50 years. It is probable that the groundwater originates from the Auriol range;
- Data are not available to stipulate on the size and lateral extent of this deep aquifer;
- The temperature observed in the deep aquifer has remained constant at 17°C over the period of extraction of the groundwater. The Dezadeash valley borders a series of major geologic faults and an area where the seismic activity is high. Therefore it is possible that "en route" to the deeper aquifer, the groundwater is heated as it comes in contact either with high temperature rock or thermal fluids. It appears that the heat transfer is well established, due to the constant temperature observed, and is not impacted by the change in groundwater flow

generated both during the recent use of the well and the high discharge rate pump test.

- The topography of the rock substratum at the bottom of the valley, the geometry of the fracture network and faults, the contact between the deep aquifer and any warm rock or groundwater are not presently known. Therefore it is not possible to define the conceptual model that would describe the geothermal conditions in the valley.
- For the duration, and under the conditions used and tested, Well #5 has provided water of good quality and at a constant temperature of approximately 17°C. Therefore the deep aquifer in which Well #5 is completed should be considered as a source of both water and energy. However, the use of Well #5 as a geothermal source should proceed with caution to take into account the various parameters that are still unknown and that would be presently very costly to characterize. As such, EBA recommends design of mid-term and long term water and energy use should only consider using a portion of what the well has been estimated to yield. This will be done to reduce the risk of "mining" both the aquifer and the source of energy and to provide a margin of safety to adjust drinking water and energy supply management plans.

2 Introduction

In the fall of 2002, a new water supply well (Well #5) was completed for the Village of Haines Junction (the Village) in a deep artesian aquifer bearing warm water (170C). The potential to use this groundwater resource to the benefit of the community was recognized by the Village. The Village has entered into a joint venture agreement with Energy Solutions Centre (ESC) in order to promote, study, and determine the feasibility of utilizing heat energy from groundwater for space heating in the Haines Junction as a means of reducing/displacing fossil fuel use.

The project team, consisting of Lessoway Moir Partners, as lead consultant, Quest Engineering Group (Quest), and EBA Engineering Consultants Ltd. (EBA) was contracted by Energy Solutions Centre to complete the preliminary assessment and feasibility study. The components of the study undertaken by the project team include:

- A Resource Assessment
- A Demand Side Assessment, and
- A Business Case Study

As Well # 5 is the first well completed in the deep aquifer, little is known about the capacity of the aquifer to yield both water and energy. EBA's role on the project team was to provide hydrogeological and geotechnical expertise for the resource assessment component of this study.

In any subsurface investigation, the quality of the data, the more special the data, and the larger the data set, all result in a higher level of confidence in the data. In this study, however, the cost of additional wells completed within the deep aquifer in which Well #5 is completed would be significant. For this reason, the resource assessment was designed in a phased approach. The first phase consisted of reviewing existing information and collecting new information at a relatively low cost in order to build a business case and identify feasible options for using warm water for drinking, heating and cooling purposes. The second phase will consist of collecting the required information to complete a pre-design, after business decisions have retained selected options. The results of this first phase of the resource assessment are reported herein.

This report has been prepared in accordance with generally accepted hydrogeological practice and engineering judgement has been used in the development of conclusions

and recommendations. For additional information and limitations regarding the use of this report, please refer to the attached General Conditions, which form a part of this report.

2.1 Objectives and Methodology for Resource Assessment

The work program methodology consisted of the following:

Task 1 - Project Start-up

All the team members attended a kick-off meeting that was facilitated by Lessoway Moir Partners. The main purpose of the meeting was to ensure that there was an understanding of the "global picture" and of the potential interaction of the various elements of the projects, from source to tap and from extraction to re-injection. The proposed tasks and schedules were reviewed, and the project milestones and communication protocols confirmed.

Task 2 - Data Collection and Review

EBA collected and reviewed reports, maps, aerial and satellite photos and other relevant information to estimate the lithology and stratigraphy in the valley near Haines Junction. This task was conducted with the following objectives:

to produce a map showing the estimated approximate extent of the deep aquifer;

to identify if there are geological data indicative of thermal conduits (e.g. faults) to which the deep aquifer could be connected; and

to complete a preliminary definition of the thermal gradient in the overburden, based on temperature information previously collected during the drilling and completion of boreholes (water wells or geotechnical boreholes) in the area of Haines Junction.

Task 3 - Aquifer testing

EBA coordinated two short "step tests" of 20 and 23.5 L/s followed by a long term pumping test at a constant pumping rate of approximately 27 L/s (360 lgpm) at Well #5 in July 2003. Well locations are indicated on Figure 1.

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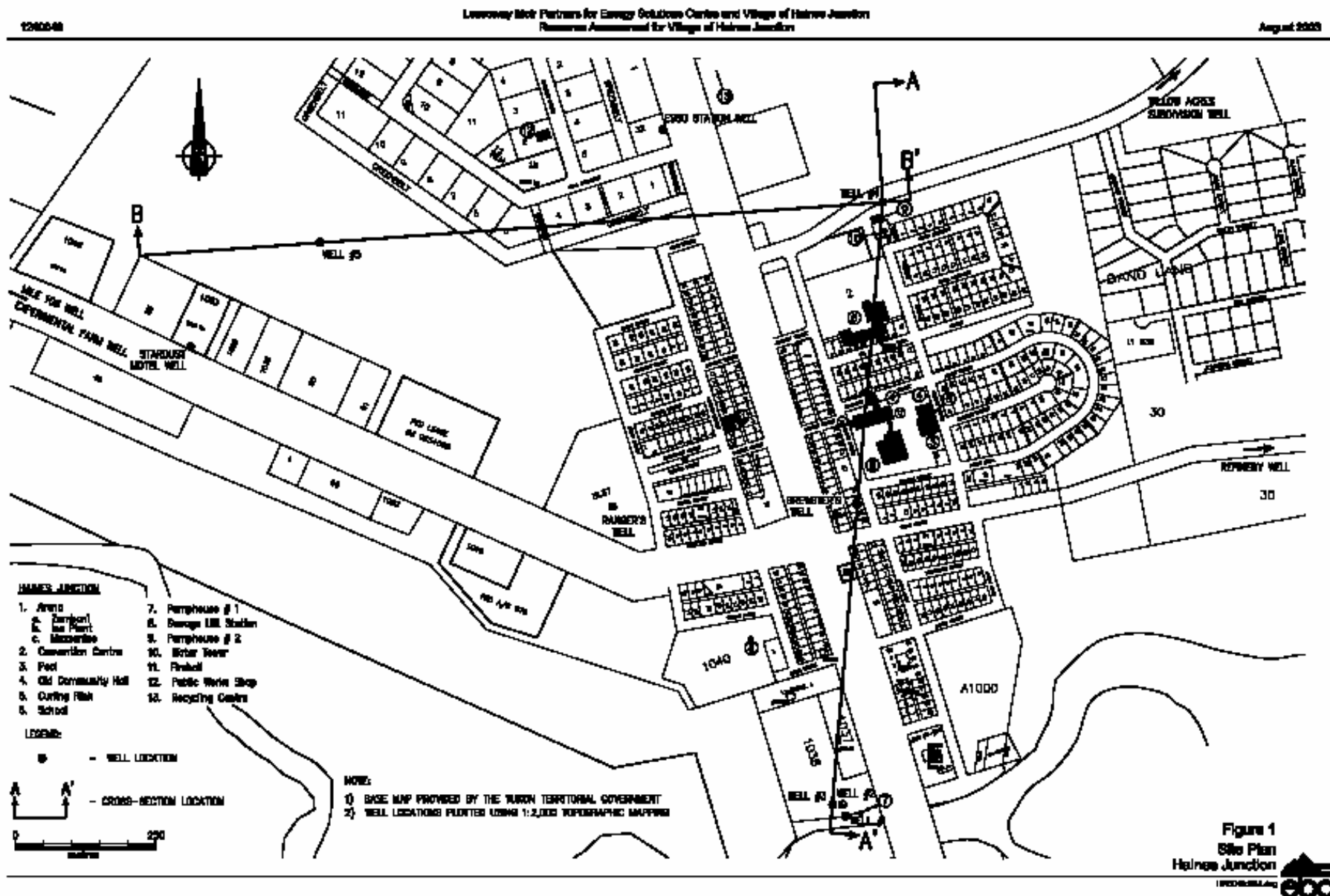


FIGURE 1

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Water level drawdown was monitored in the pumping well and at other locations to provide information on the impact of pumping on identified aquifers and aquitards. EBA installed electronic dataloggers in Wells #2, and #4 (the Village already has one in Well #3), and continuously monitored the variation of water levels for the whole duration of the pumping test. Water levels were also monitored manually and periodically for calibration purposes (quality control).

A water sample was collected and submitted for drinking water quality analyses (except coliforms) and also for bacteriological activity reaction tests (BART™). BART™ testing is conducted to assess the presence, size and level of aggression of common subsurface bacteria that can have a significant impact on the long-term operation and maintenance of water wells. A GPS survey to collect information on the location and elevation of the monitoring locations was also conducted.

Task 3 was completed to provide information on:

the estimated long term capacity (sustainable pumping rate) of the well;

aquifer parameters including transmissivity and storativity (if possible);

presence of aquifer boundaries (impermeable or recharge boundaries);

water temperature variation versus time (may be indicative of temperature gradient in the aquifer); and

variation in water quality versus time, if any.

Task 4 - Preliminary Aquifer Characterization

Task 4 consisted of compiling the information collected during the previous tasks and building a conceptual model of the spatial distribution of both geologic structure and groundwater in the subsurface, and assessing potential links between the various identified aquifers and aquitards. If sufficient data had been available, groundwater flow direction and hydraulic gradients would have been estimated.

Task 5 - Preliminary Assessment of Subsurface Temperature and Geothermal Analysis

EBA studied the vertical and spatial distribution of water temperature by using a field instrument to log water temperature at varying depths at several of the water wells in the area to obtain information on the geothermal gradient. In addition, EBA reviewed climate and soil data to estimate the geothermal conditions of the soils at shallow depths (for future civil engineering or infrastructure upgrade work), and also to complement the assessment of groundwater temperature. EBA completed the following:

- gathered meteorological and soils data for Haines Junction area.
- calculated soil thermal properties based on grain size and moisture contents.
- generated a one dimensional soil temperature profile. Our team partners have used this information to calculate seasonal heat losses from the pipe distribution system to ground.

Task 6 - Identification of Operation and Maintenance Issues

EBA gathered information to assess how the long-term use of Well # 5 may affect the observed artesian conditions. A preliminary conceptual hydrogeology and geothermal model was developed to estimate how the groundwater and energy conditions may vary due to the proposed extraction and potential re-injection of groundwater.

The extraction of water at these temperatures will enhance the development of subsurface bacteria, thus accelerating bio-fouling phenomena that are commonly observed in water supply wells. As such, a preliminary characterization of the native bacterial population was conducted using BART™ tests. Based upon these BART™ results, EBA developed a program to monitor the risk associated with bacterial growth and if necessary, EBA could develop an outline for maintenance and bio-fouling mitigation.

Task 7 - Reporting and Project Management

Results of the study are presented in this report, which is the result of several reviews of a previously submitted draft copy.

2.2 Authorization

EBA was authorized to complete the work program by Lessoway Moir Partners. The work program has been completed in a phased approach in conjunction with other phases of the overall project.

3 TECHNICAL BACKGROUND INFORMATION

The following sections provide some technical background for the remainder of this report.

3.1 Geothermal Energy, Gradients and Hydrodynamics

The Earth is a storehouse of geothermal energy that is produced internally by radiogenic heat production (heat produced by radioactive decay) and long-term cooling of the planet. While regionally variable, the ground temperature increases by about 15 to 30 degrees Celsius per 1000 metres depth into the Earth. This means that, on average, the temperature at a depth of around 500 metres is somewhere between 7 and 15 degrees Celsius higher than the temperatures at ground surface. In regions where geothermal gradients are higher (such as parts of British Columbia), temperature increases more rapidly with depth. Typically, these high gradient areas are associated with higher than normal heat flow resulting from geological causes such as recent volcanic or tectonic activity.

3.2 Aquifer Thermal Energy Storage (ATES) Systems – Applications and Aquifer Characterization

This section is intended to provide some background on the concept of aquifer thermal energy storage systems (ATES), which are referred to later in this report. Much of the information presented in this section was obtained from the review of a draft paper titled “Aquifer Thermal Energy Storage Systems” (Bridger and Allen, 2003).

The Earth's temperatures remains relatively constant over time except in the very near surface where seasonal fluctuations in ground temperature can extend to depths of several metres (such as in the Yukon where we experience ground freezing on a seasonal basis). This constancy of the temperature in the Earth's surface makes it an ideal medium for energy storage. ATEs refers to the storage of heated or chilled water in aquifers. This form of storage usually entails the injection of heated or chilled water during periods of low demand through a drilled well into an aquifer for storage. When the demand is again high, the stored water, which has usually retained an adequate amount of heat or chill, is pumped from the aquifer and converted into a useable form of energy. ATEs systems include 1) cold storage systems, 2) heat storage systems, 3) and combined cold and heat storage systems.

Aquifers have proven to be a viable option for long-term storage of thermal energy. The critical design components of an aquifer thermal energy storage (ATEs) system are:

- A production well or wells;
- A low cost source of thermal energy;
- A heat exchanger, and;
- A demand for stored thermal energy.

Assessing the suitability of the storage aquifer is a critical step in designing an ATEs system. Suitable storage aquifers are typically deep confined or unconfined aquifers located below the maximum depth of annual cyclic temperature variation.

3.3 Long Term Sustainability Issues

In order to assess the feasibility and long-term viability of the warm groundwater that is produced by Well #5, it is important to understand the characteristics of the aquifer in which the groundwater exists. As well, it is important to understand the heat energy mechanism. Whether the aquifer can sustain the production of "good" water at a consistently warm temperature at the necessary quantities is critical to the success of a large-scale geothermal project. Ideally, the aquifer and well, which is the conduit to the aquifer, should produce consistently warm water that is suitable for deriving both heat

energy and for use as potable water. Issues that need to be addressed within this phase, subsequent phases of the resource assessment, and long term monitoring are:

- What are the characteristics of the deep aquifer?
- What is the source of heat energy?
- Will continued use of this aquifer at high discharge rates deplete or “mine” the water from this aquifer?
- Will continued use of this aquifer alter the hydrodynamics of the system, thereby changing the geothermal regime?

3.4 Well Maintenance Issues

3.4.1 Biological Activity in Aquifers and Water Systems

Iron reducing bacteria (IRB), Sulphate reducing bacteria (SRB) and Slime forming Bacteria are non-health-related bacteria; however, they can cause bio-fouling, which can clog well screens, distribution piping, pumps and valves. Biofouling can cause clogging in most parts of a groundwater abstraction system including the distribution system.

The presence of these bacteria may also impinge on groundwater quality. Iron and manganese concentrations, and the presence of iron, manganese, and sulphate reducing bacteria in a well or water distribution system are interrelated. A rotten egg or sulphur odour is commonly generated by sulphate reducing bacteria (SRB) functioning in an oxygen-free environments and reducing either sulphates or sulphur to hydrogen sulphide.

Bio-corrosion is the inducement or enhancement of the electrochemical process of corrosion by the activity of sessile bacteria in forming biofilms. SRB bacteria are the key players in bio-corrosion. Bio-corrosion can also influence the quality of water in the system through:

- Increase in iron content generating red ‘rust’ water,
- Release of trace metals from corroded materials into the water.

The effects of mineral content in groundwater (in particular iron and manganese) and associated biochemical processes are complex and interrelated. These processes are also affected by temperature, dissolved oxygen content and water velocity within the well screens and distribution system. Consequently, minimizing or avoiding the factors that enhance these processes through proper well and distribution system design, installation, and operation and maintenance can assist in the prevention of biofouling problems and the associated aesthetic effects on water quality.

3.4.2 Testing Methods for Bacterial Aggressivity

Biological activity reactivity tests (BART™) are a water-testing tool for bacteria that are typically associated with groundwater systems. These tests detect the presence and degree of activity (aggressiveness) of these bacteria by time lag methods. There are bacteria specific tests including those that test for the aggressiveness of iron related bacteria (IRB-BART™) and Sulphate Reducing Bacteria (SRB-BART™).

3.4.3 Corrosivity and Encrustation

The chemical nature of groundwater can be corrosive to the well screen; pump, piping and distribution system, or it may clog the system by depositing scales (encrustation). Corrosion also causes enlargement of screen openings and can permit sediment to enter the well (Driscoll, 1986). It is important to use a well screen fabricated from corrosive-resistant material. The well screen for Well # 5 was constructed out of stainless steel and is resistant to corrosion.

Incrusting water will deposit minerals on the surface of the well screen and in the pores of the formation just outside the screen. These deposits plug both screen openings and the formation and are problematic to remove.

Several methods can be used to determine the corrosiveness or encrusting characteristic of groundwater. These methods include:

- Langelier Saturation Index (LSI);
- The Ryznar Stability Index (RSI); and

- Measuring and comparing water quality indicators of pH, dissolved oxygen, hydrogen sulphide, total dissolved solids, carbon dioxide, chlorides, carbonate hardness, iron, and manganese.

pH - Low pH, less than 7, indicates that the water is acidic and corrosive, while high pH, greater than 7.5, suggests that the water will be incrusting.

Total dissolved solids - If exceeding 1,000 mg/L may conduct enough electricity to cause serious electrolytic corrosion.

Chlorides - If exceeding 500 mg/L corrosive water can be expected.

Carbonate hardness - If exceeding 300 mg/L incrustation of calcium is likely.

Iron - If exceeding 0.5 mg/L precipitation of iron is likely, although some may precipitate at concentrations of 0.25 mg/L.

Manganese - If exceeding 0.2 mg/L and the pH is high, precipitation of manganese is likely if oxygen is present.

Groundwater analytical results from Well #5 are compared with these indices (Section 6.3) in order to determine whether there is any long term potential for corrosion.

4 Previous Hydrogeological Investigations

Several previous investigations relating to hydrogeology, and groundwater supply issues within the Village of Haines Junction have been completed. Relevant information was compiled from each of these reports as part of the current study and is presented in chronological order in Appendix A. Well locations, where known, are indicated on Figure 1.

5 REGIONAL INFORMATION

5.1 Physiography/ Topography

The Village of Haines Junction is located 158 km west of Whitehorse, Yukon, Canada at the intersection of the Alaska Highway (Hwy #1) and Haines Road (Hwy #3). The Village is situated on the northern bank of the Dezadeash River with an approximate

elevation of 600 metres above sea level (masl). Regional topography detail is indicated on Figure 2 and Figure 3.

Haines Junction is located within the physiographic region of the Shawkak Valley between the mountains of the Kluane Ranges, the Dezadeash Range, and the Ruby Range. Near the Village of Haines Junction the Shawkak Valley is about 13 km wide and extends from Pine Lake southwest to the Auriol Range. The topography gently increases from the Village to the foothills of the Auriol Range as indicated on Figure 2. The Auriol Range is shown in Photograph 1.

The Auriol Range of the Kluane Ranges is the closest range to Haines Junction and is approximately 5.5 km southwest of the Village. The Auriol Range rises steeply from the Shawkak Valley to a maximum elevation of about 2,310 masl. The Kluane Ranges are deeply dissected by V-shaped transverse valleys and are broken by major rivers such as the Dezadeash River. West of the Kluane Ranges is the Alsek River valley and the Icefield Ranges, which form the backbone of the Saint Elias Mountains and host a region of vast icefields, large valley glaciers, and high peaks such as Mount Logan at an elevation of 5959 masl.

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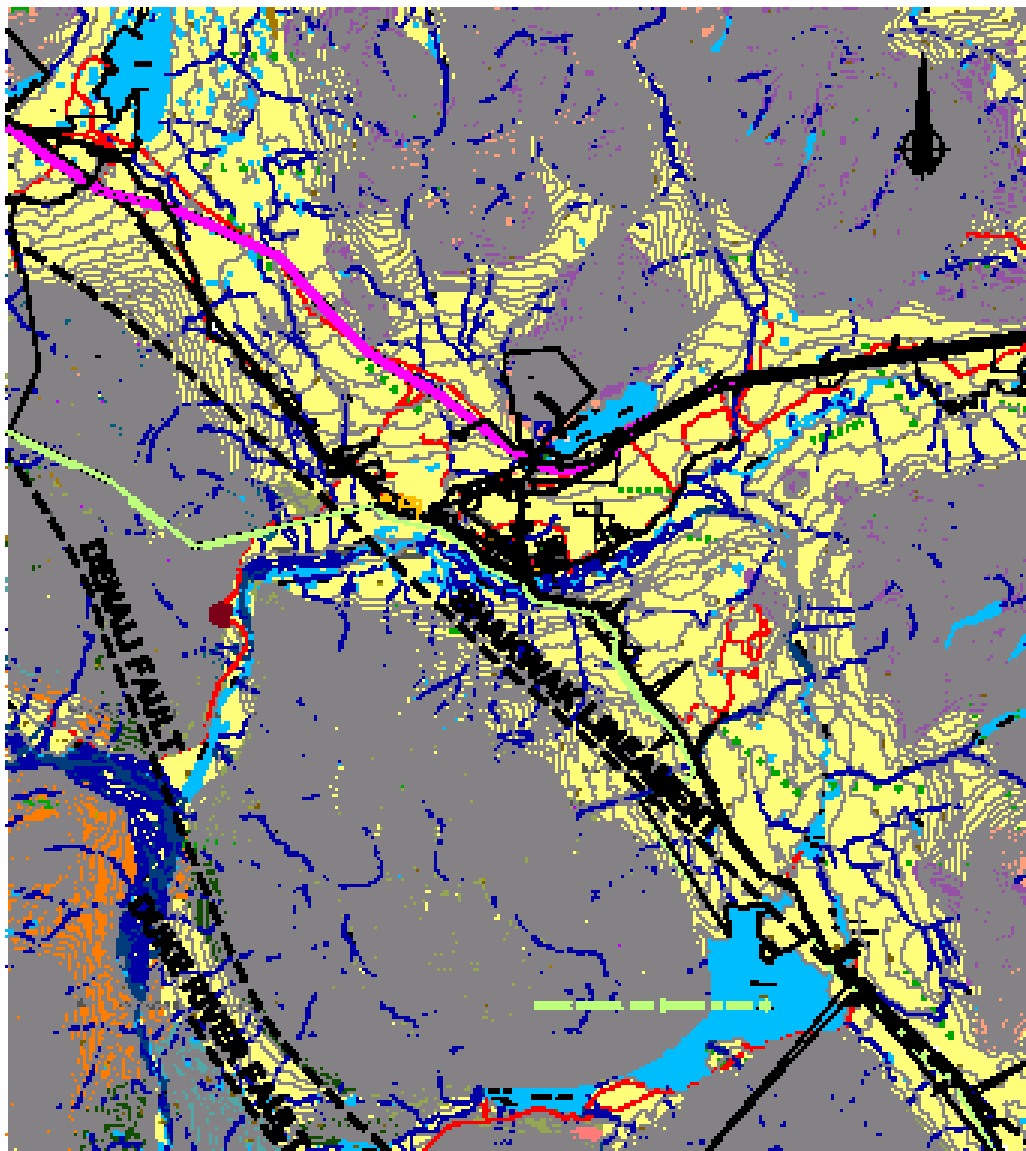


Figure 2
Regional Geology Map

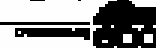


FIGURE 2
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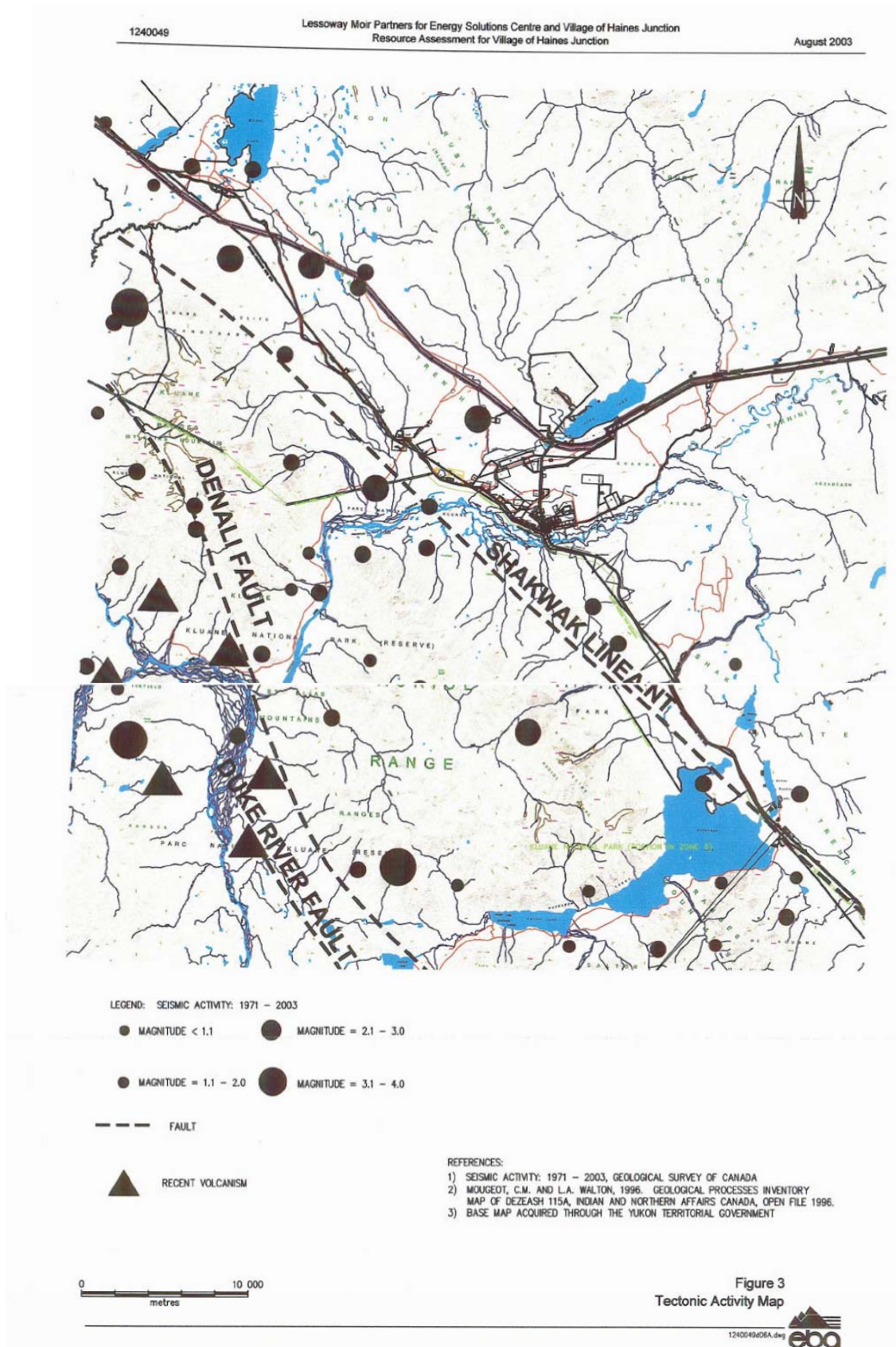


FIGURE 3
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Photograph 1: Looking south into Haines Junction. Auriol Range is in the background.

The Dezadeash Range and the Ruby Range form the western portion of the Yukon Plateau, which present a very different topography. The Yukon Plateau has a more subdued relief, with commonly rounded or flat mountaintops at elevations of 1,200 to 1,800 masl. Peaks up to 2,150 masl occur on some intrusive masses. The region is transected with an interconnecting network of valleys that drain into large river systems, such as the Dezadeash River. Except for the disappearance of the ice, the regional morphology has changed little since the last glaciation.

5.2 Geology

The geology in the region of the Village of Haines Junction consists of Quaternary sand, silt, clay and till deposits within the valleys, and partial to well exposed bedrock outcrops within the mountain ranges. The bedrock geology is described below, from oldest to youngest, followed by the Quaternary deposits.

5.2.1 Bedrock Geology

The Yukon Group is primarily located in the Yukon Plateau, Ruby and Dezadeash Ranges within the Haines Junction region, and generally consists of Precambrian quartz-mica schists, gneiss, slate, quartzite, crystalline limestone, greenstone, and chlorite and garnetiferous schists.

The Mush Lake Group, a thick assemblage of volcanic and sedimentary rocks, consists of fine-grained flows of green andesite, finely laminated light green tuffs, slates, and greywacke, basalt, rhyolite, volcanic breccia, argillite, and limestone. The Mush Lake Group is Triassic and/or Jurassic in age and underlies a large part of the Kluane front range, which includes the Auriol Range.

The Dezadeash Group forms most of the Auriol Range, is Lower Cretaceous in age, and consists mainly of a sequence of dull, dark grey to black, argillite and greywacke. The Dezadeash Group occurs in the axial zones of synclines, probably complicated by faults of the Kluane Range, and commonly exhibits strong internal folding. The respective ages of the Mush Lake Group and the Dezadeash Group illustrate that the geological contact is disconformable.

Coast Intrusions, consisting of mainly granodiorite, or peridotite and dunite exist within the mountain ranges and are from the Lower Cretaceous. The granodiorite intrusions of granite, porphyritic granite, diorite, and augen-gneiss are found intruded within the Yukon Group, while the peridotite and dunite intruded into the Dezadeash Group.

Tertiary volcanics are exposed west and southwest of the Auriol Range and are likely to be part of the St. Clare Group as defined within Muller (1967). The volcanics consist of volcanic breccia, tuff, rhyolite, dacite, andesite, basalt. Some sandstone has been associated with these volcanic deposits.

5.2.2 Surficial Geology

The most recent deposits in the Haines Junction region are the Quaternary unconsolidated and consolidated deposits. These deposits exist within river, mountain and glacial valleys, and depressions. According to Muller (1967), the Village of Haines Junction is situated within a lacustrine plain just north of fluvial floodplain of the Dezadeash River. Figure 2 shows the regional geology and surficial geology

information. Note that surrounding Haines Junction, northeast of Haines Junction along the Dezadeash River valley, and northwest and southeast of Haines Junction along the Shakhwak Valley, the surficial deposits consist of glaciofluvial outwash gravels. Southwest of Haines Junction, towards the Auril Range, the surficial deposits consist of diamicton ground moraine at the Auril foothills, and a mixture of gravelly glacial kame deposits, till covered slopes, and gravelly glaciofluvial or fluvial fans on the slopes of the mountains.

At least three major glaciers have advanced through the Shakhwak Valley and have covered the Village of Haines Junction (Muller, 1967). These glaciers deposited clay-rich tills and upon retreating, created the large pro-glacial lake, known as Glacial Lake Champagne (Day, 1962) that deposited thick sequences of clay and silt. During recent glacial surges of the late Holocene, the Lowell Glacier advanced across the Alsek Valley and blocked the south-flowing Alsek River. The resulting lake backed up into the Shakhwak Valley in the vicinity of Haines Junction and created a lake, Lake Alsek, which was at least 110 km long and 200 m deep. Each lake phase may have consisted of many short-lived cyclic filling and draining events. Radiocarbon dating has indicated that there have been several phases of Lake Alsek in the last 500 years as well as one, or more, older Neoglacial episodes of ponding. The last and least extensive expansion of the lake into Haines Junction area occurred during the 19th century and was estimated about 1850 A.D. (Clague, 1982).

The geological materials encountered beneath the Village of Haines Junction during the drilling of Well # 5 correlate to the expected deposits from the geological history described above. These deposits consist of an alternating sequence of clayey tills and fine-grained glaciolacustrine deposits consisting of silt and clay with occasional sand and gravel lenses. A flowing artesian sand and gravel aquifer was intersected beneath this sequence from 329 to 369.2 metres below ground level (mbgl).

5.2.3 Structural Geology

The Village of Haines Junction is located near two distinct major tectonic belts that may be traced far into Alaska and British Columbia. The north-eastern belt is a geanticline that extends into Alaska, and is called the Tanana geanticline. The south-western belt is a geosyncline that continues to the northwest as the Alaska Range geosyncline. The

two regions are separated by the Shakwak lineament, which is southwest of Haines Junction.

Shakwak Lineament

The Shakwak Lineament exists within the Shakwak Valley, which separates the Yukon Group (Yukon Plateau, Ruby and Dezadeash Ranges) and the Kluane Ranges. The lineament is a major fault line that extends from beneath Dezadeash Lake into Alaska. The lineament can be identified on aerial and satellite photographs and is thought to be the hinge line for the Tanana geoanticline and the Alaska Range geosyncline, along which considerable vertical movement has occurred.

Duke River Fault

The Duke River Fault is situated west of the Auriol Range and is a structural contact between pre-Permian rocks and Permian to Tertiary rocks. The fault was active after eruption of the Tertiary lavas and suggests north-eastern thrust faulting.

Denali Fault System

The Denali fault system (DFS) extends for ~1200 km, from southeast to south-central Alaska. The DFS has been generally regarded as a right-lateral strike-slip fault, along which post late Mesozoic offsets of up to 400 km are inferred (Redfield and Fitzgerald, 1993). Some areas in the eastern segment of the DFS appear to be thrust faulting (Eck, 2003). The DFS consists of several faults, which include the Shakwak Lineament. South of the Shakwak lineament the DFS continues as the Dalton Fault, followed by the Chatham Strait Fault, which extends to the Pacific Ocean and terminates at the Fairweather Fault. The DFS continues north of the Shakwak Lineament with the McKinley, Farewell Fault, Holitna Fault, and the Togiak/Tikchik Fault (Redfield and Fitzgerald, 1993). St. Amand (1957) speculated that the DFS might be continuous with the Californian San Andreas fault system.

5.3 Air Photo and Satellite Photo Interpretation

Aerial photographs and satellite images of the region of Haines Junction were reviewed to help interpret the topography, physiography, geology and location of buildings. The aerial photographs were viewed under stereoscopes to identify elevation changes,

geomorphology processes in the area, and surficial geology. The photographs were taken on August 28th, 1993 at the scale of 1:20,000. The satellite images showed the Shakwak Valley and Haines Junction from Kloo Lake to Dezadeash Lake and were used help delineate drainage patterns and outlying buildings within the valley.

5.4 Tectonic Activity

The Pacific and North American crustal plates are located west of the Village of Haines Junction, the Shakwak Valley and Kluane Ranges. The Fairweather Fault, which is only about 100 km to the southwest of the Shakwak Valley, is thought to be the present transform boundary between the two plates and is characterized by large earthquakes (Plafkar et al. 1978). Some segments of the Denali Fault System in Alaska are presently active and it is possible that the portion of the Shakwak Lineament that comprises the Denali Fault System must also be active (Clague, 1982).

Although the Denali Fault System in the region surrounding the Village of Haines Junction has been active to only a minor extent during the late Quaternary time, present-day seismicity in the region is high, as shown in Figure 3. The seismic activity between 1971 and 2003, along with geologically recent volcanic eruptions, are plotted within this figure. Seismic activity have been monitored since 1899, but only since the establishment of the Whitehorse seismograph station in 1971 have the epicenters been more accurately detected and located. Most of the local earthquakes occur in the intensely faulted region between Shakwak, Denali and Duke River Faults in the Kluane Ranges. It has been estimated that ground accelerations of 0.1 g, the approximate threshold of accelerations capable of damaging ordinary structures on firm soil, have a return period of 30 to 100 years for the Shakwak Valley Area (Stevens and Milne, 1974). This demonstrates that there is potential for significant ground disruption in the region of Haines Junction.

5.5 Groundwater Usage and Water Well Details

5.5.1 Water Well Records

The Village of Haines Junction has had five municipal water wells developed for the community. Several private water wells also exist or have existed within the Village. These wells are shown within Figure 1 and are summarized in Table 1. Water well

records were obtained from ESC who recently purchased these records from Midnight Sun Drilling. Well records are provided in Appendix B. As well, information was obtained through the review of historical reports. If available, information about the depth of the well, the static water level, existence of a well log, and water chemistry data are listed for each well in the table.

5.5.2 Village of Haines Junction

Currently, only Well # 3 and Well # 5 are used as groundwater supply wells. The other three water wells, Well # 1, Well # 2, and Well # 4, have not been abandoned and Well # 2 and Well # 4 were used as monitoring wells during the pump test at Well # 5. Well # 1 remains recognized, as a supply well within the water license in the event that this shallow cold well must be used for backup, however there is currently no pump installed within, nor piping to this well. The history of the groundwater wells in the Village of Haines Junction was documented earlier, a water well summary is provided in Table 1, and the well logs are included in Appendix B.

5.5.3 Groundwater Usage

The municipal groundwater usage for the Village of Haines Junction in 2001 was reported to be 118,584 m³. According to calculations provided by Quest Engineering (Quest, 2003), the average daily demand is 325 m³/day or approximately 3.55 L/s. In 2001 and for most of 2002, only Well # 3 supplied the village's water supply and this demand was greater than the maximum allowable safe yield of 100,000 m³/year for Well # 3. Well # 5 was connected to the Village's water distribution system beginning November 25, 2002. Both Well # 5 and Well # 3 supply the village with its municipal water. Between November 25, 2002 and July 7, 2003, Well # 5 and Well # 3 supplied the Village of Haines Junction with 22,216 m³ and 39,776 m³ of water with an average daily withdrawal of 98.7 m³/day and 224 m³/day, respectively. The water license which was amended in July 2003, allowed for only 100 m³/day of use from Well #5. Since the water license was amended, and following the completion of the pump test and recovery, the Village has relied mostly on groundwater from Well #5 with some supplement from Well #3.

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TABLE 1: WATER WELL SUMMARY

Well Name	Approx. Elevation ^A (metres above sea level)	Depth ^B (metres below ground level - mbgl)	Static Water Level ^B (mbgl)	Aquifer Interval ^B (mbgl)	Pumping Rates ^B (m ³ /day)	Well Logs (Yes/No)	Water Chemistry/ Water Characteristics ^B	Comments
Well #1	582.5	borehole: 7.6 screen: 7.0 - 7.6		7.0 - 7.6	295 - 327 m ³ /day	Yes	19 Dec. 1973 (HCL 1974); 25 May 1988; 6 June 1974 Calcium Bicarbonate	Also known as: Testhole #2- 74
Well # 2	583.0	borehole: 134 screen: 76.5 - 78.3	Artesian when drilled but currently not flowing	uncertain	100 igpm during development, 45 igpm in 1980 due to siltation (SAEL, 1980)	Yes	Medium hard, calcium-bicarbonate, 38 deg F; (HCL 1974b) Sodium Bicarbonate	Also known as: Warm Water Well #1
Well # 3	582.5	borehole: 82.3 screen: 79.3 - 82.3	-3 when drilled but currently not flowing	78.4 - 83.2	690 m ³ /day (105 igpm) during development, 298 m ³ /day (UMA, 1988)	Yes	Both Aquifers in (HCL 1978); 25 May 1988; 3 samples in Stanley Assoc. 1980 Sodium Bicarbonate	Also known as: Warm Water Well #2
Well # 4	618.0	borehole: 249.9 screen: 119.8 - 122.8	20	120.4 - 121.9	407 m ³ /day but never reached due to sediment in water (UMA, 1988)	Yes	"Chemically acceptable" in David Nairne & Assoc. Ltd, 1996, but no data, Sulphate	Also known as: TW3-89
Well # 5	608.5	borehole: 384.6 screen: 361.9 - 369.2	-56.95 on July 2, 2002	329 - 369.2	2,333 m ³ /day (GLL, 2002)	Yes	Table 3; GLL 2002 Sodium Bicarbonate	Aquifer interval from 329 mbgl to mbgl.

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Esso Station Well	613	60.0	24		32.7 m ³ /day	No	5/25/1988 Sulphate	
St. Elias School	612.5	34.0	26		51.8 m ³ /day	No	6/20/1988 Sulphate	abandoned
Brewster's Well	602	156.0	Artesian		Insufficient yield for community well	No	HCL 1974; 25 May 1988 Sodium Carbonate	NM
Willow Acres Subdivision		71.6	45.7			No	High SO ₄	Lot 13
Stardust Motel	605	79 (stated by owner)	20		Tranmissivity = 4.8 m ² /day	No	Small print in HCL letter of March 13, 1997 Sodium Carbonate	
Ranger's Well		165.0	8.5	12.2 - 15.8		Yes		Located at Park's Canada Kluane Visitor Center
Sue Burton Well		26.0				No	5/25/1988 Magnesium Bicarbonate	
Experimental Farm Well		26	Artesian			No	5/25/1988 Sodium Bicarbonate	
Refinery Well	590	6 to 9				No	Calcium Bicarbonate	obstruction in well water was hauled from well to supply the town
Mile 1018 Well						No	Temp: 36 deg F Sulphate >800 mg/l iron: 1.7 mg/l very hard: 563 mg/l Sulphate	very poor water quality similar water quality to Pine Creek

Note: A) Elevations based on published reports or 2m contour mapping.
B) Well depths, static water levels, and water chemistry based on published reports or field measurement data.

5.5.4 Private Groundwater Wells

Ten private groundwater wells are known to be located within the vicinity and Village of Haines Junction. These private wells are known as the Esso Station Well, also referenced as the Hotte well (now a Fas Gas Station), St. Elias School Well, Brewster's Well, Willow Acres Subdivision Well, Stardust Motel Well, Ranger's Well, Burton Well (location unknown), Experimental Farm Well, Refinery Well, and the Mile 108 Well. The details on each well vary and are listed in the water well summary table of Table 1. Typically these are low yielding wells suitable for domestic or limited community needs, such as a school or motel. The water quality also varies from good quality to very poor water quality. Some of these wells had high sulphate readings. Where possible, these wells are located on Figure 1.

5.6 Inferred Lithology and Local Hydrogeology

Based on a review of water well records, surficial geology maps, and consultants reports, cross sections were developed to illustrate the lithology at the known locations, and where possible, the inferred lithology between the well locations was interpreted. Cross section A-A (Figure 4) is a north-south transect through the Village, while section B-B' (Figure 5) is an east west-transect. As indicated on the cross sections, all water wells in Haines Junction have been completed within overburden materials. No bedrock wells are known to exist in the Village.

As mentioned previously, Well #5, the deepest well completed in the area was screened within a sand and gravel aquifer that was encountered between the depths of 343 and 370 m below ground surface. There is no obvious evidence that Well #5 is completed within the same aquifer as any of the other wells in the area (based on borehole log lithology, static water levels or artesian pressures and groundwater chemistry).

Based on lithology and groundwater chemistry, it appears that the Brewster well, and Village Wells #2 and #3 are likely completed within the same sand and gravel aquifer bearing sodium bicarbonate type groundwater. This aquifer appears to have a component of dip (not likely the steepest gradient) from south to north at a grade of approximately 13%. Well # 4, bearing sulphate type groundwater is not likely completed within this same aquifer. The Esso (Hotte) well, Well #4, and the St. Elias School well are likely completed within the same silty gravel aquifer bearing sulphate type

groundwater. This aquifer ranges in depth from 30 to 60 m below grade and appears to have a component of dip from south to north at an approximate grade of 5%.

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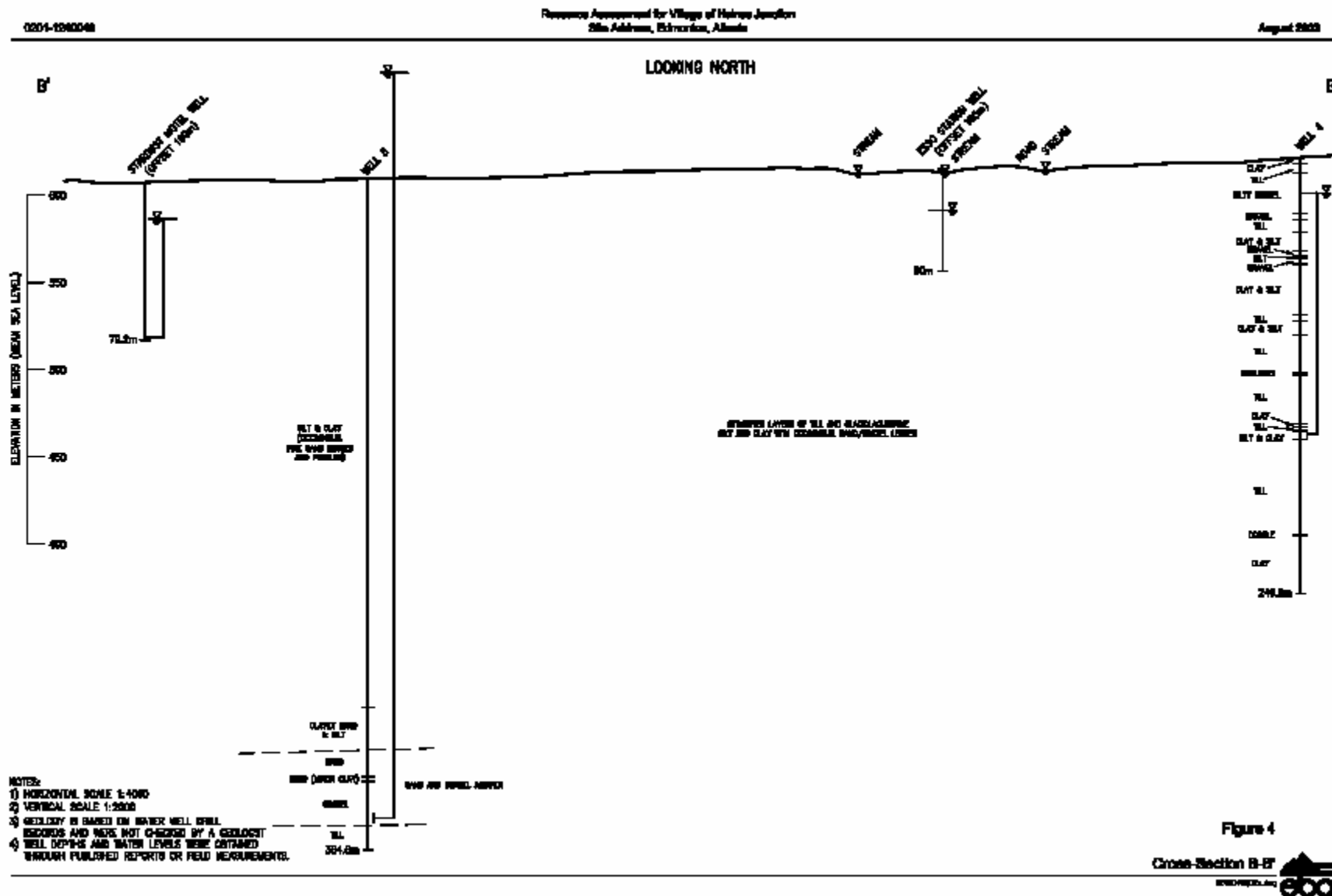


Figure 4

Cross-Section B-B'

FIGURE 4

EBA Project #: 1240049
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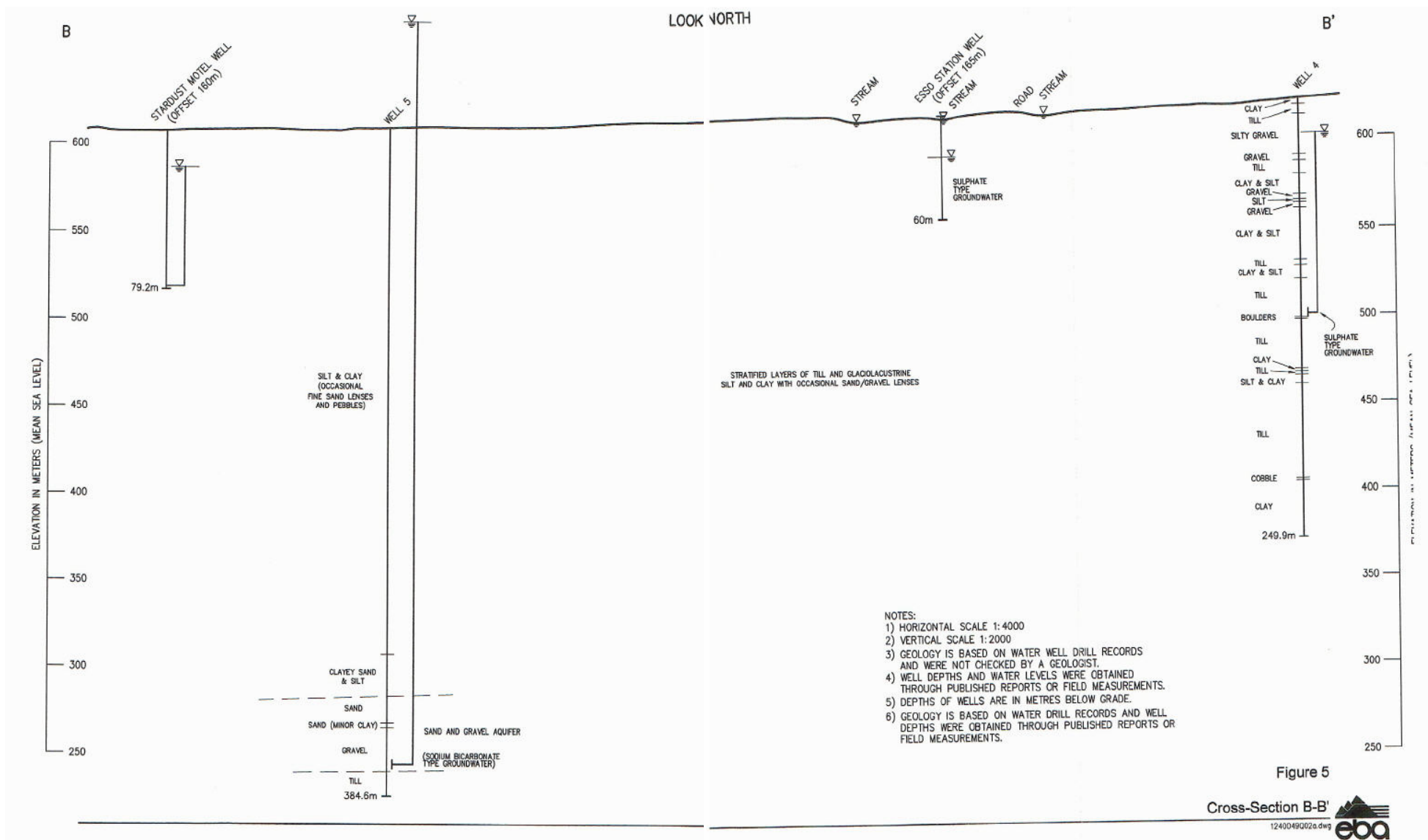


FIGURE 5

5.7 Conceptual Regional Hydrogeology

Based on the geological information collected at Well # 5, Gartner Lee Ltd (2002) proposed a conceptual hydrogeological model for Well # 5. This model consisted of alluvial fans and/or deltas that have formed off the slope of the Auriol Range (see Photograph 1) south of the Dezadeash River as a result of deposition as either deltas directly into Glacial Lake Champagne or as fans during periods of fluctuating lake levels. Their model shows a confining layer of glaciolacustrine silt and clay with occasional sand lenses and a till layer between the inferred bedrock and the fans/deltas. Based on the information collected during the review of maps, historical reports, water well records, and the results of the field program, EBA has revisited the conceptual model in light of the new information. This is presented in Section 7.1.

6 FIELD PROGRAM METHODOLOGY

6.1 Aquifer Testing

In July 2003, the Yukon Water Board issued an amendment (amendment one) to the original Type B water license (MN99-027) for the Village of Haines Junction. This amendment provided authorization for the use of Well #5 (in addition to Wells 1 and 3 already listed on the water license) for water supply in the Village of Haines Junction. The amendment provides authorization for extraction of up to 667 m³/day (7.7 L/s) as well as provisions for two pump tests at maximum discharge rates of 2333 m³/day (or 27 L/s).

EBA was on site between July 7th and 13th to coordinate and supervise the pumping tests conducted at Well #5. EBA contracted Aqua Tech supplies and services Ltd. to supply and install a submersible pump capable of pumping in excess of 27 L/s at the expected head requirements for temporary use during the test. Aqua Tech also provided the necessary equipment (generator, flow meter, discharge pipe, trash pump etc.). The equipment set-up is shown in Photograph 2. The pumping tests conducted by Aqua Tech and supervised by EBA consisted of a 2-hour step rate test followed by a 69-hour constant rate test.

Groundwater was piped through a 150 mm diameter lay-flat hose and some lengths of 200 inch diameter PVC pipe to a low lying area approximately 250 m northeast of the pumping well (See Photograph 3). The water then flowed overland on top of the till

ground surface and was ultimately discharged to the sewage outfall ditch in accordance with the Water License amendment (Photograph 4).



Photograph 2: Set-up for pumping test. Note: Generator on trailer deck (left), trash pump beside wellhead, canopy over well head (right) and discharge line running north-west from wellhead.



Photograph 3: Discharge line running northwest into wooded area, towards sewage outfall ditch.



Photograph 4: Discharge during test flowing overland into sewage outfall ditch.



Photograph 5: Well flowing under Artesian pressure prior to beginning of pump test.

6.1.1 Well Shut down

The Village of Haines Junction has used Well #5 to provide approximately 100 m³/day for water supply since November 26th, 2002. The well flowed under artesian pressure to Pumphouse 2 indicated on Figure 1, where it was chlorinated and then flowed under artesian pressure into the water tower.

On Monday, July 7th 2003, at the request of EBA, all artesian flow from the well was closed off on the valve at the wellhead. The well was then allowed to recover over a period of approximately 36 hours. Pressure at the wellhead was monitored, and prior to opening of the well at 13:00 hours on July 8th, the pressure had increased to 81 psi, or equivalent to 56.95 m of water column above the wellhead. This was assumed to be the static water level prior to the pumping test. Note that this static level is slightly lower than the artesian pressure head of 84 psi (59.06 m of water column) observed by Gartner Lee in October 2002 when the well was drilled. This difference of artesian pressure at the wellhead could be accounted for by one or more of the following explanations:

- Seasonal fluctuations of the water level in the recharge end of the aquifer; and/or
- Incomplete recovery of the Well over the 36 hour period of well closure, and/or
- Atmospheric Pressure fluctuation effects on artesian pressure in a confined aquifer, and/or
- Accuracy of the pressure guage(s) used between these monitoring events, and/or
- The static water level had decreased over the seven months of use between well construction and the July pumping tests.

6.1.2 Pump and Monitoring Equipment Installation

At 13:00 on Tuesday July 8th, the well cap on Well #5 was removed to facilitate pump installation. With the well cap removed, the well flowed freely from the 150 mm diameter Victaulic connection on the side of the well casing. The discharge was piped into a temporary "discharge basin" (See Photograph 5). The water from the basin was then pumped with a 100 mm turbine pump through a 150 mm diameter discharge line to the discharge area. The flow rate under artesian pressure was approximated by two

different methods. The volume discharged to the basin was measured (based on the dimensions of the basin) over a finite time interval. Based on this calibration test, it was calculated that the pump was flowing under artesian pressure to the basin at a rate of approximately 12.4 L/s. Just prior to the first step of the pump test, when the well was pumping through the flow meter to the discharge basin, the flow was gauged at approximately 10.8 L/s. The difference in these two flow rates is explained by the resistance provided by the flow meter and the 245 m of discharge line. Since the discharge during artesian flow was routed to the discharge tub, prior to being pumped by a trash pump through the discharge piping, the friction losses from the piping would not have restricted the flow from the well. Therefore, the measure of flow at the discharge basin, although a crude measure, is likely more accurate than this other method. Hence, it is assumed that the well flowed under artesian pressure at approximately 12.4 L/s from the time that the wellhead was opened for pump installation for 24 hours prior to the test. In essence, the well discharge test was initiated once the wellhead was opened.

While the well was opened and flowing, a 3 phase multi stage submersible pump capable of pumping at 27 L/s was installed in the well. Pump specifications and a pump curve for this pump are included in Appendix C. The pump is made entirely of stainless steel and is fitted with a built in check valve. At a rate of 430 USgpm (27 L/s) the pump can provide approximately 102 m of head at an efficiency of 75.1%. The pump is equipped with a 50 hp Franklin 6 inch motor and Model 3853500-6, 4 inch discharge Grundfoss pump end. AquaTech set the pump intake at a depth of 99.97 m below the top of the well casing. The submersible pump was connected to one hundred meters of 100 mm diameter schedule 40 steel threaded pipe, suspended from the top of the casing.

A 100 mm Barton Flow Totalizer® with a digital display readout was installed in-line with the discharge line to monitor total and instantaneous flow during the pump test (See Photograph 6). The flow meter precision is reportedly 0.25%. Specifications for the flow meter are included in Appendix C. The flow meter was installed according to manufacturers recommendations at a distance greater than 5 pipe diameters from the nearest fitting or instream device. A mechanical thermometer with a dial display was installed within the discharge pipe, at the top of the wellhead.

Ninety one metres of 25 mm diameter threaded PVC piping was installed within the well casing, alongside the piping to a depth of 91.5 m below the top of the wellhead. The

purpose of this “dip tube” was to allow access of the water level meter to monitor water levels within the well without risk of the measuring device tangling with the electrical wires running to the pump. The top of the “dip tube” was 0.30 m above the top of the wellhead. This was used as the datum or reference point for all water level measurements during the pump test (See Photograph 7).



Photograph 6: Barton flow totalizer flow meter measuring instant and total flow during second step of pump test (380 Usgpm)



Photograph 7: Obtaining manual water level readings during pump test at Well 5.

6.1.3 Step Test

A step rate pump test was conducted to verify the optimum pumping rate for a long-term test, and to see if the specific yield of the well was consistent with the observations made by Gartner Lee Ltd. (GLL) during the pumping test completed in Oct. 2002. The maximum pumping rate during the GLL pump test was 19.1 L/s. By design, the first step of the July 2003 test was completed at approximately the same discharge rate as the final GLL step (20 L/s). Flow rates were varied during each of the steps by adjusting the gate valve such that the desired flow rate was observed on the flow meter.

The first step test was started at 13:31 PM on July 9th, 2003. For the first sixty-one minutes of the test, the Well was pumped at approximately 20 L/s, then 23.5 L/s for the next sixty-one minutes of the step rate pump test. Water levels in the pumping well (Well #5) were monitored frequently following the change in discharge rate, and then regularly throughout the test. A graph indicating drawdown vs. time during the step test is provided in Figure 6. Note that the water levels became relatively stable soon after each change in the pumping rate for each step. A graph of drawdown vs. discharge (See Figure 7) indicated that the specific capacity was consistent with previous observations by Gartner Lee. After two successive pumping steps indicated that the

well was performing as expected, it was determined that the constant rate test could be conducted at the maximum pumping rate allowed by the water license. Based on a linear extrapolation of the observed drawdown vs. discharge trendline, 27 L/s is also the discharge rate that would cause drawdown to the safe available drawdown level previously estimated by GLL (140.1 m).

6.1.4 Long Term Constant Rate Pump Test

It would have been preferable to allow the well to fully recover before starting the long-term constant rate pump test. However, because the well is artesian and flow from the well could not be completely closed off with the pump and piping installed, full recovery was not possible prior to initiation of the constant rate test. There would be no genuine benefit in stopping the test, allowing it to recharge to the wellhead and then beginning the constant rate test. Hence, it was decided to progress immediately from the step test into the constant rate test. Beginning at 3:24 PM on July 9th, pumping was initiated at Well #5 at a constant rate of 27 L/s (430 USgpm).

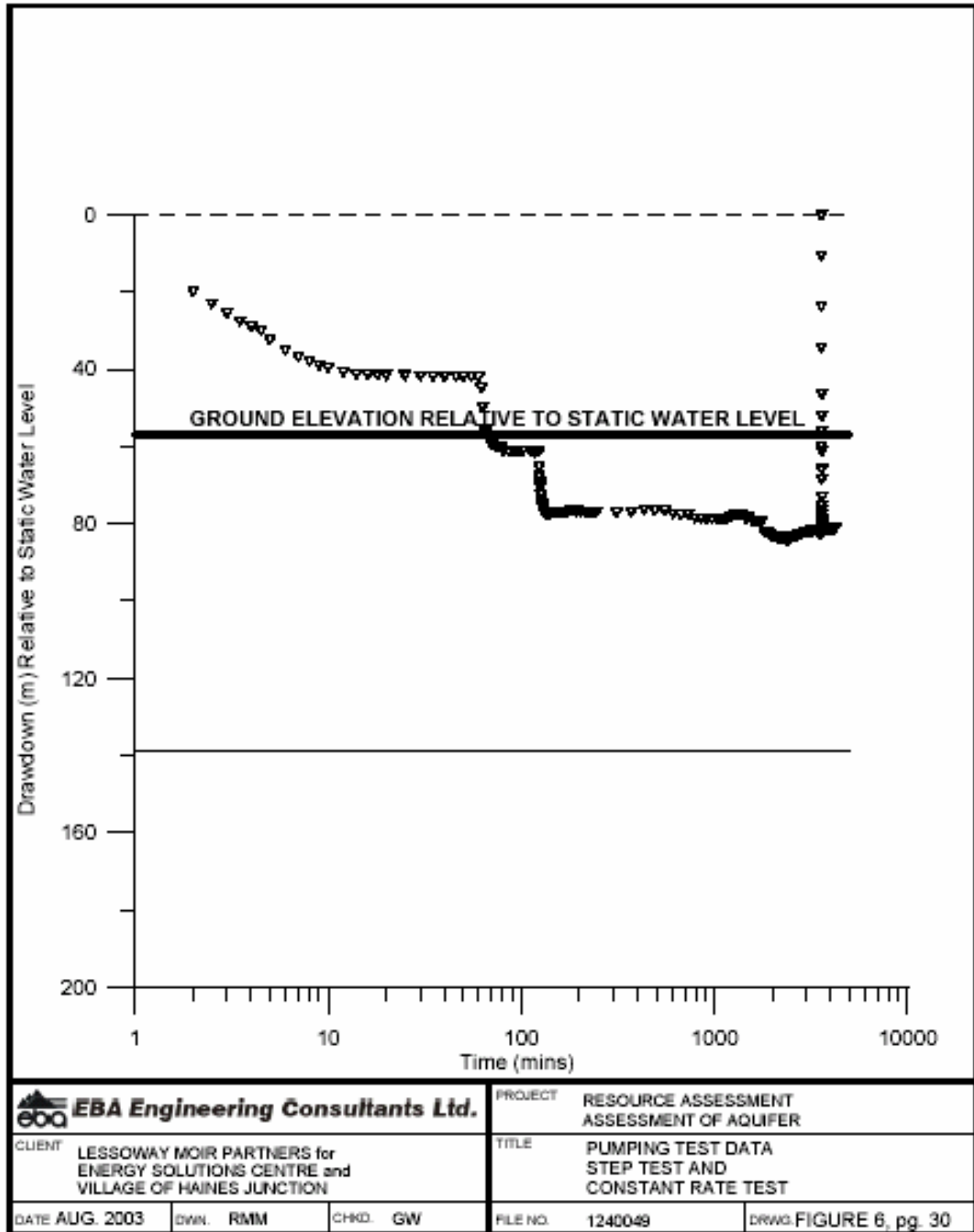


FIGURE 6

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

1240049

Leasoway Moir Partners for Energy Solutions Centre and Village of Haines Junction
Resource Assessment for Village of Haines Junction

August 2003

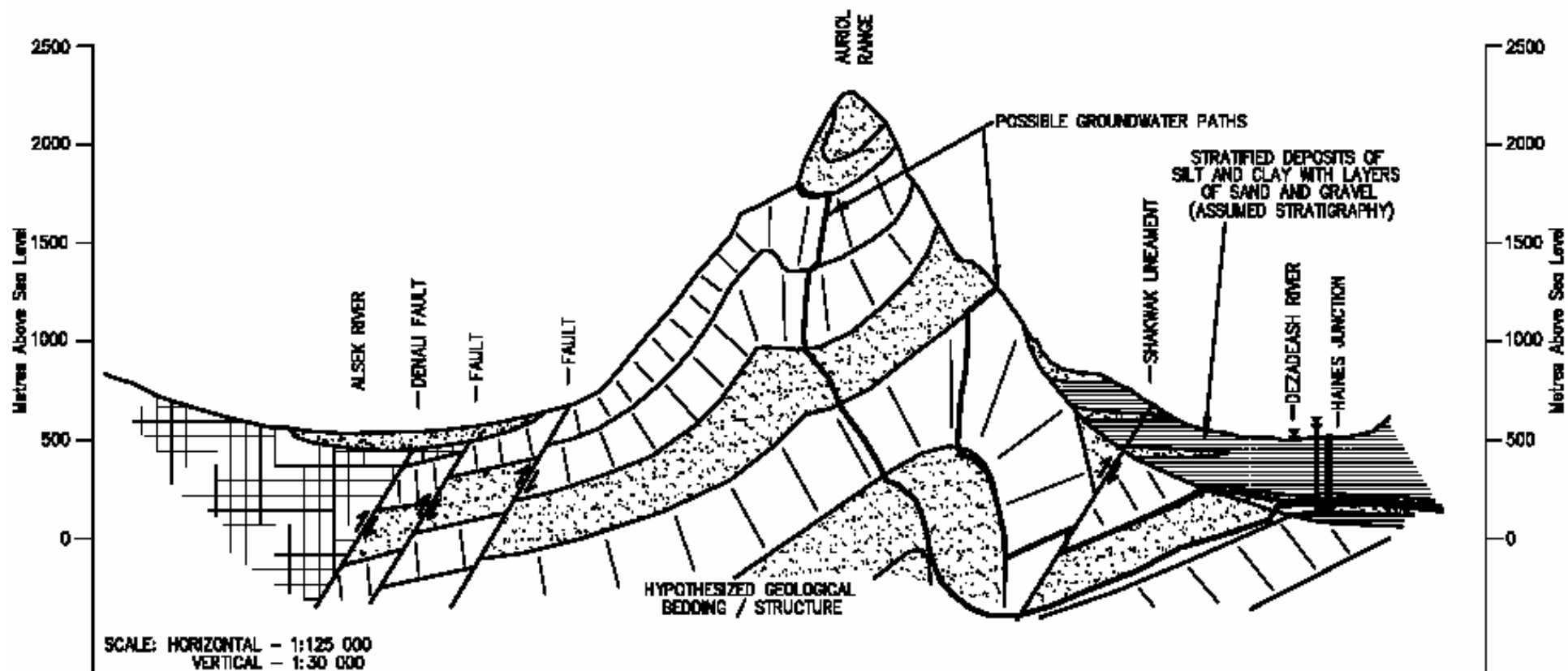


FIGURE 7

Water level data collected during the constant rate test is also provided in Appendix C. Figure 6 shows drawdown vs. time for the constant rate test. Following the flow increase from the last 1 hour step to the constant rate step, the water level became relatively constant and did not continue to decline significantly or consistently after approximately 8 minutes of pumping at 27 L/s.

As can be seen on Figure 6 undulations in the water level within the pumping well (Well #5) were observed during pumping. After approximately 11 hours of pumping, the water level dropped in elevation by approximately 1 m, and then re-stabilized. After 21 hours of pumping, the average discharge rate had fallen below 27 L/s and it was decided by the contractor that the gate valve on the discharge would be adjusted slightly to increase the average flow rate back to 27 L/s. Once adjusted the water level dropped approximately 0.8 m and it continued to drop slightly until 27 hours into the constant rate test; however, the digital display on the flow meter indicated that the discharge rate was also dropping to slightly less than 27 L/s on average. After 27 hours, the flow rate was adjusted slightly again to ensure an average of 27 L/s. The slight adjustment had resulted in a drop in the water level by almost 3 m when the next water level was taken an hour later. Again, the water level continued to drop gradually another 2 m until approximately 38 hours into the constant rate test. From 38 hours to 48 hours the water level recovered again by approximately 2 m and then remained relatively constant until approximately 56.5 hours into the constant rate test.

A coolant hose on the generator began to leak coolant at approximately 56.5 hours into the test. Sorbent spill kit material was immediately put into place to absorb any coolant under the trailer. Attempts were made to repair the leak while the generator was still running so as not to interrupt the constant rate test. With the repair attempts failing, and the generator temperature rising, it was determined that the generator had to be shut down temporarily to make the hose repair. At 12:50 AM on July 12th, after approximately 57 hours of constant rate pumping and 59 hours of total pumping duration, the generator and pump were shut down. Recovery was monitored as often as possible as the water level responded to the wellhead. As it was recovering, the contractor switched the discharge piping from the pump discharge to the turbine pump connected to the overflow basin. The water level had fully recovered to the wellhead after 2.5 minutes and the well began to overflow into the tub from which it was pumped with the turbine pump. With the generator down, the contractor was able to repair the coolant line. At 1:08 AM on July 12th, after having been shut down for 18 minutes, the

generator and pump were re-started. Water levels were monitored frequently over the first hour of the test. After one hour of pumping, the water level had dropped to within one meter of its level prior to pump shutdown. Between 1:08 AM and 12:08 PM on July 12th the pump test was continued at a discharge rate of approximately 27 L/s. No adjustments to the gate valve were made during this time. The water level remained very constant over this 11 hour period. At 12:00 PM, the coolant line began to leak coolant once again. The generator was shut-down again at 12:08 PM. The contractor observed that the water level had responded to the wellhead at 12:10:30 PM, two and a half minutes after pump shut-down, consistent with the previous initial recovery. Since the hose could not be repaired, the test was terminated approximately 69 hours into the “constant rate” test.

The well flowed openly at approximately 12.4 L/s while the pump and piping were removed from the well. A photograph during the removal of the down-hole piping and pump is provided as Photograph 8. Following disinfection of the well by super chlorination through the PVC monitoring tube, the well was capped at 16:08. A pressure gauge was fitted to the discharge line on the side of the well. The specifications for the mechanical pressure gauge are provided in Appendix C. The new mechanical gauge, supplied by Aqua Tech was similar to the gauge that had been used by the Village prior to the test. The pressure at the wellhead was initially 70 psi after the cap was re-installed. This is equivalent to 49.7 m of water column at the wellhead. The difference in pressure at the wellhead relative to the start of the test (81 psi) is not unexpected, as the well was still recovering. The pressure response at the wellhead (indicative of recovery) was monitored daily over the following week by the Village. This data was very important as it provided the late time recovery data.

6.1.5 Temperature Monitoring

The pumped water temperature was monitored with a mechanical gauge installed within the discharge piping at the elbow on the top of the wellhead. Water temperatures remained consistent throughout the test at 17oC. As mentioned previously, the geophysical investigation indicated that the temperature of ground formation and groundwater within the well screen was observed to be approximately 19.75oC during the GLL assessment. Therefore, there was approximately a 3oC difference between the water temperature within the aquifer, and the temperature at the wellhead. At a discharge rate of 27 L/s, it would take approximately 7 minutes for water to travel from the well screen to the wellhead. It does not seem reasonable for such a significant loss

in that time frame, and therefore, the hypothesis presented by GLL that the drilling mud that had been pumped into the well prior to the geophysical investigation may have influenced the observed temperature, is likely correct.



Photograph 8: Solinst Levellogger® and Barologger® dataloggers for monitoring water level and barometric fluctuations during pumping test.



Photograph 9: Aqua Tech pulling pump and piping at termination of pump test

6.1.6 Monitoring of Water Levels in Other Wells

Electronic dataloggers were installed in Wells #2 and #4 (the Village already has one in Well #3) to continuously monitor the variation of water levels for the whole duration of the pumping test. The Solinst® Leveloggers and Barologger (see Photograph 9) used in Wells #2 and #4 were rented from Solinst® in Toronto. Below are the durations and time intervals for datalogger water level monitoring at each well:

- Well #2: 10-minute intervals from 12:00 on July 9th to approx. 12:00 on July 13th.
- Well #4: 10-minute intervals from 17:00 on July 7th to 12:00 on July 13th.
- Well #3: Daily max and min. One-hour intervals during pump test.

Water level observations in these other wells during the pumping test are indicated on Figure 8. Note that no significant fluctuations in the water levels were observed. There was no indication of response at these other wells at the beginning of pumping, during the pump test, nor during recovery. This suggests that the aquifers that Well #2 and #4 are completed within are not hydraulically connected to the aquifer at Well #5.

6.2 Temperature Gradient Observations

A Solinst® T4 Multimeter equipped with a T4 Temperature sleeve was used to measure temperature profiles within several of the wells in the Village. As mentioned previously, the purpose of this profiling was to gather information regarding the regional geothermal gradient in the Haines Junction area. The T4 sleeve has an enclosed thermistor to measure resistance. The resistance is then be converted into temperature. Following the pump test program, the T4 Multimeter was used to obtain temperature readings at 10 foot (3.05 m) intervals within Wells #2, #4 and #5.

Well #5 Temperature Profile

An attempt was made to monitor temperature in Well #5, however, only the top 90 m above the submersible pump could be accessed for temperature readings. As well, since the water was flowing at the time of the measurements, accurate and meaningful readings could not be obtained, and the data captured was subsequently abandoned.

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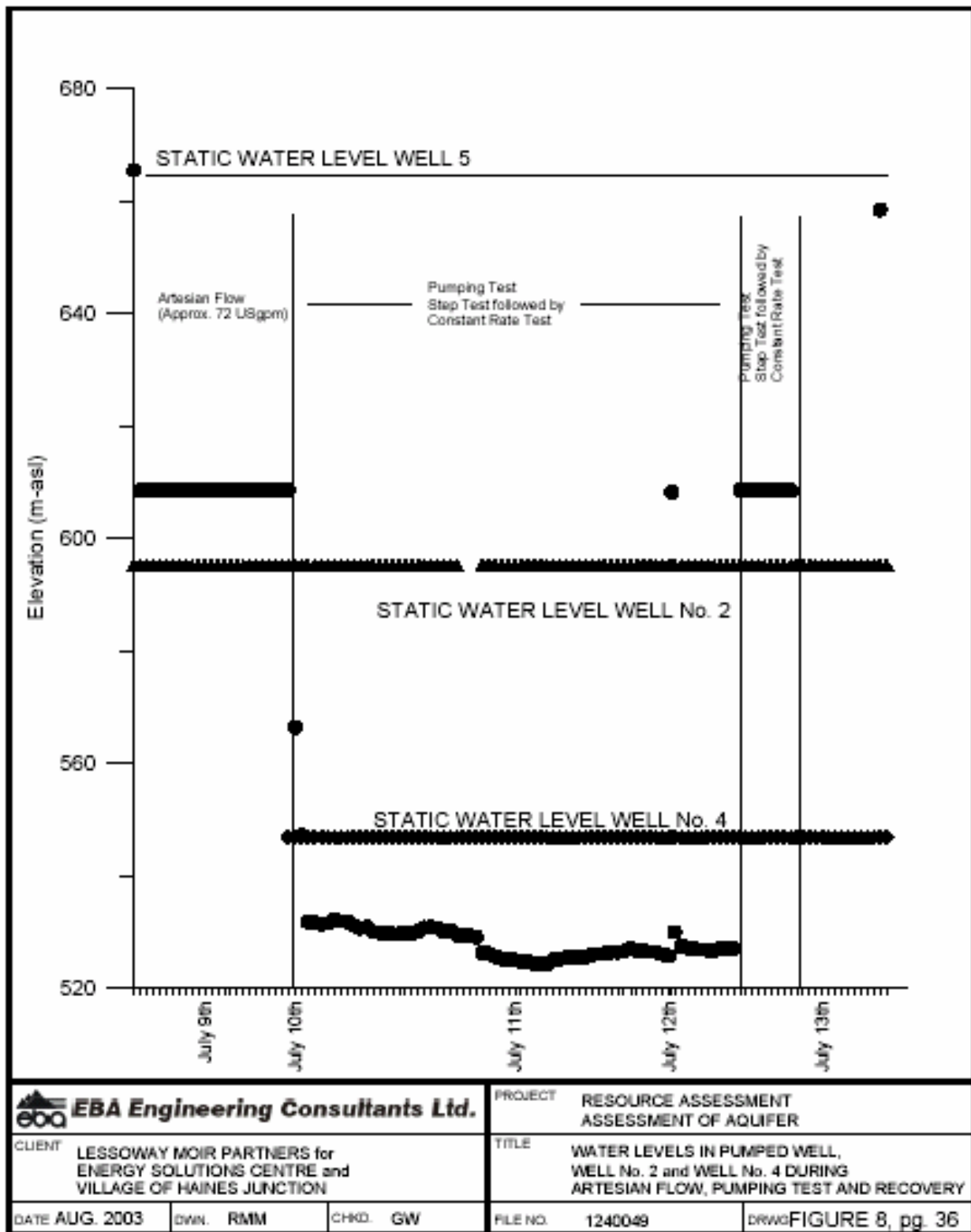


FIGURE 8

EBA Project #: 1240049
May 2004

Water temperature was measured within the lower portion of Well #5 during a geophysical investigation of the well by Aurora Geosciences for Gartner Lee in 2002. Figure 3 of the GLL report shows that the temperature was observed to range from approximately 18.5°C at 305 m btwc to 19.75°C at 365 m btwc (below top of well casing). The temperature increased most rapidly between the depths of 305 m and 330 m within the glaciolacustrine silt and clay unit (0.04 °C/m). Once in the transition facies and the sand and gravel aquifer, the temperature gradient increased only slightly with depth (0.75°C over 50 m or 0.015 °C/m). It appears that the temperature below the well screen and within the till drops slightly below 19.75 °C. However, Gartner Lee pointed out that the drilling mud that had been pumped into the well prior to the geophysical investigation may have influenced the observed temperature.

Assuming that the ground temperature near ground surface is somewhere between 2 and 4 °C (as observed in Wells #2 and #4 (see below), the gradient from the near surface soils to the highest observed temperature at 370 m btwc is approximately 0.045 °C/m. Assuming that the observed temperature within the well screen is incorrect, and the temperature at 370 m below grade is in the order of 17 °C, the gradient would be approximately 0.04 °C/m.

Well # 4 Temperature Profile

On July 14th, 2002, EBA completed a groundwater temperature profile survey at Well #4. Using the Solinst Multimeter, water temperature was observed at 10 feet (3.05 m) intervals from the static groundwater level to the bottom of the well. The temperature readout was allowed to stabilize for 3 minutes at each location and the resistance was observed from the digital display. A correction factor to compensate for cable resistance (supplied by Solinst based on instrument calibration) was applied to the measured resistance, and the in-situ resistance was converted to temperature using the conversion table provided by Solinst. In Well #4, groundwater temperatures ranged from approximately 1.7°C at 30 m below the top of the well, to 4.2°C at approximately 116 m below the top of well casing. Temperature vs. depth is plotted on Figure 9. Note that the slope of the temperature vs. depth line is relatively consistent at approximately 0.025°C/m.

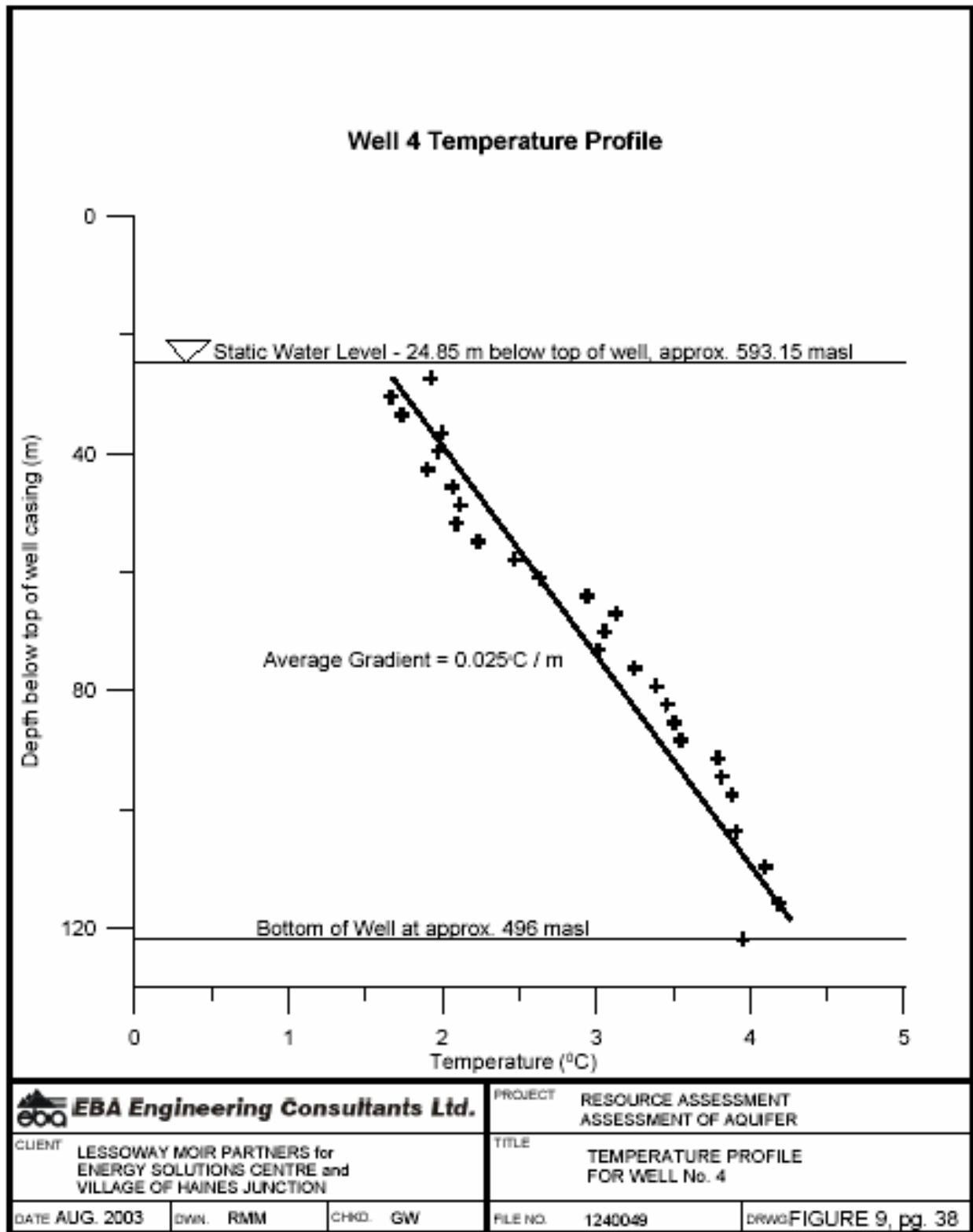


FIGURE 9

Well #2 Temperature Profile

Using the same methodology as for Well #4, the groundwater temperature profile was measured at Well #2 (see Figure 10). The temperature profile extends from the static water level to approximately 47.5 m bwtc. The bottom of well is reported to be at 78.3 mbgs according to the drillers well construction report. Reportedly this well had been taken off-line due to a siltation problem, and it is possible that the observed soft obstruction at 47.5 m is due to silt accumulation within the well casing. The observed gradient within Well #2 is generally consistent to that at Well #4 and is approximately 0.022°C/m.

6.3 Water Sampling

Groundwater samples were collected at the end of the pumping test by Ryan Martin of EBA. The samples were collected from the discharge line approximately 3 m from the wellhead. Samples were collected according to laboratory recommendations described in more detail below.

6.3.1 Analytical

All samples were collected in pre-cleaned bottles provided by ALS Analytical Laboratories. Samples were collected in the volume and container type recommended by the laboratory. Samples submitted for dissolved metals were field filtered using a dedicated disposable 45 micron filter and acidified using laboratory supplied and measured nitric acid. Samples submitted for total metals were acidified using pre-measured and laboratory-supplied nitric acid.

Samples were placed on ice, and shipped by Air Canada Cargo under chain of custody to ALS Environmental in Vancouver. ALS is a member of the Canadian Association for Environmental Analytical Laboratories (CAEAL). ALS completed all previous analytical work during the GLL well testing. Analytical results are summarized in the Table 2. Laboratory analytical reports provided in Appendix D. The lab report provides details on analytical methodologies utilized.

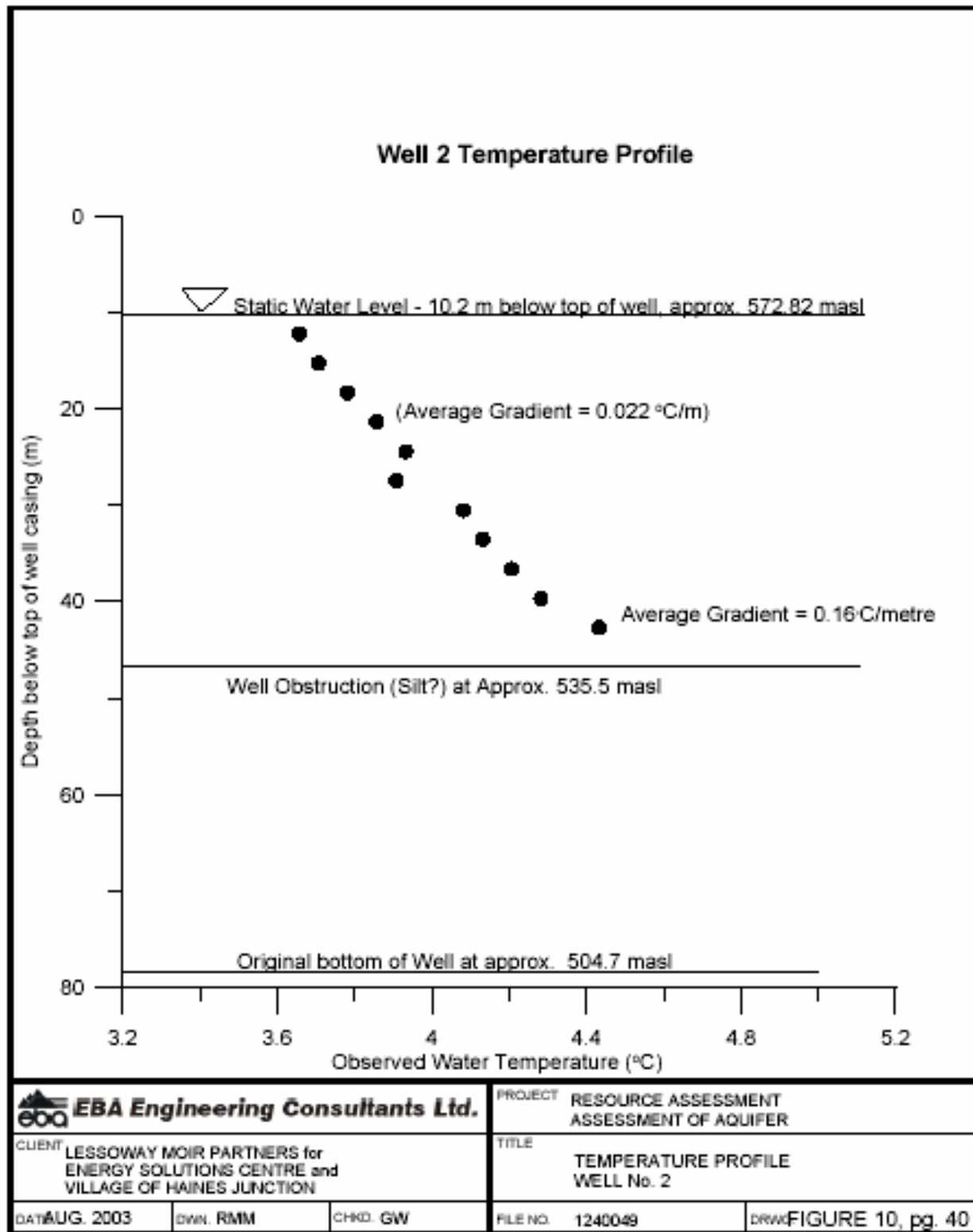


FIGURE 10

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Table 2: Summary of Groundwater Analytical Results
Physical, Anions, Nutrients and Metals Results

	Groundwater Sample				Applicable Standards
Sample ID	Well 5	Well 5	Well 5	Well 5	CCME
Date Sampled	2/10/2002 (2:25am) ^C	2/10/2002 (4:46am) ^C	2/10/2002 (12:19pm) ^C	7/12/2003	CDWQG ^A
Physical Tests					
Conductivity (uS/cm)	252	251	249	243	NG
Total Dissolved Solids	172	171	164	178	500 ^B
Hardness CaCO ₃	15.1	14.4	10.1	10.7	NG
pH	8.61	8.71	8.74	8.78	6.5-8.5
Total Suspended Solids				<3	NG
Colour (CU)	<5	<5	<5	<5	15 ^B
Turbidity (NTU)	25	22.8	13	2.9	1 or 5 ^B
Dissolved Anions					
Alkalinity-Total CaCO ₃	112	115	115	115	NG
Alkalinity-Bicarbonate CaCO ₃				115	NG
Alkalinity-Carbonate CaCO ₃				<1	NG
Bromide Br					NG
Chloride Cl	<0.5	<0.5	<0.5	<0.5	250 ^B
Fluoride F	0.27	0.26	0.26	0.23	1.5
Sulphate SO ₄	15	15	15	15	500 ^B
Nutrients					
Nitrate Nitrogen N	<0.1	<0.1	<0.1	<0.1	45
Nitrite Nitrogen N	<0.1	<0.1	<0.1	<0.1	NG
Total Metals					
Aluminum T-Al	0.61	0.63	0.32	0.06	
Antimony T-Sb	<0.0005	<0.0005	<0.0005	<0.0005	0.006
Arsenic T-As	0.02	0.021	0.02	0.021	0.025
Barium T-Ba	0.71	0.58	0.41	0.03	1
Boron T-B	0.1	0.1	0.1	<0.1	5

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Cadmium T-Cd	<0.0002	<0.0002	<0.0002	<0.0002	0.005
Calcium T-Ca	4.8	4.5	4	3.5	
Chromium T-Cr	<0.002	<0.002	<0.002	<0.002	0.05
Copper T-Cu	<0.01	<0.01	<0.01	<0.01	
Iron T-Fe	0.73	0.75	0.45	0.08	0.3 ^B
Lead T-Pb	<0.001	<0.001	<0.001	<0.001	0.01
Magnesium T-Mg	0.8	0.8	0.6	0.4	NG
Manganese T-Mn	0.025	0.023	0.013	0.003	0.05 ^B
Mercury T-Hg	<0.0002	<0.0002	<0.0002	<0.0002	0.001
Potassium T-K	0.4	0.4	0.4	0.3	NG
Selenium T-Se	<0.001	<0.001	<0.001	<0.001	0.01
Sodium T-Na	52	52	52	57	200 ^B
Uranium T-U	<0.0001	<0.0001	<0.0001	<0.0001	0.02
Zinc T-Zn	<0.05	<0.05	<0.05	<0.05	5 ^B
Dissolved Metals					
Aluminum D-Al	-	-	<0.01	0.01	-
Antimony D-Sb	-	-	<0.0005	<0.0005	-
Arsenic D-As	-	-	0.02	0.021	-
Barium D-Ba	-	-	<0.02	<0.02	-
Boron D-B	-	-	0.1	<0.1	-
Cadmium D-Cd	-	-	<0.002	<0.0002	-
Calcium D-Ca	-	-	3.4	3.4	-
Chromium D-Cr	-	-	<0.002	<0.002	-
Copper D-Cu	-	-	<0.001	<0.001	-
Iron D-Fe	-	-	<0.03	0.11	-
Lead D-Pb	-	-	<0.001	<0.001	-
Magnesium D-Mg	-	-	0.4	0.4	-
Manganese D-Mn	-	-	<0.002	<0.002	-
Mercury D-Hg	-	-	<0.0002	<0.0002	-
Potassium D-K	-	-	0.3	0.3	-
Selenium D-Se	-	-	<0.001	<0.001	-
Sodium D-Na	-	-	52	54	-
Uranium D-U	-	-	<0.0001	<0.0001	-
Zinc D-Zn	-	-	<0.05	<0.05	-

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- Footnotes:** Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.
A) Canadian Drinking Water Quality Guidelines (Updated April 2002)
B) Aesthetic Objective
C) Analytical results from Gartner Lee Ltd (2002)



6.3.2 Isotopes

A water sample from Well #5, collected in a 1 L sterilized amber glass container was shipped under chain of custody to the Environmental Isotope Lab at the Department of Earth Sciences at the University of Waterloo, in Waterloo Ontario. Care was taken to ensure that there was no entrapped air, or “headspace” within the sampling container. The sample was analysed for the following isotope concentrations:

- Enriched Tritium (3H)
- Deuterium (2H)
- Oxygen – 18 (18O)

Isotope analytical results are summarized in Table 3 below:

	Groundwater Sample	
Sample ID	Well 5	Repeat
Date Sampled	12/07/03	
Physical Tests		
Oxygen-18	-23.34	-23.22
Deuterium	-176.63	-177.93
Tritium	<0.8 +/- 0.5	

Notes:

Tritium is reported in Tritium Units.

1TU = 3.149 Picocuries/L

1TU = 0.11815 Becquerels/L

Analyses conducted by University of Waterloo Isotope Laboratory

Table 3: Summary of Isotope Analytical Results

The Environmental Isotope Laboratory analytical report is provided in Appendix D.

6.3.3 BART™

Samples for BART™ testing were collected using aseptic techniques in the sample vials provided by Droycon Bioconcepts Inc. The samples were collected while wearing clean latex gloves, and care was taken to ensure that the inside of the bottles and lids did not come into contact with any foreign objects during the sampling process. The samples were transported to the EBA office in Whitehorse where they were stored away from direct sunlight and at room temperature. The samples were inspected daily, or as often

as possible for visual reactions. Observations were recorded and are presented in Table 4. A photograph of the BART samples on Day 4 of observation is shown below (Photograph 10).



Photograph 10: Biological Reactivity Test (BART) on day 4. SRB (sulphate reducing) on left (black), IRB (iron reducing) in middle (red) and SLYM (slime forming) on right (green).

6.4 Determining Geothermal Conditions in Shallow Soils

EBA reviewed shallow borehole information from previous investigations completed by EBA and JR Paine Associates. Climate data from the Canadian Climate Normals (1961-1990) as recorded at the Haines Junction airport was also reviewed. Using a numerical model, EBA calculated the soil thermal properties based on grain size and moisture contents. A one dimensional soil temperature profile was developed. This information may be used by the other team partners to calculate seasonal heat losses from the pipe distribution system to ground. Additional details are presented in Section 6.5.

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Table 4: Observations During BART TESTS

	Day 1	Day 2	Day 3	Day 5	Day 6	Day 7	Day 9	Comments
Iron Reducing BART IRB BART	fine bubbles on side wall and bottom of ball, clear, yellowish green pigment in bottom half of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, clear, yellowish green pigment in bottom half of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, clear, yellowish green pigment in bottom half of column, may be some solids accumulating in bottom of cone.	fine bubbles on side wall from half way down to bottom of column, some yellowish brown solids forming on sidewall above line and in meniscus, yellowish green pigment in bottom half of column, may be some solids accumulating in bottom of cone.	Coarse bubbles on top half of ball, yellowish orange slime above line around ball, yellowish orange pigment from top to bottom.	Coarse bubbles on top half of ball, orangish brown slime above line around ball and within meniscus, yellowish orange pigment from top to bottom, fluid becoming cloudy.	Coarse bubbles on top half of ball, orangish brown slime above line around ball and within meniscus, yellowish orange pigment from top to bottom, fluid becoming cloudy.	Observations indicate that IRB bacteria are present and relatively aggressive. Noticeable reactions were visible after approximately 4 days. Order of magnitude population is 5,000 cfu/mL. After 6 days anaerobic bacteria presence was also indicated.
Slime Forming Bacteria BART SLYM BART	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, reddish brown pigment across bottom third of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, reddish brown pigment across bottom third of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, reddish brown pigment across bottom third two thirds of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, reddish brown pigment across bottom third two thirds of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, yellowish pigment from bottom of ball to bottom of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, yellowish pigment from bottom of ball to bottom of column, no solids or biofilm noticeable.	fine bubbles on side wall and bottom of ball, water level approx. 3 mm above line, clear, yellowish pigment from bottom of ball to bottom of column, very small threadlike strands in base of cone (only noticeable when inner vial removed).	Observations indicate that although there may be some tight slime bacteria present, they are not aggressive.

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	Day 1	Day 2	Day 3	Day 5	Day 6	Day 7	Day 9	Comments
Sulphate Reducing Bacteria BART SRB BART	fine bubbles on side wall, clear, water level approx. 5 mm above line, slight yellow tinge near bottom of column, no solids or biofilm noticeable.	fine bubbles on side wall, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, no solids or biofilm noticeable on ball or base of column.	fine bubbles on side wall on bottom 3/4 of vial, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, possibly some in bottom of cone, no black discolouration.	fine bubbles on side wall on bottom 1/2 of vial, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, solids in bottom of cone, no black discolouration.	fine bubbles on side wall on bottom 1/2 of vial, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, solids in bottom of cone, no black discolouration.	fine bubbles on side wall on bottom 1/2 of vial, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, solids in bottom of cone, no black discolouration.	fine bubbles on side wall on bottom 1/2 of vial, clear, thin yellowish layer of slime on the bottom 4 mm of column, water level approx. 5 mm above line, some solids in bottom of cone, no black discolouration.	Observations indicate that although some reactions were observed, they were not consistent with any of the standard SRB reactions. No black was ever observed. Therefore, if SRB bacteria are present, they are not considered aggressive.

7 RESULTS

7.1 Aquifer Testing

7.1.1 Pumping Test Results

The trends observed during the pumping tests were interpreted to determine aquifer characteristics. For the analysis below, it is assumed that the aquifer thickness is 40.2 m (as reported by GLL).

When pumping is stopped, aquifer water levels rise toward their static water level. This rate of recovery provides a means of calculating the transmissivity. If no observation well is available, the recovery data from the pumped well usually provides the best means for calculating the transmissivity of the aquifer. The Theis recovery method is commonly used to determine the aquifer transmissivity. Note that storativity (the volume of water that an aquifer releases from storage per unit surface area of aquifer per unit decline in the component of hydraulic head normal to that surface) cannot be determined from recovery data. Storativity is an important aquifer characteristic for flow modelling and geothermal design.

Using appropriate equations, the transmissivity of an aquifer can be evaluated through the interpretation of the residual drawdown plot, or the residual drawdown versus the ratio(t/t') of time since the pump started (t) to the time since the beginning of the recovery period (t'). A plot of the recovery (residual drawdown) vs. t/t' is provided as Figure 11. The pumping duration (t) was considered to include the time during the pump installation when the well was flowing under artesian pressure, as well as the step test and constant rate test.

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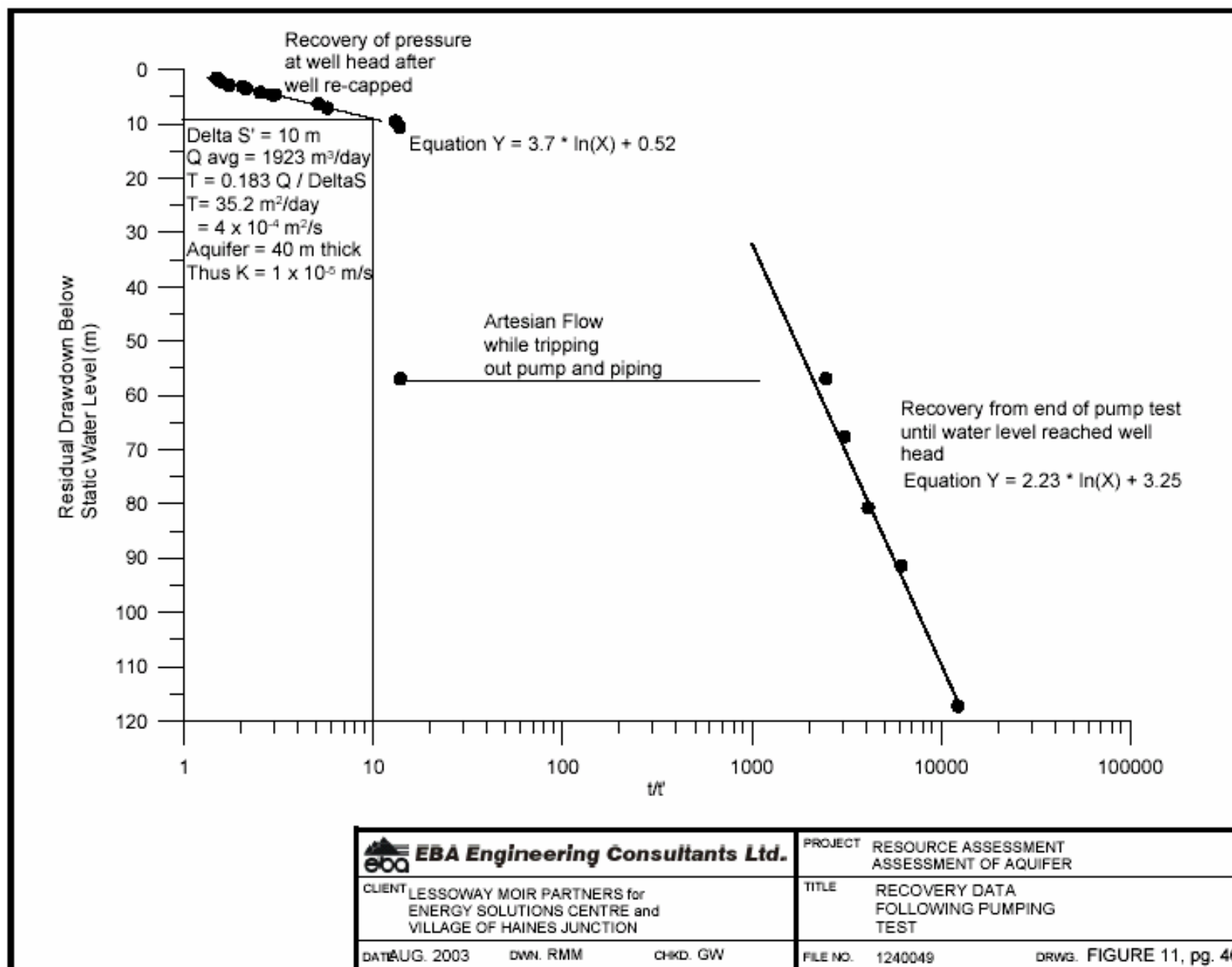


FIGURE 11

For an “ideal” aquifer the residual drawdown approaches zero as the t/t' approaches 1. Therefore, as indicated in Figure 11, the aquifer in which Well #5 is completed responded in an ideal fashion. Based on the slope of the late time data recovery (measured as pressure at the wellhead), a transmissivity value of $4 \times 10^{-4} \text{ m}^2/\text{s}$ was calculated for the deep aquifer. By analysing the late time data, the effects of well casing storage are eliminated. The flow rate of 22 L/s, was used for the calculation is the average flow rate of the artesian flow, the step test and the constant rate test. Assuming an aquifer thickness of 40.2 m as reported by GLL, this translates to a hydraulic conductivity (K) value of $1 \times 10^{-5} \text{ m/s}$. According to Freeze and Cherry, this is typical of a silty to clean sand (Freeze, 1979). This is also relatively consistent with the T and K values obtained by GLL where they analysed the pumping data using the Hantush Jacob Solution for a leaky confined aquifer.

There was no observed drawdown that could be attributed to the pumping of Well # 5 in any of the observation wells (Well #2, #3 and #4). Unfortunately, since there are no observation wells completed within the same aquifer as Well #5, aquifer storativity could not be calculated. As previously mentioned, storativity is an important aquifer characteristic for flow modelling and aquifer thermal energy storage design.

Horizontal Hydraulic Gradient and Groundwater Flow Direction

Without at least three observation points completed in the same aquifer, the direction of the groundwater flow cannot be estimated and a groundwater gradient cannot be calculated. Without storativity and gradient information for the aquifer, the potential for hydrological and geothermal modelling is significantly limited.

7.1.2 Temperature Profiling

The temperature gradient observed during the temperature measurements within Well #2 and Well #4 were 0.022 and 0.025 °C/m (22 °C /km, and 25 °C/km), respectively. Driscoll (1986) states that at depths greater than 30 m, the average geothermal gradient is approximately 19.7 °C/km. Therefore, the geothermal gradients observed within each of these wells lie within the range of, or perhaps slightly above, typical geothermal gradients. Note that a slightly higher geothermal gradient for this area may be anticipated based on the level of tectonic (seismic) activity. If it is assumed that the geothermal gradients measured at Well #2 and Well #4 are representative for the shallow aquifers, then if the gradient was extrapolated to a depth of 365 m (depth of

Well #5), the temperature would be roughly 8 to 9 °C, not 17°C as observed at Well #5 at this depth. This suggests that the groundwater intercepted by Well #5 is heated relative to its predicted temperature. The source of heat is uncertain; it may be at depth (beneath the aquifer) or water itself may retain heat from a distant source. Some theories on the source of the heat energy are provided in Section 7.2 and 7.3.

7.2 Groundwater Analytical Results

7.2.1 Analytical

As indicated in Table 2, for the parameters tested, there were no exceedences of any health based, Canadian Drinking Water Quality (CDWQ) guidelines with the exception of Turbidity. As well, there were no exceedences of any aesthetic guidelines, with the exception of pH.

Not surprisingly, there were some significant differences between the water sampling results obtained during this field program, and those obtained by GLL in October 2002. As indicated by GLL in their report, the results presented were reflective of the water quality immediately following the development process. GLL pointed out that trace amounts of drilling fluid, used during the completion of the well, may influence water quality. Also, GLL commented that elevated concentrations of iron during the 2002 sampling program may be related to elevated turbidity levels, and that a reduction in groundwater turbidity may reduce the iron concentrations.

Noteworthy changes between the water quality results from samples collected at the end of the GLL pump test in November 2002 and the water quality at the end of the long-term pump test in July 2003 are the following:

- Considerably reduced turbidity (from 13 to 2.9 NTU)
- Significantly decreased total aluminum concentrations (from 0.32 mg/L to 0.06 mg/L). The most recent sampling results are now below the CDWQG aesthetic objectives.
- Considerably decreased total iron concentrations (0.45 mg/L to 0.08 mg/L). The most recent sampling results are now below the CDWQG aesthetic objectives.

A more than 10 times reduction in barium concentrations. The GLL report states that at depth to overcome hydrostatic conditions, a barite compound was added to the

bentonite mud to increase its density. The reduction in barium concentration is likely due to the fact that most of the residual barite-based drilling fluid has been removed from the aquifer formation around the well.

With the exception of turbidity, all significant changes in water quality between the samples collected by GLL in 2002 and the recent water sampling results are for total metals concentrations. Dissolved metals concentrations for all metals tested are very similar. The use of Well #5 by the Village of Haines Junction since November 2002, coupled with the aggressive pumping of the well during this most recent long-term pump test has continued to develop the well. It is obvious from the reduced turbidity readings between the two sampling events that there are less solids or organic matter within the groundwater. This observation suggests that the GLL hypothesis that “elevated concentrations of total iron in the groundwater may be related to elevated turbidity levels and that a reduction in groundwater turbidity may reduce the total iron concentrations” was accurate. Due to the significant decrease in barium concentrations, it is likely that the use of the well by the Village, and the most recent pumping test have also been successful in removing much of the residual drilling fluid (with barite additive) from within the aquifer.

The Village of Haines Junction routinely monitors turbidity, water temperature, and pressure at the wellhead and pumphouse. Based on a review of the monitoring data, it has been observed that turbidity values are typically lower than 1 NTU, and average lower than 0.1 NTU when the well is flowing under artesian pressure (See Section 6.4). Pumping during the pumping test has resulted in a partial development of the well and probably mobilized part of the large volume of grout injected during sealing and completion of the well. This would explain the turbidity value measured in the sample collected at the end of the pumping test.

7.2.2 Geothermometry

Chemical geothermometry can be a useful tool for determining the equilibration (or source) temperature of a fluid based on its chemical composition. A fundamental assumption of geothermometry is that the effects of dilution from surface and/or shallow groundwaters are insignificant and that thermodynamic equilibrium has been attained (Fournier, 1981). Geothermometric calculations are based on the assumption that groundwater equilibrates with hydrothermal minerals in the reservoir rock. The concentrations of various ions (e.g., Na⁺, K⁺ and Ca²⁺) and silica (SiO₂) are

temperature-dependent, and reactions with the circulating aqueous solutions are typically sluggish (Yorath et al., 1991). Therefore, for relatively rapid transit times to the surface, such as would be accomplished up fracture zones, it is unlikely that re-equilibration with the surrounding rocks could occur. This suggests that the chemical signature of a water can provide some idea as to temperature regime when the minerals were first dissolved.

There are many types of geothermometers; some more suitable than others for different types of temperature conditions. In general, geothermometers based on ratios are more resistant to dilution effects than those based on absolute concentrations (Banks et al., 1998); however dilution by mixing with fresh meteoric waters can significantly limit geothermometry.

The silica-based geothermometers could not be used (no dissolved silica analyzed), and several ion-based geothermometers gave negative values, indicating that the methods were inappropriate. The Na/K geothermometer (Fournier 1979) yielded an equilibration temperature of 52°C and the Na-K-Ca geothermometer (Fournier, 1979) yielded a temperature of 26°C. Although these values may appear to be realistic, the total dissolved solids (TDS) concentration of the groundwater was 178 mg/L, and the concentrations of metals, such as Na (54 mg/L) and Ca (3.4 mg/L), and total alkalinity (115 mg/L) suggest a very immature groundwater, not one that has equilibrated at high temperature. Furthermore, the aquifer materials present would suggest a Ca-bicarbonate type water, rather than a Na-bicarbonate water, therefore the source of Na is questionable. Because both geothermometers are based on Na, the geothermometry calculations are deemed unreliable.

7.2.3 Isotopes

Oxygen-18 (18O) and Deuterium (2H)

The isotopes of water (^{18}O , ^2H) are incorporated within the water molecule (H_2^{18}O , $1\text{H}_2\text{H}^{16}\text{O}$). The ratio of these isotopes is important because species-dependant behaviour during phase changes (evaporation, condensation, sublimation, freezing), mixing, and diffusion within the water cycle produce a natural labeling effect. Such isotope fractionation processes contribute to a systematic global distribution of stable isotopes in precipitation and in various hydrological components. The statistical evaluation of isotope measurements in precipitation shows that Deuterium values of precipitation and natural waters of meteoric origin are linearly correlated with those of

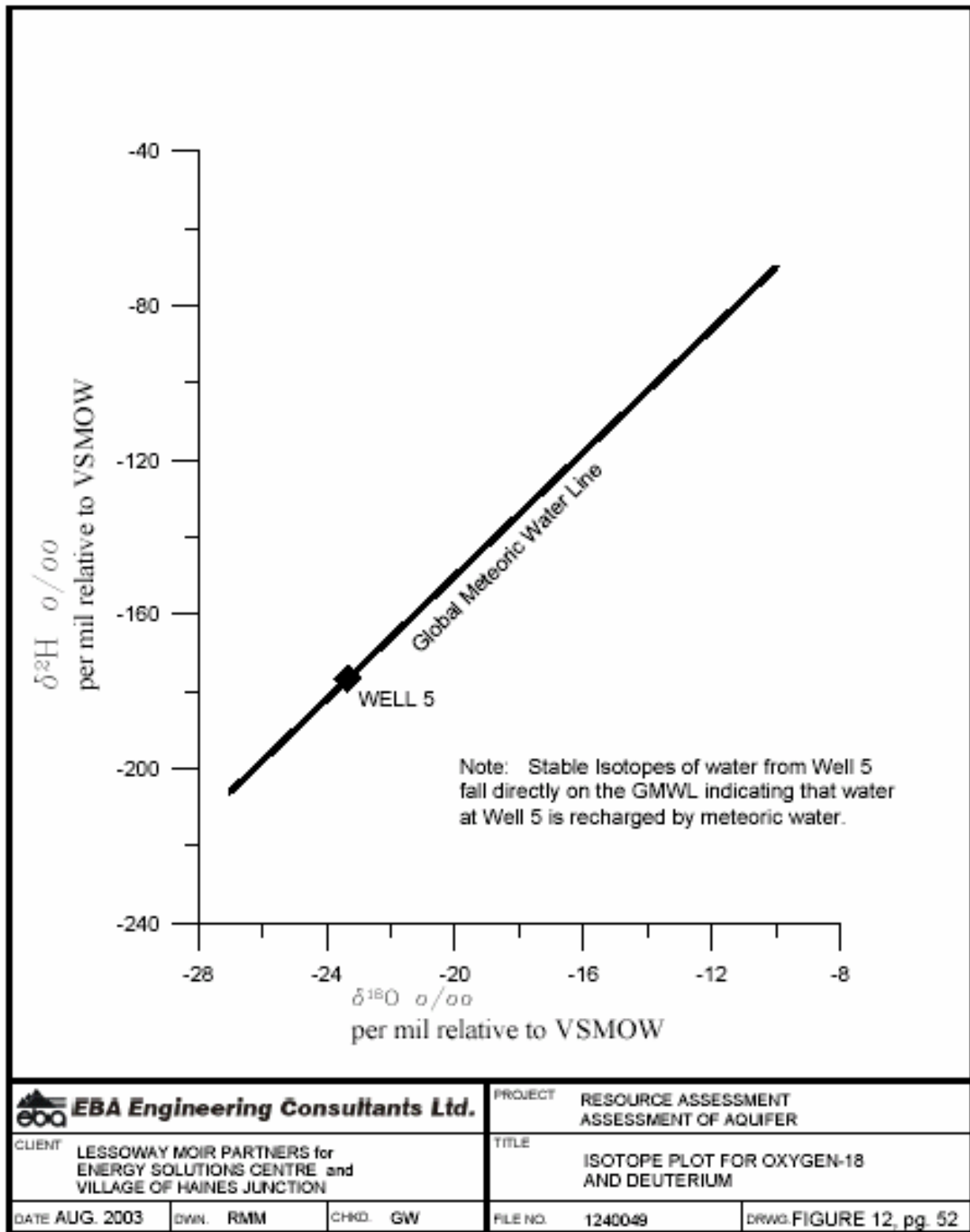
18O, forming the so-called global meteoric waterline (See Figure 12). For water subjected to evaporation, the linear correlation between the Deuterium and 18O values still holds, but the slope of this line is less steep. Therefore, the meteoric water line can be used as a reference line against which any measuring point can be compared. The result of the comparison provide a fingerprint of a sample and indicates whether the sample represents surfacewater, groundwater recharged by rain (which falls along the meteoric line, or a mixture between fresh groundwater and another source such as evaporated lake water. Isotope results for Oxygen-18 vs. Deuterium were plotted for Well # 5 on Figure 12. Note that they fall along the global meteoric water line. This indicates that the water is of meteoric origin.

In glaciers, the lighter oxygen isotope preferentially gets locked in the ice leading to the enrichment of heavy oxygen in the glacial meltwater. Based on the fact that the isotope ratio for Well #5 falls directly on the GMWL, it appears that the source of the water from Well #5 is not significantly related to glacial meltwater. However, more detailed stable isotope data for glaciers in the region would be needed to confirm this.

Tritium (3H)

Radiogenic tritium (3H), another isotope found in the water molecule (1H3H16O), is useful for dating water. Tritium is a naturally occurring radioactive isotope of hydrogen. Atmospheric nuclear weapons testing beginning in about 1952 increased tritium levels in the environment by several orders of magnitude. This bomb pulse has provided a large event marker that can be used in time scale studies. With a half-life of 12.3 years, it can be used as a tracer for dating groundwater. The naturally occurring tritium level in pre-bomb rainwater was 5 to 10 Tritium Units (TU).

In Anchorage in 1994, precipitation had concentrations between 5 and 38 TU (USGS website). Based on these levels, and the Tritium half-life, water containing 3H concentrations greater than 1.3 TU is considered “modern” post 1951 recharge. The concentration of tritium in a sample collected from Well #5 was less than 0.8 TU +/- 0.5 (See Table 3). Therefore, it appears that the groundwater sampled from Well #5 was recharged from atmosphere prior to 1952. As such, it can be inferred that groundwater may have flowed in the subsurface for at least 50 years before reaching Well #5. However, given the low concentration of Total Dissolved Solids (TDS) for the water sampled at Well #5, it is unlikely that the water is significantly older than 50 years, otherwise the concentration of TDS would be considerably higher.



7.2.4

FIGURE 12

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7.2.5 BART

As indicated previously, a summary of the individual observations and interpretation of the results of the BART™ testing conducted from the well field is attached as Table 4. Moderately aggressive very aerobic slime forming iron related bacteria have been observed, iron related bacteria may be active and heterotrophic bacteria are present. No sulphate reducing bacteria were observed. Dense slime forming heterotrophic bacteria were detected, but are considered to have a very low aggressivity at this time. The results do not appear to demonstrate significant biofouling bacteria activity in the well.

The specific capacity of 0.19 L/s/m for this current long-term pump test is the equivalent to the specific capacity data reported by GLL for the pump test completed in October 2002. This also indicates that there has been little or no clogging due to biofouling occurring in and around Well #5.

It should be noted that the BART™ tests did not identify sulphur reducing bacteria populations within the well. The absence of a positive test result does not preclude the presence of these bacteria, as the nature of these bacteria is that they tend to form a tight biofilm against the well screens or other materials that is often covered by other more aerobic bacteriological populations. The test is dependent on the bacteria being released into the water flow during the sampling event and it can, therefore, be difficult to show a definite absence.

7.2.6 Variation of Water Quality vs. Time during pump test

During the pumping test, EBA routinely measured the conductivity of the discharge water to determine whether there were any anomalies or trends. Conductivity values were relatively consistent throughout the test. No noticeable change was observed.

7.3 Water Quality - Operation and Maintenance Issues

The Langelier Saturation Index (LSI) and the Ryznar Stability Index (RSI), and some of the water quality indicators were analyzed to determine the corrosiveness of the groundwater from Well #5.

Langelier Saturation Index

The Langelier Saturation Index (LSI) is an equilibrium model derived from the theoretical concept of saturation and provides an indicator of the degree of saturation of water with respect to calcium and carbonate. Water with a LSI of 1.0 is one pH unit above saturation and by reducing the pH by 1 unit the water will be brought into equilibrium. The results of the LSI are defined as:

- If the LSI is negative: No potential to scale, the water will dissolve CaCO_3 ;
- If the LSI is positive: Scale can form and CaCO_3 precipitation may occur;
- If LSI is close to zero: Borderline scale potential. Water quality or changes in temperature, or evaporation could change the index.

The LSI is probably the most widely used indicator of water scale potential and is defined as:

$$\text{LSI} = \text{pH} - \text{pH}_s$$

Where:

- pH is the measured groundwater pH
- pH_s is the pH at saturation in calcite or calcium carbonate.

The pH of the groundwater at Well # 5 was 8.78 on July 12, 2003, while the pH_s was calculated as 9.02. Therefore the LSI of the groundwater at Well # 5 was -0.24 and indicates that the groundwater does not have any potential for scaling.

The Ryznar Stability Index

The Ryznar stability index (RSI) attempts to correlate an empirical database of scale thickness observed in municipal water systems to the water chemistry. Like the LSI, the RSI has its basis in the concept of saturation level. RSI attempted to quantify the relationship between calcium carbonate saturation state and scale formation. The RSI is defined as:

$$RSI = 2(pH_s) - pH;$$

or as

$$I = S - C - pH$$

Where:

- S is obtained using the total dissolved solids of the groundwater and a graph that has the S value as a function of the total dissolved solids; and
- C is obtained using the methyl orange alkalinity, the calcium ion concentration of the groundwater and a graph that has the C value as a function of the methyl orange alkalinity and the calcium ion concentration;

The empirical correlation of the Ryznar stability index can be summarized as follows:

- If the RSI is less than 6, the scale tendency increases as the index decreases;
- If the RSI is greater than 7, the calcium carbonate formation probably does not lead to a protective corrosion inhibitor film;
- If the RSI is greater than 8, mild steel corrosion becomes an increasing problem.

The pH of the groundwater at Well #5 was 8.78 on July 12, 2003, while the pH_s was calculated as 9.02, C was calculated as 5.4, and S equals 23.03. Therefore the RSI of the groundwater at Well # 5 was calculated to be 9.26 and 8.85 using the two different methods. The RSI indicates that the groundwater does not have any potential for scaling but may be corrosive to mild steel.

The water quality from Well # 5 on July 12, 2003, had a high pH of 8.78, and low total dissolved solids, chlorides, carbonate hardness, iron, and manganese. Therefore, the pH indicates that encrusting is likely to occur while the other indicators do not suggest corrosion or scaling.

The Langelier Saturation Index and Ryznar Stability Index indicate that the groundwater from Well # 5 will not deposit scale but may be corrosive to mild steel. We agree with the conclusions of Gartner Lee Ltd (2002) that while the RSI and LSI indices are more useful as scaling potential than of corrosion potential, and that corrosion is unlikely to occur as the groundwater has a high pH of 8.78. Since the well screen is constructed of

stainless steel, it is not anticipated that corrosion will result at the well screen, and it is not likely that significant corrosion of distribution piping will occur due to the high pH.

7.4 Well # 5 Long Term Data Analysis

Since the beginning of the use of Well #5, turbidity and temperature readings have been recorded by the Village of Haines Junction. Mechanical pressure and temperature gauges fitted at the wellhead and pumphouse were observed daily. Turbidity readings were also recorded daily. EBA reviewed the daily records for 2003 up to the time of the well shut down prior to the pump Test. Table 5 provides a summary of the long-term data and the variations of the parameters monitored with time.

Table 5: Village Monitoring of Turbidity, Pressure and Water Temperature

	Turbidity at Wellhead (NTU)	Pressure at Wellhead (psi)	Water Temperature at Wellhead (°C)	Water Temperature at Pumphouse (°C)
Period	January 1st 2003 to July 4 2003			
Number of Samples	106	107	107	95
Average	0.08	72.95	15.21	14.26
Maximum	0.15	78	16	16
Minimum	0.02	50	14	14

The following observations and trends are made from the long term monitoring data:

- The temperature at the wellhead was constant and did not indicate any seasonal variation over the duration of monitoring period.
- The temperature at the pumphouse was relatively consistent seasonally and over the duration of monitoring period. Heat losses to the surrounding near surface soils did not appear to be more significant in the winter months.
- There was an average loss of approximately 0.95 °C between the wellhead and the pumphouse.
- The average and maximum turbidity readings are both below the CDWQG aesthetic and health based objectives.

The pressure at the wellhead is variable and dependant on the discharge rate to the pumphouse but does not indicate any decreasing trend with time.

The following observations and trends can be determined from comparing the Village long-term data with the observations during the pump test:

- The turbidity appears to be lower when the well is flowing under artesian pressure than when it is being pumped.
- The temperature is consistently higher during pumping than during artesian discharge. This is likely a function of the velocity of the water in the well, and thus the retention time within the well casing over which the water loses heat energy to the cooler formations surrounding the well casing as the water travels to the surface.

EBA concurs with the Gartner Lee recommendation that the collection of long-term water usage and pressure at Well #5 will help to predict the long-term sustainability of this important groundwater resource. Following the recovery period after the long-term pump test, the Village resumed use of Well #5. Since the amendment to the water license allows significantly increased use of the well, it has been relied upon as the primary potable water supply for the Village since July 23rd, 2003. The Village monitors the daily extraction from Well #5. Prior to the amendment to the Water license, the Village extracted just less than 100 m³ per day (1.15 L/s) from Well #5 on average. Since July 23rd, the average daily use from Well 5 averages approximately 300 m³/day. When the Well is in use, pressure at the wellhead and at the pumphouse is also monitored and recorded by the Village. Obviously, when the well is flowing, the pressure at the wellhead and within the distribution line is lower than when the well is closed. Minor variations in flow alter the pressure at the wellhead. Therefore, to get an accurate interpretation of the piezometric level, or artesian pressure within the aquifer, it is best to observe the pressure when the well is not flowing. Monitoring of the pressure response and the total pressure after a standard shut down period gives a basis for comparing long term effects of use of the well. Soon after the Well use was resumed, EBA proposed the implementation of pressure response monitoring at Well #5. The well is shut down for 24 hours on a weekly basis, and the Village observes the pressure recovery at the wellhead. Data are presented in Table 6 below:

Well 5 Shut Down Period	Initial Pressure Prior to Shut Off	Pressure at Well Head after 8 hrs	Pressure at Well Head after 24 hrs
Aug 6,7	69.5 psi	NR	77 psi
Aug 13,14	68 psi	78 psi	78 psi
Aug 20, 21	67 psi	78 psi	78 psi
Aug 27, 28	67 psi	76 psi	76 psi
Aug 3, 4	67 psi	77 psi	78 psi

Table 6: Pressure at Wellhead after 24 hour shutdown

The information summarized in Table 6 indicates, that although the well is flowing under artesian pressure at an average daily rate of 300 m³/day, it is still responding consistently to near static pressure after 24 hours. Full recovery would likely take longer. Slight variations would reflect gauge reading error, or barometric and earth tide effects as previously described.

7.5 Geothermal Conditions in Shallow Soils

EBA completed an analysis to predict soil temperatures at depth in Haines Junction. Soils information has been obtained from both JR Paine and EBA borehole logs from Haines Junction, and climate data from the Canadian Climate Normals (1961-1990) as recorded at the Haines Junction airport. Details are as follows:

- assumed 2.0 m of clay and silt at a moisture content of 20% over silt till at a moisture content of 10%
- unfrozen thermal conductivity of 2.0 W/m oC for clay and silt, 2.6 W/m oC for silt till
- Latent Heat of 110.2 MJ/m³ for clay and silt, 56.1 MJ/m³ for silt till.
- applied surface temperature of -13.3 oC over 6 months of winter

Assuming a symmetric distribution, the computed temperature ranges are:

Depth = 0.5 m, T = -8 to +8 oC

Depth = 1.0 m, T = -5 to +5 oC

Depth = 1.5 m, T = -3 to +3 oC

Depth = 2.0 m, T = -1 to +1 oC

Depth = 2.5 m, T = -0.5 to +0.5 oC

Depth = 3.0 m, T= 0 oC

8 INTERPRETATION AND DISCUSSION

8.1 Revised Conceptual Hydrogeology Models

EBA has considered two potential conceptual models as presented herein. The first conceptual hydrogeology model is consistent with the model presented by Gartner Lee in their 2002 report. We will refer to this as the “Alluvial fans/deltas controlled conceptual hydrogeological model”. This conceptual hydrogeological model is presented schematically in Figure 13. This model proposes that a likely recharge zone is the alpine moraine glacial deposits on the foothills of the Auriol Range. The water bearing units encountered at Well #5 could represent alluvial fans or deltas that have formed off the slope of the Auriol range south of the Dezadeash River. These deposits likely formed through deposition of sand and gravel either as deltas directly into the Glacial Lake Champagne or as fans during periods of fluctuating lake levels and are inferred to be connected with the alpine moraine deposits. The sand and gravel deposits are confined above by glaciolacustrine silt and clay and below by clay-rich till.

The travel time for the groundwater to flow to Well #5 was estimated for the alluvial fans/deltas controlled conceptual hydrogeological model as follows:

- A travel time was estimated using:
- Darcy’s law, $Q = KiA$;
- The transmissivity calculated during this assessment (with a slight degree of variability (half an order of magnitude above and below the calculated value),
- The aquifer thickness reported by GLL (2002);
- An estimated porosity that is typical of sand and gravel aquifers;

- The elevation difference and horizontal distance between the inferred recharge zone and Well # 5; and
- The expected groundwater travel distance.

Aquifer characteristics are spatially variable and it is likely that the transmissivity, aquifer thickness, and porosity are not constant between the recharge zone and Well # 5. Therefore, a sensitivity analysis was conducted on these variables and the expected travel time for the groundwater to flow from the Auriol Range to Well #5 is given as a possible range. The sensitivity of the transmissivity and thickness of the aquifer was represented by hydraulic conductivity because within a confined aquifer the hydraulic conductivity equals transmissivity divided by the aquifer thickness (see Table 7).

Table 7: Travel Time Sensitivity Analysis for Conceptual Model

Aquifer Characteristics		Estimated Travel Time (years)
Hydraulic Conductivity (m/sec)	Porosity (%)	
5 x 10 ⁻⁵ (thick aquifer – 40 m)	30	24
5 x 10 ⁻⁵ (thin aquifer – 20 m)	30	12
1 x 10 ⁻⁵ (thick aquifer – 40 m)	30	120
1 x 10 ⁻⁵ (thin aquifer – 20 m)	30	60
5 x 10 ⁻⁶ (thick aquifer – 40 m)	20	240
5 x 10 ⁻⁶ (thin aquifer – 20 m)	20	120

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

1240049

Lessoway Moir Partners for Energy Solutions Centre and Village of Haines Junction
Resource Assessment for Village of Haines Junction

August 2003

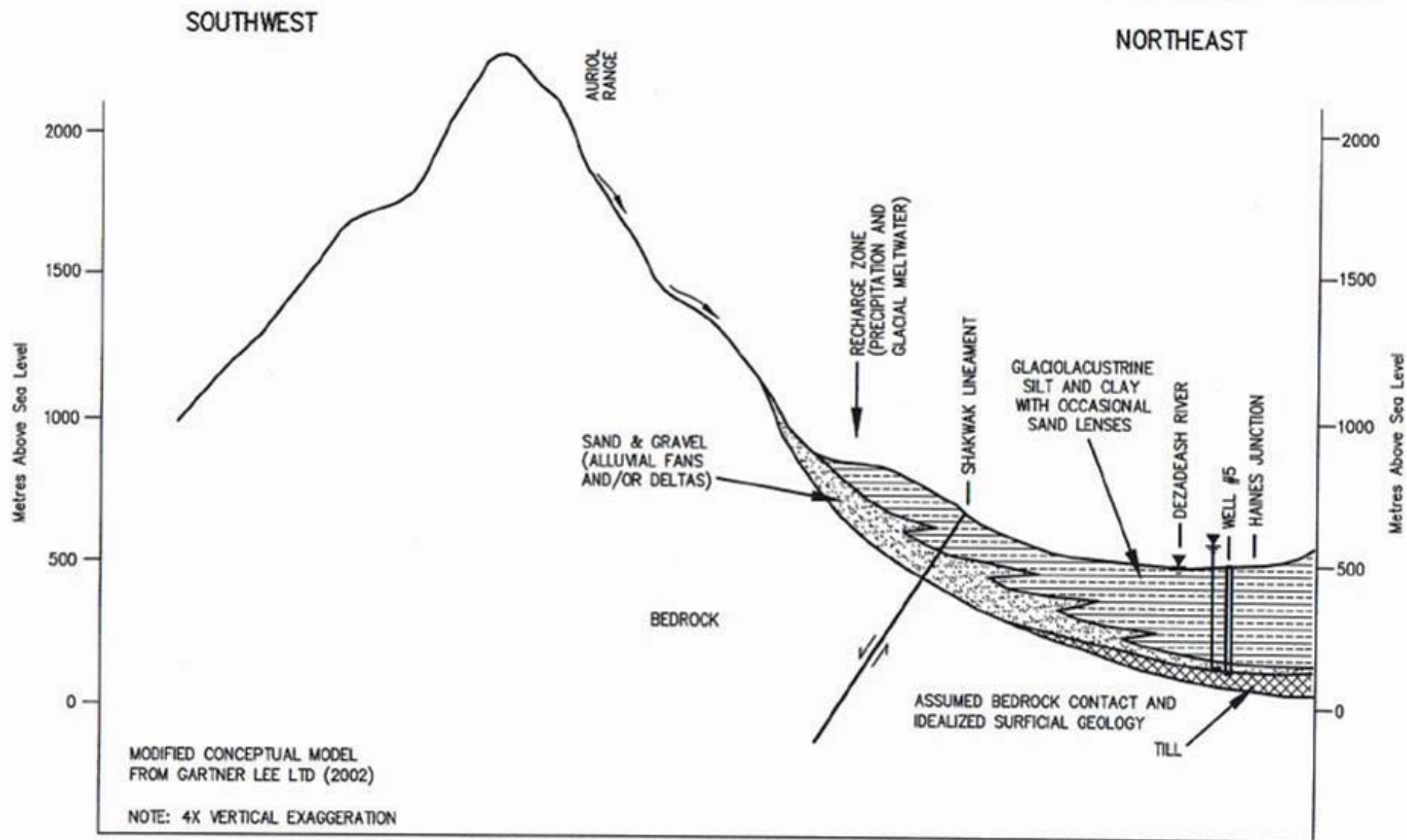


FIGURE 13

The estimated travel time for the groundwater to flow from the Auriol Range to Well # 5 is between 12 to 240 years depending on the variable aquifer characteristics. Based on the dissolved mineral content and TDS of the water at Well #5, and the tritium results, it is likely that the actual travel time is towards the middle of this estimate. This supports the transmissivity value obtained by evaluation of the recovery data.

Bedrock Structure Controlled Conceptual Hydrogeological Model

A second potential conceptual model consisting of a "bedrock structure controlled conceptual hydrogeological model" is presented schematically in Figure 14. Given the complex structure of the area, and the presence of the Shakwak Fault, it is possible that regional structure plays some role in the movement of groundwater and its thermal characteristics. However, there are too many unknown variables to estimate the time it would require for groundwater to flow from the Auriol Range to Well # 5 if it flowed through structurally controlled flow paths. It is predicted that the travel time would be longer than the estimated time for the alluvial fans/deltas controlled conceptual hydrogeological model, as the structurally controlled flow path would be longer and would still have to flow through some of the same sands and gravels as the other model.

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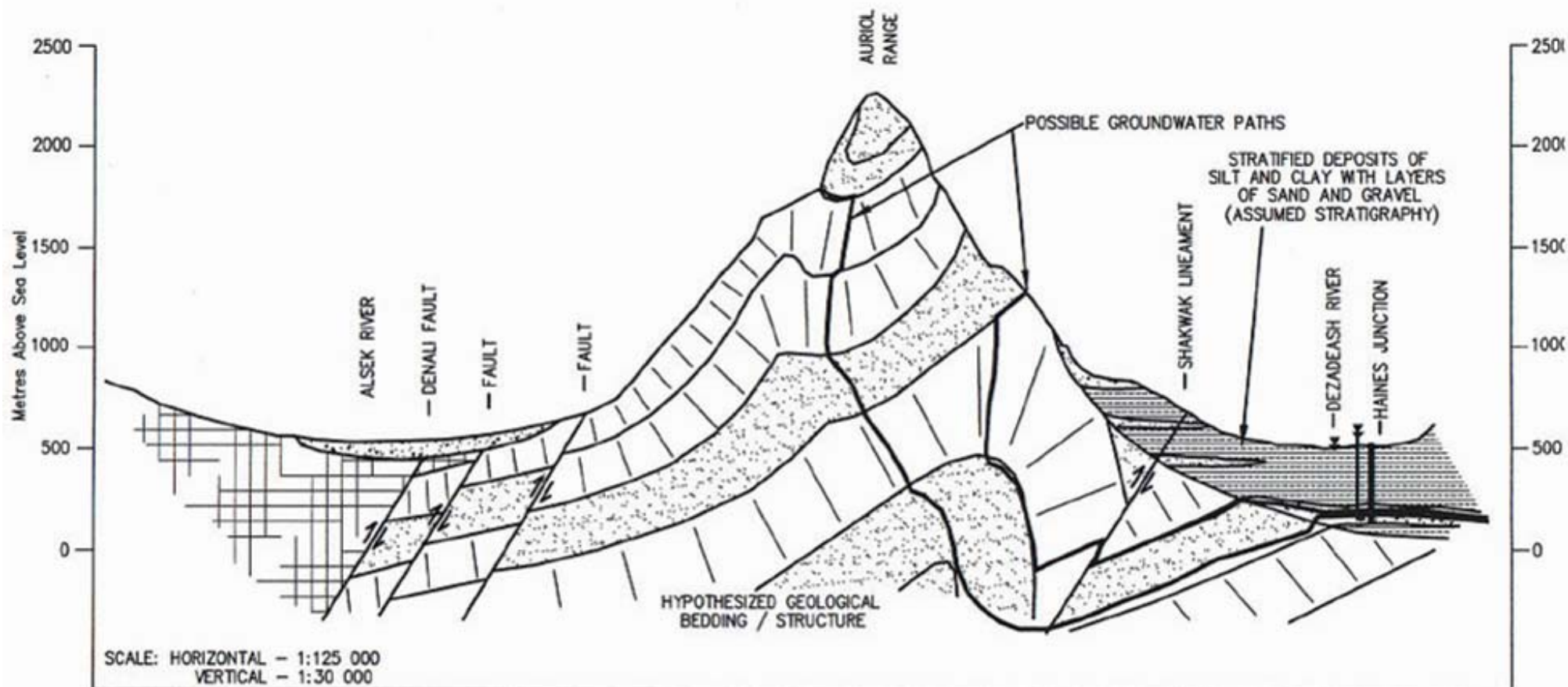


FIGURE 14

8.2 Long Term Well Capacity

The specific capacity of a well is a measure of its productive capacity and is calculated by dividing the flow rate during the test by the observed drawdown during the test. The specific capacity of Well #5 following 69 hours of continuous pumping at 27 L/s is 0.19 L/s/m. To calculate the well capacity for a Certificate of Public Convenience and Necessity in the Province of BC, the BC Ministry of Water Lands and Parks (MWLAP), Groundwater Section requires the yield of a well based on the specific capacity of the well at a given pumping rate to be multiplied by the safe available drawdown. The safe available drawdown is based on the slope of the time versus drawdown curve and assumes that the well will be pumped for 100 days of continuous pumping with no recharge to the aquifer. The available drawdown in the well is determined by the length of the water column above the pump intake at the time of year when groundwater levels are lowest, subtracted by pumping interference from neighbouring wells and multiplied by a safety factor of 70 percent. As mentioned by Gartner Lee, it is assumed that if a pump is installed, it would be housed within the 244 mm diameter casing (i.e above the Liner Hanger) to maximize pump size and capacity. The slope of the latter portion of the drawdown versus time curve is used to determine the amount of drawdown after 100 days of continuous pumping (see Figure 15). Table 8 illustrates the computation of the safe available drawdown and long term yield of Well #5 assuming that there are no other wells utilized within the deep aquifer.

Table 8: Computation of Safe Available Yield:

Parameter	Unit	Key	Value
Specific capacity of well *1	L/s/m	la	0.188
Depth to top of liner casing	lm	lb	141.1
Estimated lowest static water level (depth from ground level)	lm	lc	-55
Interference from other wells	lm	ld	0.0
CPCN Safety Factor (70%)		le	0.70
Available drawdown (assuming well pump at 141.1 m btwc)	lm	f = b-c-d	196.1
Safe available drawdown	lm	g = e x f	137.3
Safe estimated sustainable yield	L/s	h = a x g	25.8

NOTE: 1 Estimated from the drawdown versus time curve, after 100 days of continuous pumping with no recharge.

Village of Haines Junction Geothermal District Heating
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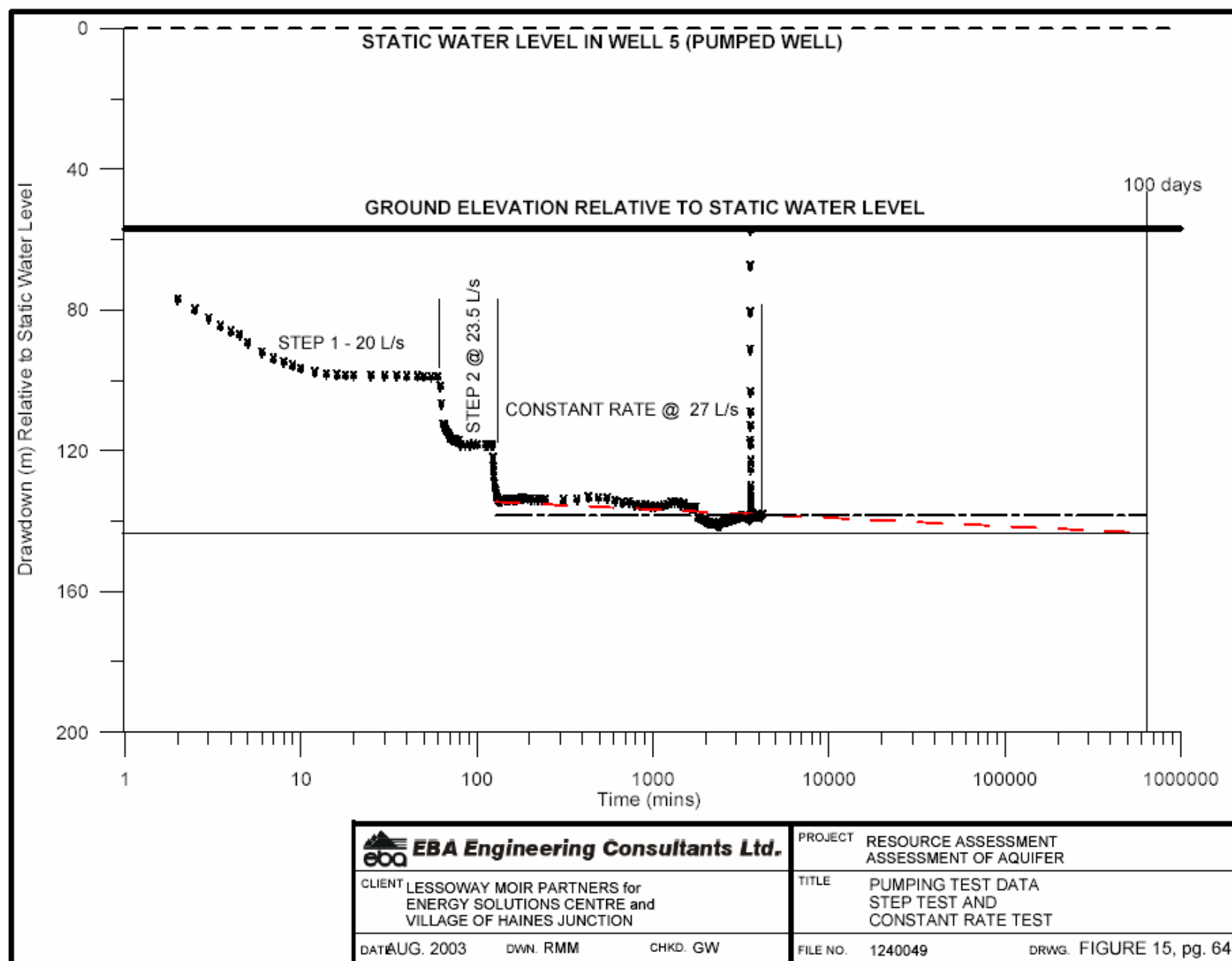


FIGURE 15

The amount of safe available drawdown in Well #5 is 137.3 m, assuming that:

- the pump intake is positioned just above the casing liner,
- there is no pumping interference from other wells (other wells not yet completed in this aquifer),
- the estimated lowest static water level is 1.75 m lower than the static water level observed during this study, and
- a 70 percent safety factor is applied.

Based upon the drawdown versus time curve, a conservative estimate of the specific capacity after 100 days of continuous pumping with no recharge would be 0.188 L/s/m. Considering a safe available drawdown, the well could theoretically be pumped at a rate of 25.8 L/s.

Field experience and laboratory tests show that the average entrance velocity of water moving into the screen should not exceed 0.03 m/s (Driscoll, 1986). At flows lower than this velocity, the friction losses in the screen openings are negligible and the rates of incrustation and corrosion will be minimal. A pumping rate of 25.8 L/s (the safe estimated sustainable yield) would result in an entrance velocity of approximately 0.02 m/s. This is considered acceptable for the proper operation of the well.

8.3 Aquifer Parameters

As mentioned previously, the only aquifer parameters that could be ascertained from this hydrogeological investigation are the transmissivity and the hydraulic conductivity. Based on the late time recovery data, these have been estimated at 4×10^{-4} m/s and 1×10^{-5} m/s, respectively.

8.4 Aquifer Boundaries

During the pumping test, no trends were observed that would be indicative of a boundary condition being intercepted by the drawdown cone generated during the long term pumping test. Aside from the slight undulations in the drawdown, or pumping water level (PWL) during the test, the PWL became relatively flat. As mentioned in the GLL report, this type of hydraulic response (i.e. no additional change in drawdown with

respect to time) is indicative that the confined aquifer is a “leaky” aquifer. This means that the aquifer is recharged during pumping from the less permeable strata above and below the aquifer.

8.5 Water Temperature Variation vs. Time

The Village has monitored temperature at the wellhead during use of Well #5. There has been no significant or noticeable change over the use of the well thus far. Given the significantly high volume of water that has been extracted from Well #5 to date and the observation that there has been no significant change in the water temperature, this supports the fact that this aquifer could support a sustainable source of heat energy. Continued monitoring of temperatures over time, however, is necessary.

8.6 Variation of Water Quality vs. Time

As indicated in Section 6.2.5, there were no obvious changes in the conductivity during the long term pumping test. As well, after reviewing the routine monthly analytical results for this well (provided by John Gibson), it is obvious that the water quality has remained relatively constant over the past six months of use of this well. Given the significant volume of water that has been abstracted from Well #5 to date and the observation that there has been no significant change in the water quality, this supports the fact that this aquifer is large in extent which is encouraging with respect to the long term sustainability of this aquifer

8.7 Preliminary Conceptual Geothermal Regime

The following presents a conceptual geothermal regime in the subsurface below Haines Junction. The relatively young chemical composition of the groundwater at Well #5 (as evidenced by its low TDS), and its origin as meteoric water suggests a relatively fast contact time of meteoric water with subsurface materials. Normally, geothermal fluids (i.e. fluids of high temperature) have significantly higher TDS because minerals are more readily dissolved at higher temperatures. Consequently, the water in the aquifer at Well #5 likely does not originate as a high temperature source; otherwise it would have a high TDS. Rather, it might be concluded that the fresh groundwater travels quite rapidly from its place of origin and that it is heated up rather quickly en-route to Well #5 or beneath the aquifer that Well #5 taps. This might suggest the presence of a conduit system at depth, which is consistent with the fracturing present in this area. Heat energy may be

provided by conduits such as deep seated faults that extend to great depth (note seismic activity in proximity to the Shakhwak lineament) or perhaps associated plutonism. The southern Yukon and Northern BC have several thermal springs that originate from deep-seated fractures. Shallow groundwater, recharged at high elevation may flow briefly through a fracture zone associated with the Shakhwak Fault and acquires heat energy during its travel. As it travels further within the aquifer, it retains its heat energy. The conceptual model presented is highly speculative and would require considerable detailed information to confirm, nevertheless, it does offer an explanation for the observed warm temperatures at Well #5.

8.8 Energy Balance, Conceptual Geothermal Storage Options and Re-injection

Aquifer Thermal Energy Storage (ATES) scenarios that encompass cold storage, have not yet been completed as cooling demands have not yet been provided. At this time, it is assumed that only heating demands are required.

In order to minimize the impact on the aquifer and reduce the risk of supply depletion, excess water not used by the Community should be re-injected into the aquifer. EBA considers the surface release of waste cold water (water from which heat has been extracted for heating) to be non-environmentally sound because ecosystems supported by surface water are inherently sensitive. In addition, the continued abstraction of water from the aquifer may, over the long term, jeopardise the sustainability of the resource, both hydraulically and thermally.

EBA has discussed the potential of extending Well #4 into the deep aquifer. Trent Jamieson, of Midnight Sun Drilling, does not think that this would be possible. There is no viable option for placing the necessary grouting around the top of the well to withstand the artesian pressures of this deeper well.

If groundwater is re-injected to an aquifer, the injection well should be located downgradient from the production well so that the waste colder water is distributed downgradient from the production well. Plugging of injection wells by sand, chemical deposits, or bacterial growth is a major problem that can be alleviated, but usually not completely eliminated by specifying longer screens for the injection well. According to Driscoll (1986), where possible, the well screen for an injection well should be at least twice as long as an equivalent production well screen.

For future business case consideration, it should be noted that the cost of an injection well, including capital costs, operation, monitoring and maintenance are likely to be in the range of three to four times that of an extraction well. It should also be noted that in order to overcome the artesian pressure within Well #5, pumping would be required, and therefore, this cost should be included in capital, operational and maintenance costs in consideration of the business case.

It is not advisable to re-inject chemically altered water be re-injected to any aquifer. This would include chlorinated water.

There is insufficient hydrogeological information at present (ie. gradient, flow direction and travel times are yet unknown) to recommend minimum distances for locating a re-injection well relative to the source well (Well #5).

8.9 Seismic Risk to Long Term Sustainability of Resource

Since the aquifer in which Well #5 is completed is possibly hydraulically connected with, and is in close proximity to a parallel fault (Shakwak Lineament), there is some risk that seismic activity may result in alteration of the aquifer and well performance. Assessment of this risk is beyond the scope of the current study.

9 CONCLUSIONS

One of the objectives of this long term pumping test was to assess if other existing wells would respond to pumping from Well #5. None of the wells monitored indicated a response to pumping from Well #5. Therefore the data collected during the pumping test only provided information on:

- The transmissivity and hydraulic conductivity of the aquifer;
- The well efficiency;
- The water chemistry; and
- The water temperature.

The following cannot be assessed because they would need at least two monitoring locations.

- Storativity of the aquifer;
- Hydraulic gradient;
- Groundwater flow direction;
- Horizontal temperature gradient in the deep aquifer; and
- Recharge area.

The high discharge rate pumping test followed a long time period when the well was left flowing and was used as a water supply; being equivalent to a long term pumping test at a lower pumping rate. Based on the interpretation of the available information, the following can be concluded:

Boundary conditions (either indicative of an impermeable barrier or of a recharge) have not been identified;

The aquifer behaves as a "leaky" aquifer with an estimated transmissivity of 4×10^{-4} and a resulting hydraulic conductivity of 1×10^{-5} m/s, assuming an aquifer thickness of 40 m. These values are similar to the values proposed by GLL. Based on the pumping tests, the specific capacity of Well #5 is calculated to be 0.19 L/s/m. If Well #5 is pumped exclusively (no well interference), the estimated safe yield is 25.8 L/s.

The various parameters monitored on the water flow, the water chemistry and the water temperature have indicated relatively constant conditions. The high flow rates used during the pumping test have not resulted in an apparent stress to the aquifer;

The water chemistry and isotope analysis indicate that the water is low to moderately mineralized, of meteorological origin and has been resident in the subsurface for more than 50 years. Combined with the fact that a higher elevation recharge zone would be required to maintain the observed artesian conditions, it is probable that the groundwater originates from the Auriol range;

Data are not available to predict on the size or lateral extent of this deep aquifer;

The temperature observed in the deep aquifer has remained constant at 17°C over the period of extraction of the groundwater. This temperature is not due to the natural temperature gradient observed in the area (i.e. using the temperature gradient calculated in Wells #2 and #4 in the overburden deposits), which would result in a

temperature of 8 to 9°C at 365 m. Therefore another heat transfer process creates the observed conditions. The Dezadeash valley borders a series of major geologic faults and an area where the seismic activity is high. Therefore it is possible that "en route" to the deeper aquifer, the groundwater is heated as it comes in contact either with high temperature rock or thermal fluids. It appears that the heat transfer is well established, due to the constant temperature observed, and is not impacted by the change in groundwater flow generated both during the recent use of the well and the high discharge rate pump test.

The topography of the rock substratum at the bottom of the valley, the geometry of the fracture network and faults, the contact between the deep aquifer and any warm rock or groundwater are not presently known. Therefore it is not possible to define the conceptual model that would describe the geothermal conditions in the valley. Only hypothetical conceptual models can be generated.

For the duration, and under the conditions used and tested, Well #5 has provided water of good quality and at a constant temperature of 17°C. Therefore the Well should be considered as a source of both water and energy. However, the use of Well #5 as a geothermal source should proceed with caution to take into account the various parameters that are still unknown and that would be presently very costly to characterize.

10 RECOMMENDATIONS

10.1 Production Rate

A safe sustainable yield of 25.8 L/s has been calculated for Well #5, based on limited available information. However, the level of uncertainty of the long term (e.g. 20 years) sustainability of Well #5 is still relatively high due to the number of unknown parameters characterizing both the groundwater regime and thermal regimes.

As it is very costly to drill monitoring wells to further characterize both the aquifer and the geothermal conditions, design of mid-term and long term water and energy use should only consider using a portion of what the well has been estimated to yield. This will be done to reduce the risk of "mining" both the aquifer and the source of energy and to provide a margin of safety to adjust drinking water and energy supply management plans. For example, if after a certain period of time (e.g. 5 or 10 years after the well has

been put into production), monitoring trends start indicating a reduction in the performance of the well (e.g. drop of artesian pressure or drop of water temperature) then it will be possible to compensate by increasing the yield of the well for a relative short term (e.g. up to a year) to come up with alternative plans.

If meanwhile another user shows interest in using this water supply, this user should be involved in the characterization of this resource.

10.2 Resource Assessment

10.2.1 Ongoing long term monitoring and interpretation

It is recommended that a datalogger be installed at the wellhead to continuously record temperature and pressure. Specifications will be supplied at the request of the Village.

The 24 hour shut-down and monitoring of pressure response at the wellhead should be continued on a monthly basis. This information should be interpreted by a Hydrogeologist on a semi annual basis.

10.2.2 Additional investigations

The first step of an additional investigation should consist of installing at least one monitoring well (that could potentially be converted into another production well or re-injection well). In addition, a passive pump test (letting Well #5 discharge under artesian pressure) or active (similar to the pump test recently conducted) could be conducted on that new well. Required information on the groundwater flow direction and groundwater regime would be gained as well as data that would allow a better assessment of the long term behaviour of the aquifer.

The costs associated with a thorough and long-term investigation should be included in a risk-cost-benefit analysis to assess if, how and when this investigation should be conducted.

10.3 Well Monitoring and Maintenance

EBA recommends the implementation of a monitoring program for Well #5 due to the fact that moderate to aggressive bacteriological populations have been measured within the Well. Specifically, EBA recommends the following actions:

The Village should continue monitoring the iron and manganese concentrations, conductivity, TDS and pH on a monthly basis.

The Village should repeat the BART™ sampling on a bi-annual basis to track any changes of the bio-chemistry of the Well so that if there is a shift in the bacteriological activity, it can be addressed before it significantly impacts well performance or water quality.

EBA considers it important for the Village to track the well efficiency on a monthly basis to permit early detection in the event that conditions in and around the well begin to deteriorate.

10.4 Pump Installation

If it is desired to install a pump in Well #5 at some future date, it is recommended that the pump intake be positioned just above the casing liner (approximately 140 m below top of well casing) to maximize available drawdown. As per the agreement with Aqua Tech, the pump that was purchased by Aqua Tech for these pumping tests, could be purchased back from them by the Village of Haines Junction at a significant discount. Aqua Tech would credit 80% of the pump rental charged for the test, to the purchase of this pump.

11 Limitations

Information presented in this report is based on inferred lithology, and conceptual models. Conclusions and recommendations presented in this report are based on the Hydrogeological Assessment as described in the previous sections. This report has been prepared for the exclusive use of Lessoway Moir Partners, Energy Solutions Centre, and the Village of Haines Junction. It has been prepared in accordance with generally accepted hydrogeological practices. For further limitations regarding the use of this report, reference should be made to the EBA Environmental Report - General Conditions attached, which form a part of this report.

12 Closure

EBA trusts this report meets your present requirements. If you have questions or concerns, please do not hesitate to call the undersigned.

Respectfully submitted;
EBA Engineering Consultants Ltd.

Prepared by:

Reviewed by:

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RMM/cm/gw

C:\WINDOWS\Desktop\1240011-R01 Draft.doc

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Hydrogeological Consultants Limited, May 1989. Haines Junction Water Test Hole Adjacent to the Water Tower (Re: preliminary test hole near location of future Well # 4).

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APPENDIX A

SUMMARY OF HYDROGEOLOGICAL INVESTIGATIONS

APPENDIX A – Summary of Previous Hydrogeological Assessment Work
(sorted chronologically)

Report: February 1974 – Hydrogeological Consultants Ltd. *A Review of Groundwater Data – Haines Junction, Y.T.*

Hydrogeological Consultants Ltd (HCL) reviewed the existing wells in Haines Junction with relation to the increasing the water supply for the community.

The wells in the Village are shown on an aerial photograph and consist of:

- 1) The community well (dug and cement-cribbed close to the river);
- 2) The Yukon Territorial Government Well (1000 feet upstream of Well #1); and
- 3) Domestic wells within the Village of Haines Junction (known as: Refinery Well, Mile 1018 Well, and Brewster's Lodge Well).

HCL identifies a shallow and deep groundwater source. The deep groundwater source is the water source for the Brewster's Lodge Well, which is 156 m deep, flowing artesian and soft.

Chemical analyses were determined and are reported for:

- 1) Community well;
- 2) The Yukon Territorial Government Well;
- 3) Brewster's Lodge Well; and
- 4) Pine Creek (surface water).

HCL suggests that the most favorable water source for an increased water supply for the Village of Haines Junction would be from a groundwater well that terminated in the deep aquifer.

Report: August 1974 – Hydrogeological Consultants Ltd. *Haines Junction, Y.T. 1974 Water Well Drilling*

Hydrogeological Consultants Ltd (HCL) supervised the drilling of two water test holes that were completed by Midnight Sun Drilling Co. Ltd in April 1974. The test holes were located near the old excavated well in Haines Junction.

Test Hole #1 was drilled to a depth of 15.2 mbgl and was screened between 4.0 to 5.2 mbgl, while Test Hole #2 was drilled to a depth of 13.7 mbgl and was screened between 7.0 to 7.6 mbgl.

Test Hole #1 had siltation problems and was abandoned, while Test Hole #2 was tested using a step-drawdown pump test and a 960-minute continuous rate pump test. HCL concluded that Test Hole #2 was likely to be connected to the Dezadcash River and could yield 3.0 to 3.8 l/s. Test Hole #2 became known as Well #1.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

The water chemistry analysis stated that the water supply was moderately hard and basically a calcium-bicarbonate water type with a temperature of 3°. The chemical analysis and pump data were presented in the report.

Report: April 1978 – Hydrogeological Consultants Ltd. Haines Junction, Yukon Territory – Water Well #2

The Government of the Yukon Territory decided to develop a second community water well, for the Village of Haines Junction, as a secondary water supply source. The government hoped that the water supply from the second well would be warmer than the existing 2°C water supply so that the water would not need to be heated prior to distribution. Hydrogeological Consultants Ltd (HCL) supervised the drilling and conducted a hydrogeological investigation of the test well.

A test hole was drilled approximately 21 m west of the existing pump house to a depth of 134.4 mbgl. Two potential productivity zones were screened between 133.8 mbgl to 134.7 mbgl, and 76.5 mbgl to 78.3 mbgl. Both of zones had flowing artesian conditions. Hydraulic testing and chemical analyses were conducted at each of the screened intervals and are included in the report.

Upon reviewing the drill cuttings and hydraulic tests, HCL concluded that the lower screen was within gravelly till and the upper screen was within clay till with gravel and cobbles. Well #2 was completed and screened in the upper unit at 76.5 mbgl to 78.3 mbgl.

The natural flow rate was in the order of 2.7 L/s and was anticipated sand-free water at a yield of 7.6 to 11.4 L/s.

Report: Stanley Associates Engineering Limited, March 1979 – Government of Yukon – Haines Junction Water Supply Study

As the municipal water system at the Village of Haines Junction was at its capacity, Stanley Associates Engineering Ltd (SAE) was contracted to evaluate the immediate and long-term water supply needs for the Village.

SAE projected population and water demands from 1979 to 1983 to increase from 300 to 1000 people and an average daily water demand from 215,935 L/d to 568,250 L/d. The maximum projected storage requirement increased from 886,500 L in 1979 to 1,409,250 L in 1983.

The current water supply wells, Well #1 and 2, produce 3.4 l/s and 2.6 l/s. Well #2 produced less than initially expected due to a persistent sediment problem. The aquifers at Haines Junction consist of a shallow gravel aquifer, a middle aquifer, and a deep aquifer.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Four additional and alternative water sources were studied and cost estimated. These water sources consisted of:

- 1) Expansion of the existing shallow well system;
- 2) Expansion of the existing deep well system;
- 3) Surface water from the Dezadeash River; and
- 4) Surface water from Pine Lake.

The cost analyses within the report stated that the future water supply for the Village of Haines Junction should be wells or the Dezadeash River.

Report: Stanley Associates Engineering Limited, July 1980 – Warm Water Well #2 – Haines Junction, Yukon Territory

Stanley Associates Engineering Ltd (SAEL) was retained by the Yukon Territorial Government to conduct the hydrogeological investigation and supervise the drilling of a deep-water well to replace Well #2 and increase the water supply capabilities of the Village of Haines Junction.

Well #3 was drilled by Midnight Sun Drilling Co. Ltd. 18.6 m west of Well #2 to a depth of 85.4 m. A well screen was installed from 79.3 mbgl to 82.3 mbgl within a fine to coarse sand and gravel aquifer that was flowing artesian. Aquifer testing, consisting of a step drawdown test and a constant rate test, was conducted on Well #3 and a maximum continuous safe yield of 690 m³/day was estimated.

From the analyses of two groundwater samples, the groundwater quality was rated very good, a temperature between 6.5 to 7.0°C, but dissolved gas that should be treated through venting.

Well construction details, aquifer test data, and chemical analysis data are included in the report.

Report: November 1988 – UMA Engineering Ltd. Village of Haines Junction – Water System Improvements: Status Report and Improvement Options.

UMA Engineering Ltd. projected the future population and the maximum annual water demand in the Village of Haines Junction to be 1000 people and 263,165 m³. The Village has three water supply wells but due to sediment problems Well #2 has virtually been abandoned and the water from Well #1 has to be heated in the winter prior entry into the distribution system. Therefore, the Village relies entirely on Well #3 and there is no backup source.

UMA reviewed the surface water and groundwater alternatives stated by SAEL, 1979, the existing wells within the Village, and all the previous reports. A map was included in the report that shows the location of the existing wells. Water quality analyses were also reviewed and reported for the existing wells. From these reports and analyses UMA recommended that a water test hole be drilled in the vicinity of the elevated storage tank to a maximum estimated depth of 150 m.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Letter: May 1989 - Hydrogeological Consultants Ltd. *Haines Junction Water Test Hole Adjacent to the Water Tower*

A letter from R.J. Clissold, President and Senior Hydrogeologist of Hydrogeological Consultants Ltd. (HCL) to UMA Engineering Ltd. stated the results of the Test Hole No. 1-89.

Test Hole No. 1-89 was drilled to 249.9 mbgl within the fenced area around the water tower. Three significant intervals were encountered:

- Upper Interval: 57.3-61.6 m - sulphate type water that would require treatment
- Middle Interval: 93.3-97.8 m - a lot of silt
- Lower Interval: 157.0-159.1 m - silt with water

HCL recommended drilling a second test hole either 1) close proximity to the Brewster Water Well, or 2) on the west side of the Village of Haines Junction.

Letter: June 1989 - Hydrogeological Consultants Ltd. *Village of Haines Junction Groundwater Investigation*

A letter from R.J. Clissold, President and Senior Hydrogeologist of Hydrogeological Consultants Ltd. (HCL) to UMA Engineering Ltd. stated the results of the Test Hole No. 2-89.

Test Hole No. 2-89 was drilled to 182.9 mbgl approximately 100 m north of the water tower. A sand and gravel aquifer was encountered from 59.4 to 64.0 mbgl and from 120.4 to 123.1 mbgl. Water chemistry analyses were collected from each aquifer and indicated that the lower aquifer is more suitable to municipal needs.

Letter: February 1996 - Hydrogeological Consultants Ltd. *Haines Junction 1996 Groundwater Program*

A letter from R.J. Clissold, President and Senior Hydrogeologist of Hydrogeological Consultants Ltd. (HCL) to David Nairne & Associates Ltd. Summarized the groundwater investigations to date in the Village of Haines Junction. This included the attempts to control the silt problems at Well #4 (Test Hole No. 3-89).

HCL recommended that either 1) further investigations should be conducted on Well #4, or 2) that a new test well should be drilled to a similar depth of Well #4.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Report: February 1996 – David Nairne and Associates. Status Report / Technical Brief – Water Supply Well #4 and Proposal for Additional Investigations for the Village of Haines Junction

David Nairne & Associates Ltd. (DNA) produced a status report / technical brief regarding Well #4. This report included a detailed chronology of the events surrounding the construction of Well #4, recent investigations and status of the well, and the possible options for restoration of the much needed water supply in Haines Junction, which included cost estimates and recommendations.

DNA recommended that no further studies be conducted on Well #4 and that the locating and developing of a new Well #5 be conducted. The proposed work plan was included for the investigating and supervising of Well #5.

Letter: March 1997 Hydrogeological Consultants Ltd. 1996/97 Groundwater Program

A letter from R.J. Clissold, President and Senior Hydrogeologist of Hydrogeological Consultants Ltd. (HCL) to Building Industry Consultants that summarized the current water levels and production from Well #3, an aquifer test and chemical analysis from the Stardust Motel Water Well, and the proposed location and drilling costs for the 1997 Water Test Hole (proposed Well #5).

Based on the good groundwater quality and high-permeability aquifer at the Stardust Motel Water Well, HCL recommended a proposed drilling location for the 1997 Water Test Hole (proposed Well #5). A map showing the proposed location was included in the letter.

Report: December 2002 – Gartner Lee Limited. Haines Junction Water Well #5 Completion Report

The new groundwater well (Well #5) was completed by Midnight Sun Drilling Co. Ltd., between August 13 and September 13, 2003, to a depth of 369.2 m and was screened between 361.9m to 369.2 m below ground level (mbgl) with a 127 mm diameter, 60-slot stainless steel screen within a sand and gravel aquifer. Well #5 is a flowing artesian well with an estimated hydrostatic head of approximately 59 m above ground level and artesian flow rate of 13 L/s. The aquifer pump test was conducted by Aqua Tech Supplies & Services Ltd.

The simplified stratigraphy of Well #5 is shown in Table 1. GLL inferred that the artesian conditions at Well #5 were likely encountered at a depth of approximately 329 mbgl. The water bearing unit could represent alluvial fans or deltas that have formed off the slope of the Aurioi Range south of the Dezadeash River.

Table 1: Simplified Stratigraphy of Well #5

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Depth (mbgl)	MATERIAL TEXTURE	Stratigraphic Unit
0 – 329 m	SILT and CLAY, occasional fine sand lenses and pebbles	Glacial Lake Champagne Glaciolacustrine deposits
329 – 343 m	SILT, SAND and GRAVEL	Transitional Facies – interbedded and mixed fluvial and glaciolacustrine deposits
343 – 370 m	SAND and GRAVEL	Alluvial and/or deltaic deposits
> 370 m	CLAY, SILT and GRAVEL	Till

Well #5 was developed by air lifting, between September 14 and September 25, 2002, to remove the fine sediments around the well screen and to maximize the water yield of the well. Following development, the maximum long-term safe yield of Well #5 was estimated at 27 L/s using a 6.8 hour, 3 stage step test with the maximum discharge rate of 19.94 L/s. On the basis of visual inspection, the discharged water appeared to be 'sand free' throughout the pumping test.

A relatively constant water temperature of 16.9°C was measured from the water discharged from Well #5 during the short-term pump test.

The water quality of Well #5, with the exception of turbidity, meet the applicable health-based Canadian Drinking Water Quality Guidelines (CDWQG) for the parameters that were tested. The elevated turbidity was inferred to be due to trace residual amounts of the drilling fluid and significantly less according to the Mayor of Haines Junction, John Farynowski, during a conversation on November 8, 2002.

Total iron concentrations in the groundwater from Well #5 exceeded the aesthetic CDWQG (0.3 mg/L) by a factor of two. Analysis of the dissolved and total metal concentrations indicated to GLL that the elevated iron concentrations may be related to the elevated turbidity levels and the reduction in turbidity may reduce the total iron concentrations.

The measured pH of the groundwater from Well #5 was between 8.5 to 9 pH units, while the CDWQG suggest an acceptable range for drinking water of 6.5 to 8.5 pH units.

APPENDIX B

WATER WELL RECORDS

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

11 03 16:15 UMA EDMONTON

- 4 -

P.5/17

well #1

HAINES JUNCTION TEST HOLE # 2-74

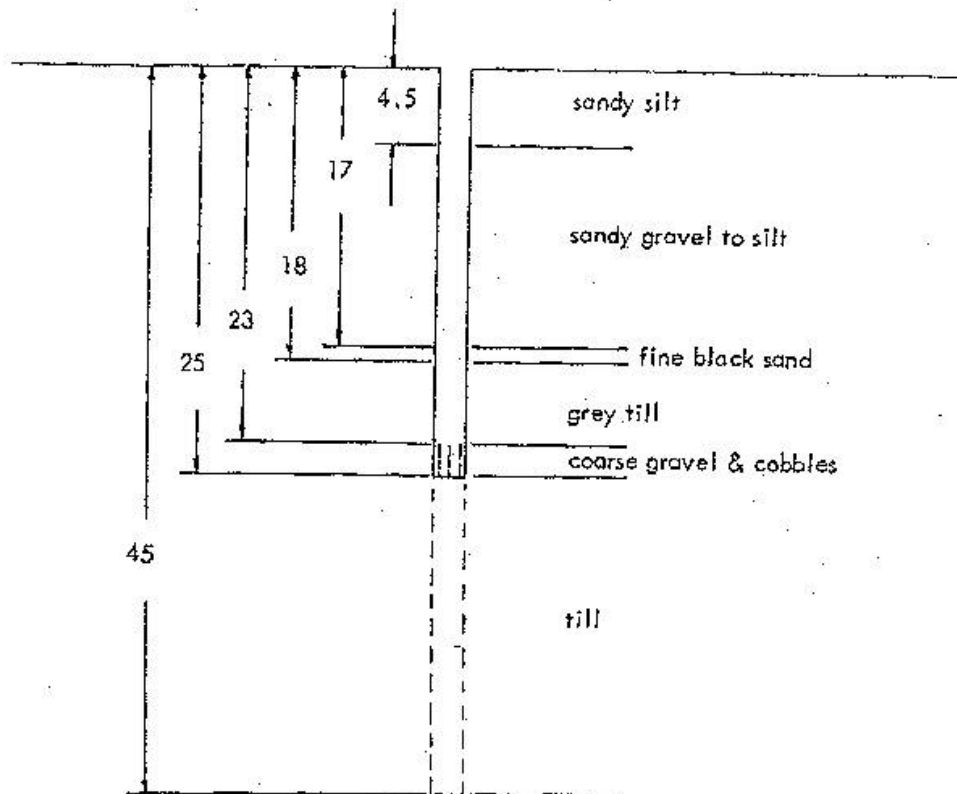


Figure 2. Diagram of Water Test Hole #2-74.

h
11/4

- 3 -

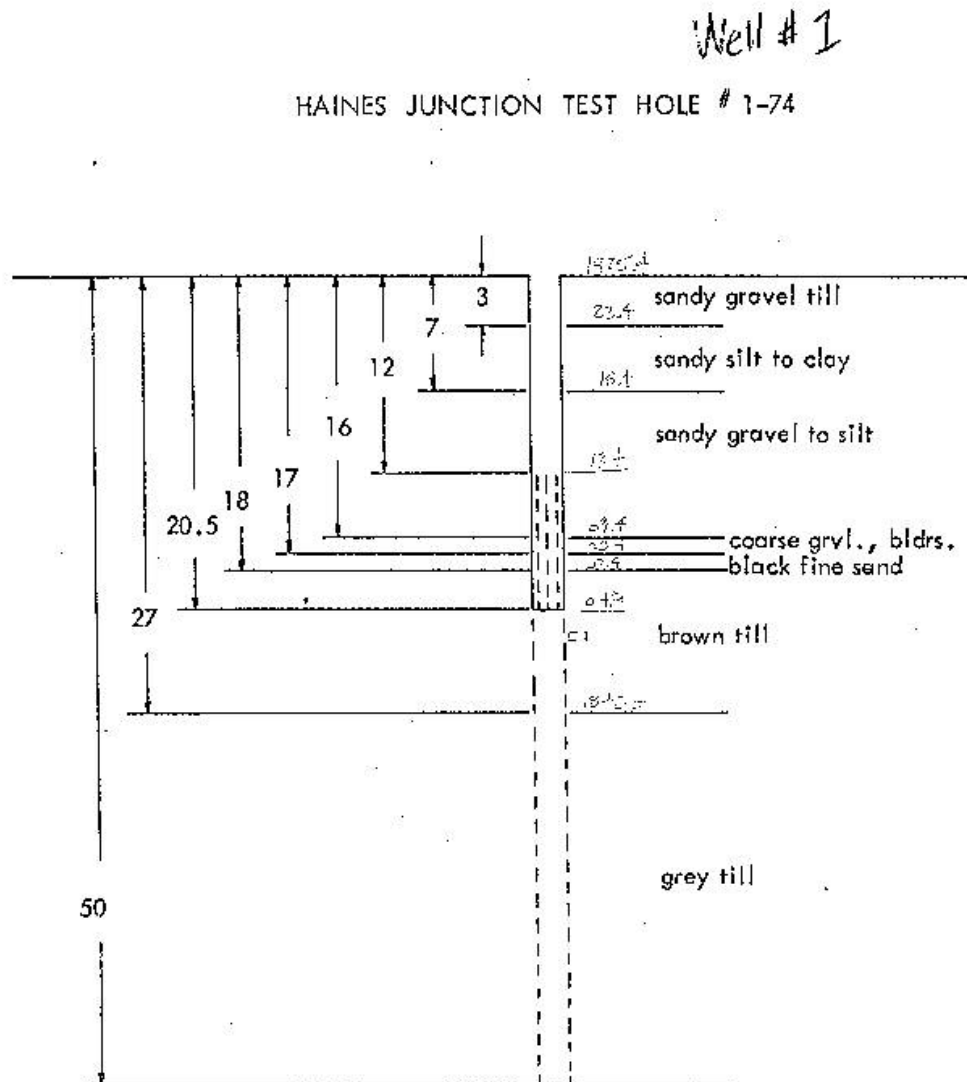


Figure 1. Diagram of Water Test Hole #1-74.

hydrogeological
consultants

- 8 -

HAINES JUNCTION

Well #1

WATER TEST HOLE
#1 - 74

LITHOLOGIC LOG

Feet	Log
0 - 3	sandy gravel till
3 - 7	sandy silt to clay
7 - 16	sandy gravel to silt
16 - 17	coarse gravel, cobbles
17 - 18	black fine sand
18 - 27	brown till
27 - 50	gray till

Casing set with bottom closed at 20.5 feet; perforated 12 to 17 feet

WATER TEST HOLE
#2 - 74

Feet	Log
0 - 4.5	sandy silt
4.5 - 17	sandy gravel to silt
17 - 18	fine black sand
18 - 23	gray till
23 - 25	coarse gravel and cobbles
25 - 45	till

Casing perforated 23 to 25 feet; 6 5/8-inch 0.188 wall

h
Haines Junction
Geothermal District Heating
Resource Assessment for Heat Potential Study

MIDNIGHT SUN
BILLING CO. LTD.
PH: 668-2434
WHITEHORSE Y.T.

PH: 668-2434

P.O. Box 4391

Started 14... 24... 1972

Completed Sept. 19... 1977

NAME AND ADDRESS OF CLIENT	DESCRIPTION OF WORK	LOCATION OF WORK
Mr. J. G. S. C. T.	water well	Marine City Tennison

FORMATION LOG			DESCRIPTION OF WORK	TIME			
FROM	TO	FORMATION		DATE	FROM	TO	HOURS
			MOVE				
			Landling	Aug 20	12:00	2:30	2 1/2
			Traveling	"	2:30	5:30	3
			loading water stand by	"	5:30	6:30	1
			setting up	"	6:30	7:00	1/2
0'	1'	Gravel		"	7:00	9:00	2
"	"	clay					
1'	14'	Gravel					
14'	28'	Gr. Clay					
28'	41'	coarse Gr. cobbles (Till)					
			Shr changing sub color				
41'	64'	coarse Gr. old Cobble (Till)		Aug 21	7:30	10:00	2 1/2
64'	129'	clay Gr. (soft Till)					
129'	181'	clay w/ coarse Gr.					
			pulling rods, doubling win line	"	11:00	12:00	1
			tearing water pump off				
			drill truck				

[illegible]

SIGNATURES

MIDNIGHT SUN.....
FILE.....

CLIENT.....
TITLE.....

PH: 668-2434
P.O. Box 4391

Started Aug. 20, 1977
Completed Sept. 19, 1977

Well
#2

CLIENT.
TITLE.

MIDNIGHT SUN DRILLING CO. LTD.
 PH: 668-2434
WHITEHORSE Y.T.
 P.O. Box 4391

Started. A. 25. 20. 1977

Completed Sept. 19 1977

NAME AND ADDRESS OF CLIENT		DESCRIPTION OF WORK		LOCATION OF WORK	
Hains JCT		water well		Hains JCT	
FORMATION LOG		DESCRIPTION OF WORK		TIME	
FROM	TO	FORMATION		DATE	FROM TO HOURS
		MOVE			
		setting up + reaming		Aug 24	7:30 7:30 12
		Run to 200' 16" casing			
		reamed 2 3/8" to 40'			
		reamed 2 3/8" to 40'			
		set 45' of 8" casing			
		cement out side 8" casing		Aug 25	7:00 9:00 2
		reaming 2 3/8" to 307		"	9:00 7:00 10
		unable to add 2nd hearing			
		up hole			
		reamed 2 3/8" to 447'		Aug 26	7:30 6:30 11
		hearing hole			
Rcd. of Casing & Pipe		Remarks:			
Size	Type	Size	Type		
8"				15 bags cement	
Feet	Inch	Feet	Inch		
45'					
STATIC LEVEL				Total Rig Time	35 hrs.
Ground level				Total Standby	hrs.
Top of casing				Drilling Mud	49 sacks

Well
#2

SIGNATURES

MIDNIGHT SUN.....
TITLE.....

CLIENT.....
TITLE.....

MIDNIGHT SUN DRILLING CO. LTD.
PH: 668-2434
WHITEHORSE Y.T.
P.O. Box 4391

Started Aug. 20, 1977

Completed. Sent... 19. 1977

NAME AND ADDRESS OF CLIENT				DESCRIPTION OF WORK		LOCATION OF WORK					
				water well		Harris, T. T.					
FORMATION LOG											
FROM		TO		FORMATION		DESCRIPTION OF WORK		TIME			
								DATE	FROM	TO	HOURS
				MOVE							
				moved up hole, unable to add sand at 700'				Sept 3	7:30	6:30	11
				pumping mud & weight down hole				Sept 4	8:00	6:00	12
				trip in circulated mud not able to control water flow. ran 309' of 6" casing				Sept 5	7:00	6:00	11
				washing & hammering 6" casing to 398' 7"				Sept 6	7:30	6:00	10 1/2
				washing hole to 441'				"	6:00	8:30	2 1/2
				mixing mud pumping inside casing 6"				Sept 7	8:00	10:30	2 1/2
				water pump changing affiliation				"	10:30	2:00	2 1/2
				vib. truck				"	2:00	6:00	4
Rcd. of Casing & Pipe				Remarks:							
Size	Type	Size	Type								
6 5/8"				52 bags weight Baxoid							
Feet	Inch	Feet	Inch								
398	7"										
				STATIC LEVEL		Total Rig Time		58	hrs.		
				Ground level		Total Standby			hrs.		
				Top of casing		Drilling Mud		84	sacks		

Well
#2

MIDNIGHT SUN.....
TITLE.....

CLIENT.....
TITLE.....

PH: 668-2434
P.O. Box 4391

Started Aug. 20, 1977

Completed, SEPT. 19, 1977

NAME AND ADDRESS OF CLIENT		DESCRIPTION OF WORK		LOCATION OF WORK		
		water well		Haine J.C.T.		
FORMATION LOG						
FROM TO FORMATION		DESCRIPTION OF WORK MOVE	TIME			
DATE	FROM		TO	HOURS		
		15' of excavating up drilled out Bore lowering screen & cave pulling screen	Sept 14	7:30	2:00	6 1/2
		mixing material weight drilled out 12' cave to 443'	"	2:00	5:00	2
		welding	"	5:00	7:30	2 1/2
		changing generator belt	Sept 15	7:00	1:00	6
		setting up sealing clutch etc	"	1:00	2:00	1
		pulling out motor pump clutch	"	2:00	5:00	3
		waiting for parts	Sept 16			
		repairing mud pump clutch	Sept 17	7:30	2:00	6 1/2
		mixing mud as weight drilled out bottom 8' cave to 442' Tripout bit	Sept 17	2:00	6:00	4
		milled 68" casing across set in mast.	"	6:00	7:30	1 1/2
Rcd. of Casing & Pipe Size Type Size Type		Remarks:				
Feet	Inch	Feet	Inch	3 Baroid		
STATIC LEVEL			Total Rig Time	35	hrs.	
Ground level			Total Standby		hrs.	
Top of casing			Drilling Mud	11	sacks	

Well
#2

MIDNIGHT SUN.....
TITLE.....

SIGNATURES

CLIENT.....
TITLE.....

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



FIELD REPORT

Started Aug. 20....1977

Completed, Sept. 19...1977

NAME AND ADDRESS OF CLIENT		DESCRIPTION OF WORK	LOCATION OF WORK	
		water well	Haines S.S.T.	

FORMATION LOG			DESCRIPTION OF WORK	DATE	TIME		HOURS
FROM	TO	FORMATION			FROM	TO	
			MOVE				
			put up hole tripped	Sept 18	7:00	11:00	4
			put dropped screen				
			to 441'				
			Tripped in setting screen	"	11:00	1:00	2
			swedge packer	"	1:00	2:00	1
			starting air compressor	"	2:00	4:00	2
			Developing	"	4:00	7:00	3
			Developing	Sept 19	7:00	7:00	12
			moving rig	"	7:00	8:30	1 1/2

Rcd. of Casing & Pipe				Remarks:
Size	Type	Size	Type	
6"				screen 2' 4"
				packer 5"
20	4			casing 60' 2"
20	1			overall 63' 11" *
14	9			

STATIC LEVEL	Total Rig Time	25 1/2	hrs.
Ground level	Total Standby		hrs.
Top of casing	Drilling Mud	3	sacks

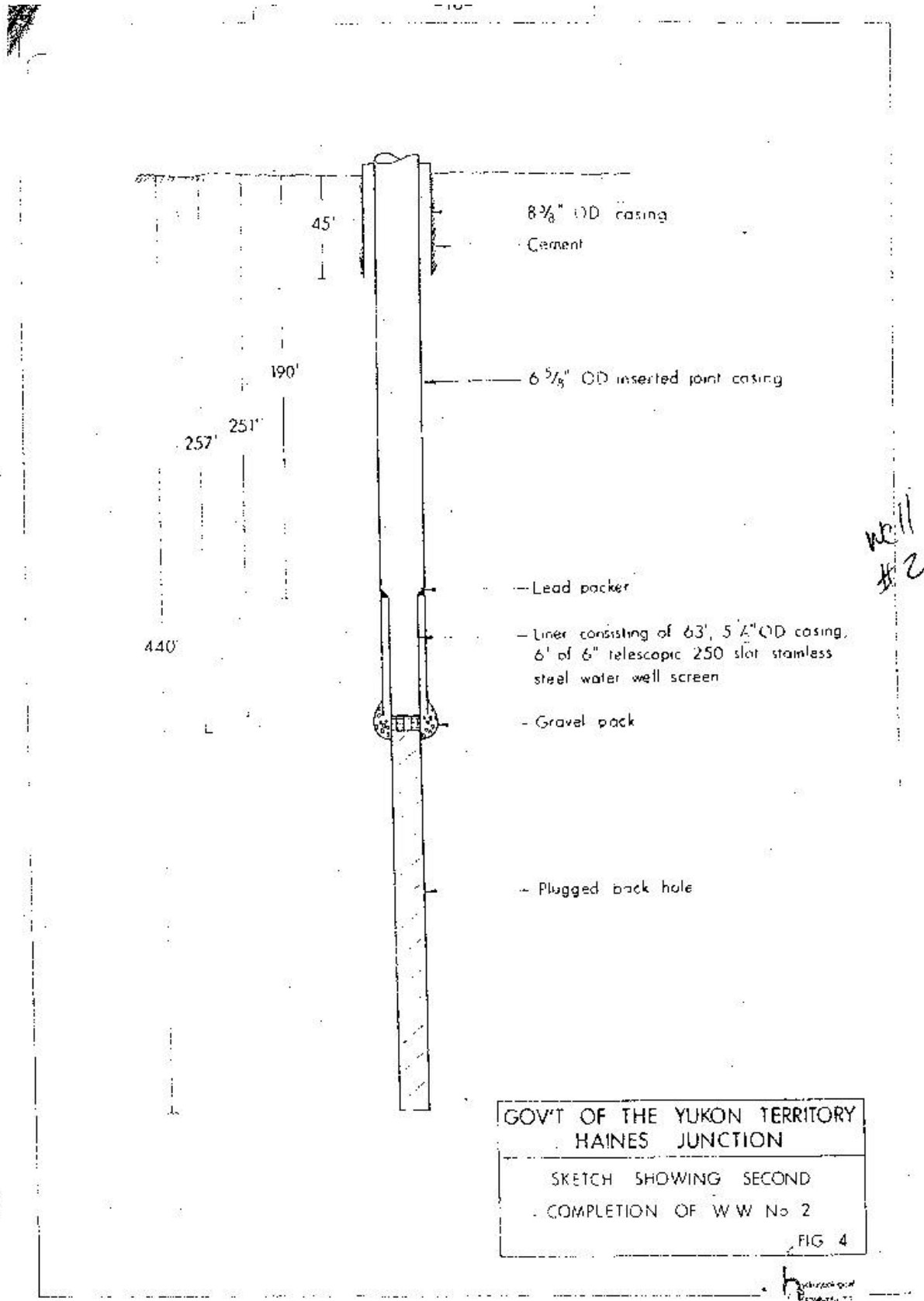
Well #2

SIGNATURES

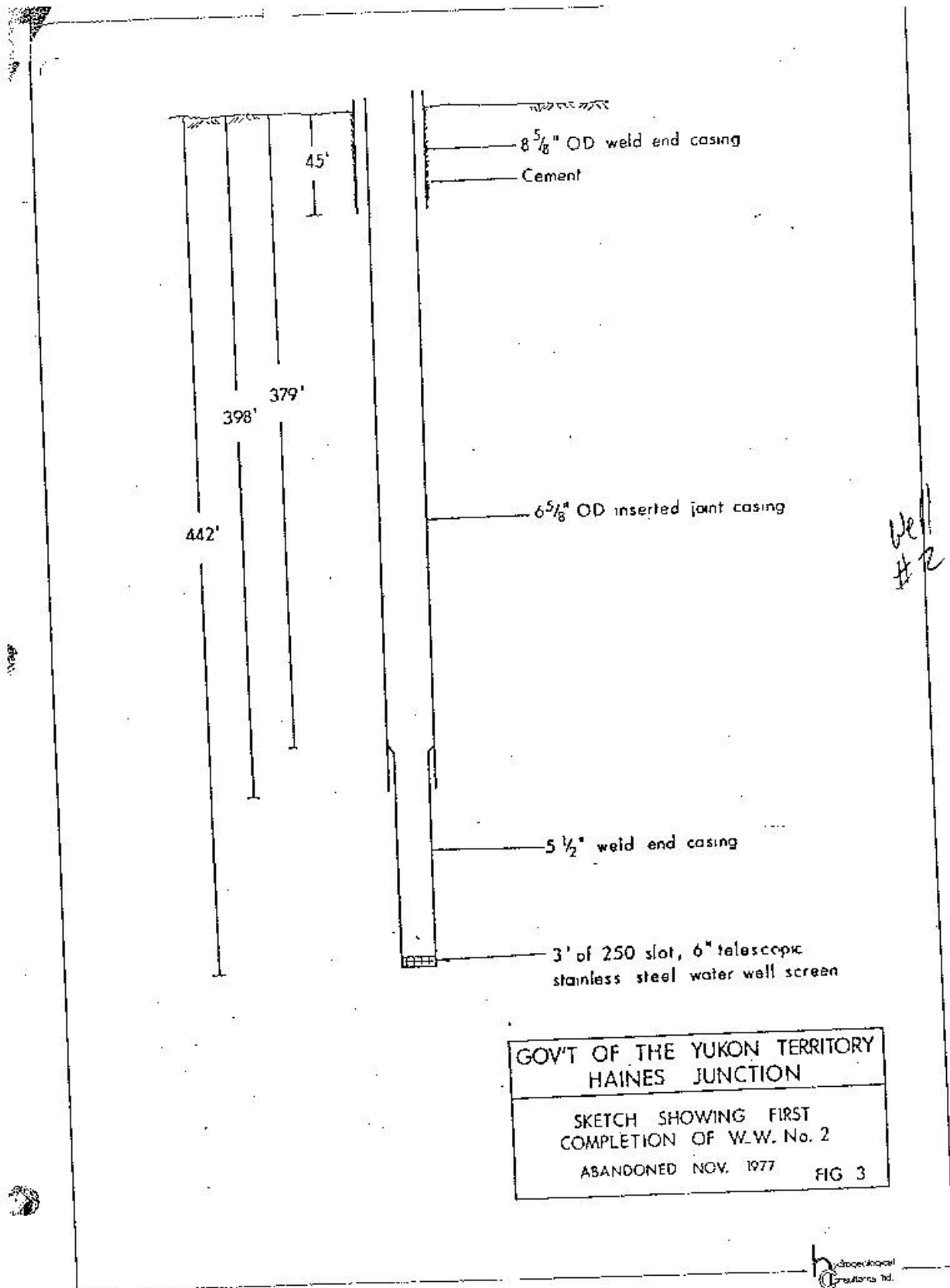
MIDNIGHT SUN.....
TITLE.....

CLIENT.....
TITLE.....

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

A-1

HAINES JUNCTION,
YUKON TERRITORY

WATER WELL No. 2

Driller's Litholog

Depth in feet	Lithologic Description
0 - 1	gravel
1 - 11	clay
11 - 14	gravel
14 - 28	gravel and clay
28 - 69	till with coarse gravel and cobbles
69 - 129	clay till with some gravel
129 - 210	clay silt with some gravel
210 - 359	clay till with gravel and cobbles
359 - 374	silt with some gravel
374 - 388	till, gravelly
388 - 399	sandy silt, some gravel
399 - 437	gravelly till
437 - 441	gravel

Well
#2

45 feet of 8 5/8-inch O.D. casing - cemented
251.4 feet of 6 5/8-inch O.D. inserted joint casing
60.1 feet of 5 1/2-inch O.D. casing (including lead packer)
6.7 feet of 6-inch telescopic stainless steel water well screen
bottom of screen 257 feet.



Started May 28... 1980

Completed. J. Nov. 1, 1920

NAME AND ADDRESS OF CLIENT	DESCRIPTION OF WORK	LOCATION OF WORK
Stanley Egan	W L W	Hains Jct

FORMATION LOG			DESCRIPTION OF WORK	TIME			
FROM	TO	FORMATION		DATE	FROM	TO	HOURS
			MOVE				
2'	49	Gravelly till cobbles		May 30	8:00	8:00	12
2'	126	Clay Gr.					
1	144	Clay					
4'	176	Clay		May 31	9:00	10:00	13
6'	197	Clay Hard silt					
17	206	Hard silt					
26'	218	Hard silt same Gr.					
8'	235	Gravelly till					
5'	257	Coarse Gravelly till					
7'	273	Coarse Gr. fine sand					
2'	280	silty fine sand					
		pulled casing back to 270'					(1)

rd. of Casing & Pipe				Remarks:
Ze	Type	Size	Type	
	et	Inch	Feet	Inch
				STATIC LEVEL
				Total Rig Time 25 hrs.
				Ground level
				Total Standby hrs.
				Top of casing
				Drilling Mud sacks

MIDNIGHT SUN.....
 TITLE.....

CLIENT.....
TITLE.....

Pg 110



Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



FIELD REPORT

Started May 28, 1988

Completed June 1, 1988

NAME AND ADDRESS OF CLIENT	DESCRIPTION OF WORK	LOCATION OF WORK
Staley Eng.	W/U	Haines JCT. Toward Wm.

FORMATION LOG	TO	FORMATION	DESCRIPTION OF WORK	TIME			
				DATE	FROM	TO	HOURS
			MOVE				
			Tripping out	June 1	8:00	10:00	2
			setting screen	"	10:00	12:30	2.5
			Developing	"	12:30	5:00	4.5
			moving off	"	5:00	7:00	2
			Traveling	"	8:00	10:00	2

Well #3

Type of Casing & Pipe				Remarks:
Type	Size	Type		
6"	3"			Bottom of screen 270'
				5 1/2" bit pin
				2-5' 50 slot screens
				lead packer
				152 gpm
STATIC LEVEL				Total Rig Time 13 hrs.
Ground level				Total Standby hrs.
Top of casing				Drilling Mud sacks

SIGNATURES

MIDNIGHT SUN.....
J.E.....

CLIENT.....
TITLE.....

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Well #3
Warm Water Well #2 - Haines Junction Y.T.

Testhole Log

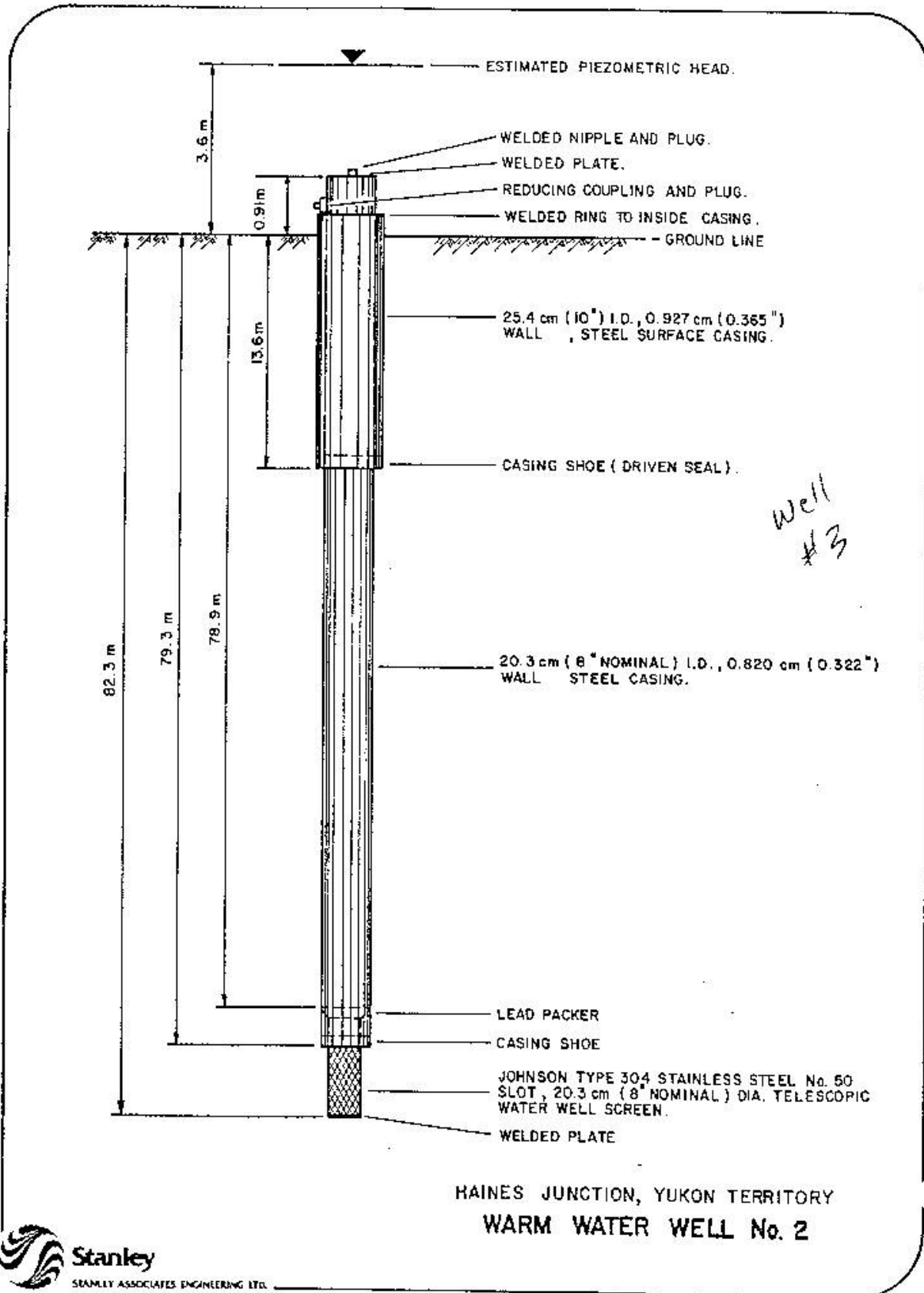
Drilling Dates: May 29 to May 31, 1980
Drilling Company: Midnight Sun Drilling Co. Ltd., Whitehorse, Yukon Territory
Location: 18.5 m west of Warm Water Well #1

<u>Depth (m)</u>	<u>Lithologic Description</u>
0.0 - 0.3	gravel
0.3 - 2.5	clay
2.4 - 6.0	gravel
6.0 - 7.3	clay
7.3 - 15.0	till, gravelly, grey, some cobbles
15.0 - 38.5	till, pebbly, grey
38.5 - 53.6	clay, grey
53.6 - 60.0	clay, and silt, interbedded, grey
60.0 - 63.0	silt, compact, grey
63.0 - 66.5	silt, compact, gravelly
66.5 - 71.5	till, grey, increasing gravel content with depth
71.5 - 78.4	gravel, coarse, angular, silty containing colluvial grey till and hard clay
78.4 - 83.2	gravel and coarse sand, some fine sand (aquifer)
83.2 - 85.3	sand, fine to medium, silty

Well
#3

14.1

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



Field Report

Completed.....19....

well
to

CLIENT.....

TITLE.....

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



PH. 633-3070 TELEX 036-8496
P.O. BOX 4391
WHITEHORSE, YUKON

Field Report

Started Sept. 4.....1989

Completed.....19....

NAME AND ADDRESS OF CLIENT		DESCRIPTION OF WORK	LOCATION OF WORK	
		W/U	Haines JCT.	
		89.10.27		

FORMATION LOG			DESCRIPTION OF WORK	TIME			
FROM	TO	FORMATION		DATE	FROM	TO	HOURS
			MOVE				
200	217	Gr.	sand silt	Sept. 10	8:00	11:30	15.5
17	237	clay					
237	338	wet	silt same Gr.				
338	395	Dry	silt clay				
395	400	Gr.	sand silt				
400	403	Till					
			trip out	Sept. 11	8:30	11:00	2.5
			cutting casing shoe off	"	11:00	9:30	10.5
			set screen	Sept. 12	8:00	1:00	5+
			Develop	"	1:00	8:00	7+
			started to clean at 6:00				
			Develop	Sept. 13	8:00	8:00	12+
			Develop	Sept. 14	8:00	12:00	4+
			move off	"	8:00	2:00	2+
			Travel to whse	"	2:30	5:00	2.5

L. d. of Casing & Pipe				UNLOAD	IGOR	Remarks:
Size	Type	Size	Type			
1-6"	std	5-8"	std			1-6" std shoe
3'	of	5-8"	std			3' of 5-8" stand pipe
5-8"	bit	pin				5-8" bit pin
50	slot					50 slot
8"	riser					8" riser
K	rock					K rock
70	GPM					70 GPM
Static Level				Total Rig Time		hrs.
Ground Level 82'				Total Standby		hrs.
Top Of Casing				Drilling Mud		sacks

Well #4

SIGNATURES

MIDNIGHT SUN.....

CLIENT.....

TITLE.....

TITLE.....

Extra Pages

DATE April 9/77



Field Report

Completed, Oct. 20, 1991

Well
#4



Field Report

Started. June 9.....1989

Completed... 24 Nov. 1964

Well
#4

MIDNIGHT SUN.....

CLIENT.....

TLE.....

TITLE.....

Field Report

Completed. 2.4.5.19.19.59.

Cell
44

CLIENT.....

TITLE.....

Field Report

Completed.....19...

Well
#4

CLIENT.....

TITLE.....

Field Report

#f Test hbl for 189 Started... May 3 1921
Completed May 9 1921

Well
#4

CLIENT.....

TITLE.....

Field Report

Completed. MAY. 9. 1989

Well #4

CLIENT.....

TITLE.....



Started... July 29... 1991

Completed. Feb. 31, 1971

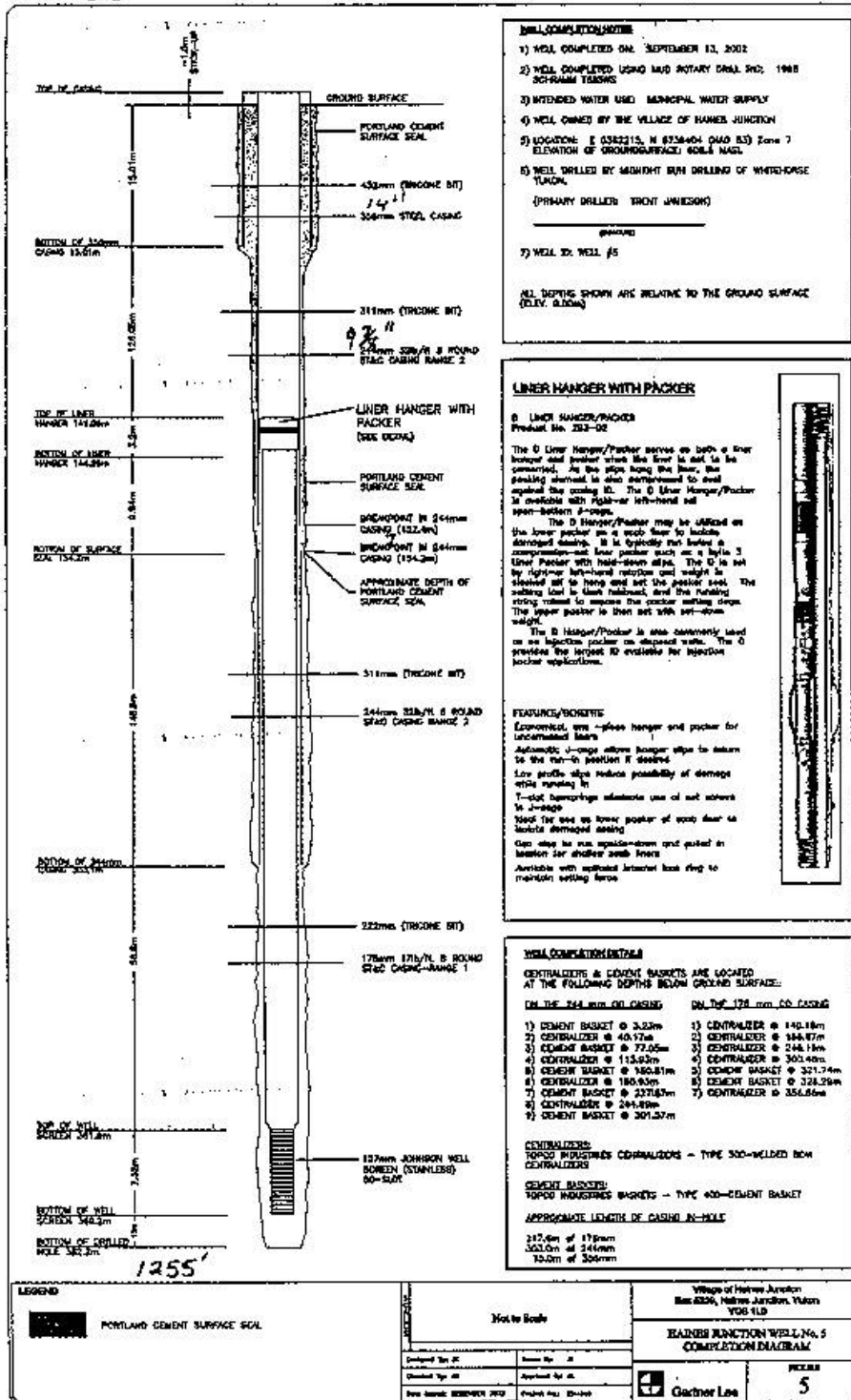
Well
#4

CLIENT.....
TITLE.....

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Flowing at P.M. 80
Temp: 15°C - 4 7/8" hole & installed 8 7/8" casing
to 20°C

Depth - 1255'

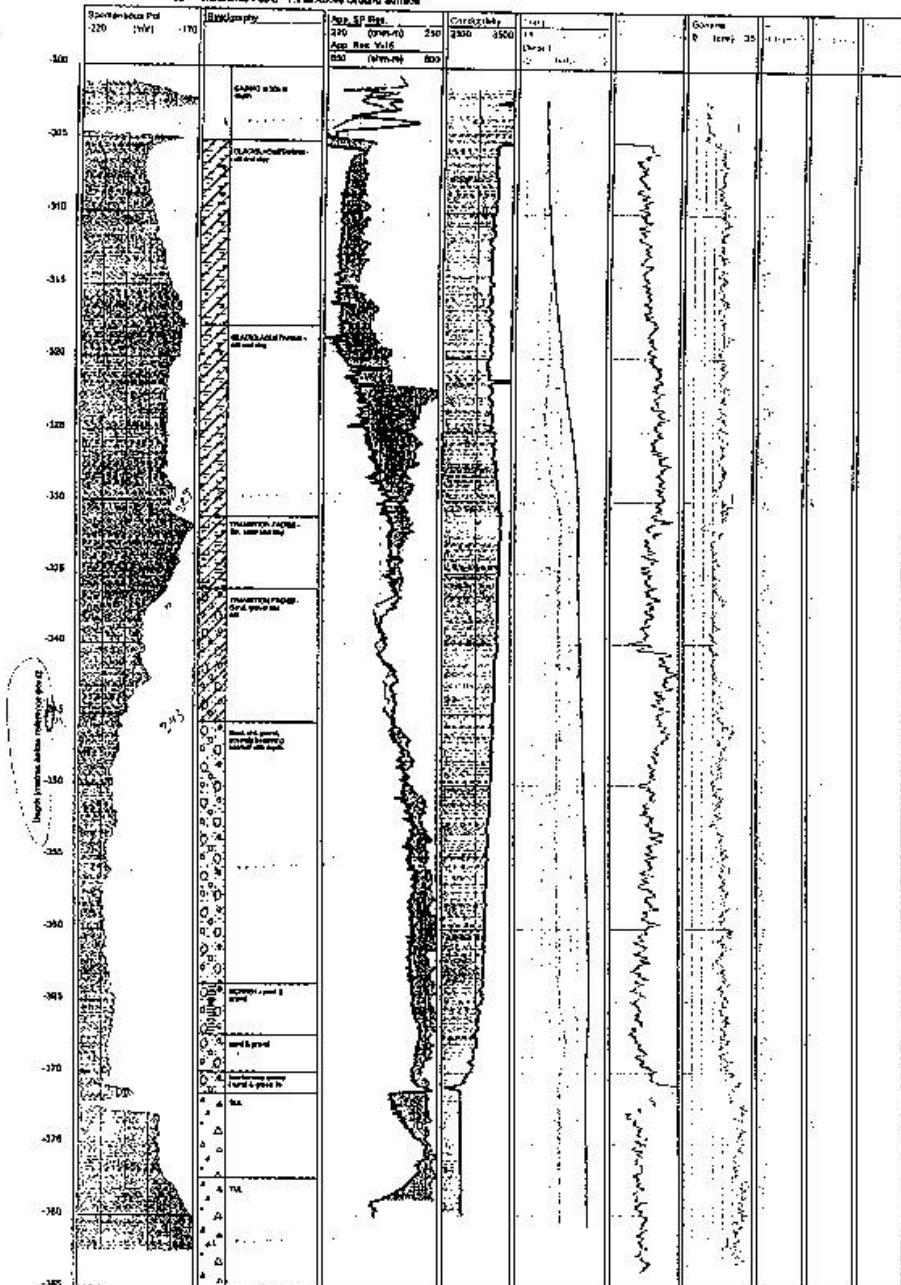


Well #5

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Figure 3. Geophysical and Borehole Log of Well No. 5
Location: Haines Junction, Yukon

Notes Logged By: Aurifer Geosciences Ltd., September 9, 2002. Log #3 & #4
Logging Tool: 875 Coda. BPO-02 Multi-parameter Probe
Log Prepared By: Gartner Lee Limited, 22-345
Well Location: 062255E 872640N, Zone 7 (NAD83)
Ground Elevation: 608.5 m ASL. Reference Point: 1.2 m Above Ground Surface



Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

indicated significantly lower resistivity in sections where the SP and gamma logs indicated possible clean and permeable beds. This suggested that any mud invasion the occurred after pumping the pill was minimal.

6. Temperature log: The temperature log generally repeated between runs. The maximum bottom hole temperature recorded was over 20 °C during the open hole down run.

The following is an interpretation of the log results based on discussions with Trent Jamieson and Jonathan Kerr. Interpreted depths are taken from the resistivity log.

Interval	Interpreted section	
305.7 - 331 m	Clay rich sand / silt	This section of the log is characterized by higher SP response, relatively higher gamma, lower SPR and 15" resistivity, higher conductivity and an increasing temperature gradient.
331.0 - 332.3 m	Permeable sand	Positive SP deflection, gamma decrease (strongest in SP log). Also weak and non-repeated conductivity decrease for 0.5 m in this interval. Section below this has lower gamma response. May correspond to noticeable decrease in sample clay content noted at sample logged at 329 m (GL1).
332.3 - 341.5 m	Sand or gravel	Lower gamma and conductivity response, increasing resistivity. SP response gradually declining. Slight increase in magnetic susceptibility at 340 m. Also note change in temperature gradient near 330 m which repeats in both logs. This appears to be a resistive sand lower in clay than overlying material (<330 m)
341.5 - 343.0 m	Permeable sand	Positive SP deflection, immediately above a small gamma increase (sand over clay seam). No appreciable change in resistivity.
343.0 - 345.0 m	Sand or gravel	Same response as 332.3 - 341.5
345.0 - 347.0 m	Dirty sand	Gamma response increases, suggesting possible minor increase in clay content.
347.0 - 370.0 m	Gravel	Gravel reported from drill samples in this interval. Subtle decrease in magnetic susceptibility towards base. Gamma response is flat to vary slightly increasing. Temperature increasing with a gradient similar to overlying sand. SP is flat and relatively negative with respect to surrounding strata. Resistivity increases towards base. Conductivity decreases towards base suggesting that the unit may coarsen towards the bottom.

Well #5

Haines Junction borehole logging report - page 6

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

370.0 - 373.0 m	Permeable gravel	Strong positive SP deflection. Positive magnetic susceptibility increase (?lag deposit of magnetic clasts?). Resistivity increases over this interval with a very weak 16" response and a repeated conductivity response which corroborates the resistivity. Gamma response begins to increase at the top of this unit and carries on into the overlying till layer. Temperature gradient changes from positive to negative over this interval suggesting possible inflow of cold water or change in thermal conductivity
373.0 - 384.6 m	Glacial till	Marked change in SP response. Increase in gamma response suggesting increase in clay content. 16" resistivity appears to decline over this interval; conductivity does not repeat in this interval. Clay rich glacial till with subangular clasts was recovered from a sample at 378.9 m and similar material was recovered from the temperature probe casing at the base of the logging tool.

It should be stressed that the geophysical log responses are not strong enough to independently estimate overburden composition.

e. Conclusions. The bore hole log results suggest the following conclusions:

1. The drill hole appears to have intersected a sequence of gravel and sand in the interval from 331 to 373 m.
2. There appears to be three zones which are more permeable than the remainder of the section. The lowest interval, from 370 - 373 m appears to be the thickest and displayed the strongest indication of permeability.
3. The warmest water in the drill hole appears to originate from 331 - 370 m.

Respectfully submitted,
AURORA GEOSCIENCES LTD.



Haines Junction borehole logging report - page 7

APPENDIX C

PUMP AND EQUIPMENT SPECIFICATIONS

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

March 7, 2003

EBA Engineering Consultants Ltd.
Calcite Business Centre Unit 6
151 Industrial Road,
Whitehorse, Yukon Y1A 2Z7

Attention: Ryan Martin

Re: Cost Quotation for Well Testing at Haines Junction Well Sites

Please find enclosed our price quotation for the proposed water well work at Haines Junction. I'm enclosing the pump curve for the pump we propose to use for this work. I was not able to secure a rental pump. As I have to purchase the pump for this job and have no leads for the sale or future rentals for this pump, the cost has to be born by the client. The village may well want to purchase the unit upon completion of the work. We would credit 80% of the rental fee for the pump towards the purchase thereof.

As discussed with you my hourly rate for consulting services is \$65.00 per hour, based on time spent from shop to shop.

The cost of the work follows:

Mobilization - Demobilization	\$ 4240.00
Installation & Removal of Test Pumps	\$ 5210.00
Conduct 76 Hour Constant Rate Test	\$ 18300.00
Conduct 14 Day Constant Rate Test	\$ 44940.00

I hope this information is helpful in your evaluation of the project costs.

AQUA TECH SUPPLIES & SERVICES LTD.

Per:

Bert Albisser
Bert Albisser

* Note pump cost ~ \$ 8,500

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

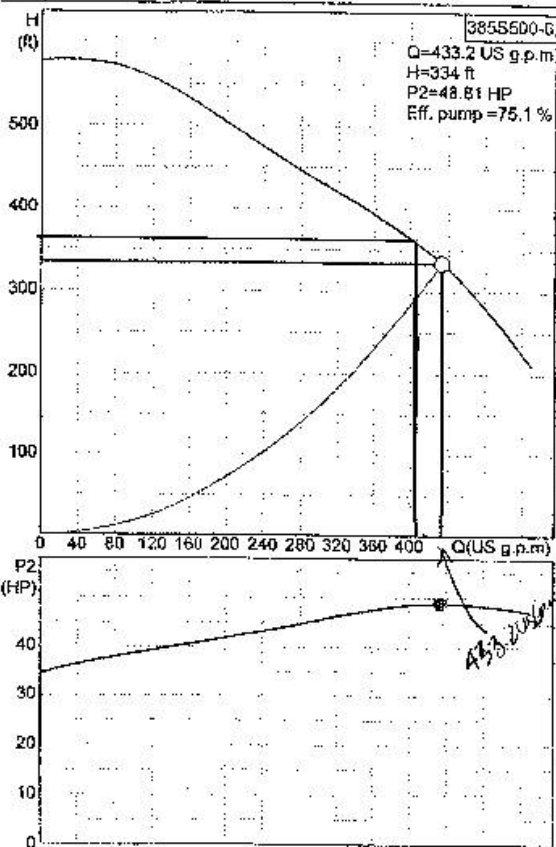


Phone: 867-668-5544
Fax: 867-668-7182
Date: 3/6/2003
Created by: Bert Albisser

Project: HJEBATEST
Reference Number:
Position: 1.0

Client: EBA ENGINEERING
Client Number: EBA
Contact: RYAN MARTIN

Description	Value
Product No	16873506
Product name	385S500-6
Pump No	16870006
Motor No	823229F
Stages	6 No of
Start. method	DOL
Motor diameter	6"
P2	50 HP
Phase	3
U	480 V
Rated current	67.7 A
Service factor	1.15
I start	414 A
n	3450 rpm
Eff. 1/1	82.5 %
f	60 Hz
Rated flow	384.8 US g.p.m
Rated head	374 ft
Model	C
Motor type	Super - 6"
Impeller	Stainless steel
	1.4301 DIN W.-Nr.
	304 AISI
Sales region	Namreg
Cos phi	0.85
Motor protec	None
Thermal protec	External
Pump outlet	4" NPT
Max flow	526.7 US g.p.m
I max	77 A
Pump	Stainless steel
Motor	Stainless steel
	1.4301 DIN W.-Nr.
	304 AISI
Pump	1.4301 DIN W.-Nr.
	304 AISI
Axial load max	6014 lb
Applic. motor	Franklin
Valve	Y
Borehole	6" mm
Min flow	52.8 US g.p.m
KVA code	H
Standard	200 A
Delay	90 A
Starter	3
Heather	K83



Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

03/07/03 PRT 10129 PAA 867668/182

Aqua Tech

003



Phone: 867-668-5544
Fax: 867-668-7182
Date: 3/6/2003
Created by: Bert Albisser

Position	Count	Description	Single Price
1.0	1	385S500-6 Product No.: 16B73606 Multi-stage submersible pump for raw water supply, groundwater lowering and pressure boosting. The pump is suitable for pumping clean, thin, non-aggressive liquids without solid particles or fibres. The pump is made entirely of Stainless steel DIN W.-Nr. 1.4301 DIN W.-Nr. and suitable for horizontal as well as vertical installation. The pump is fitted with a built-in non-return valve. The motor is a 3-phase motor of the canned type with sand shield, liquid-lubricated bearings and pressure equalizing diaphragm. Liquid: Max liquid t at 0.05 m/sec: 36 deg F Technical: Rated flow: 384.8 US g.p.m Rated head: 374 ft Materials: Material, pump: Stainless steel 1.4301 DIN W.-Nr. 304 AISI Material, impeller: Stainless steel 1.4301 DIN W.-Nr. 304 AISI Material, motor: Stainless steel 1.4301 DIN W.-Nr. 304 AISI Installation: Size, pump outlet: 4" NPT Motor diameter: 6" " Minimum borehole diameter: 8" mm Electrical data: Motor type: Super - 6" Rated power (P2): 50 HP Mains frequency: 60 Hz Rated voltage: 3 x 460 V Starting method: DOL Start method: DOL Rated current: 67.7 A Service factor: 1.15 Rated current: 77 A Starting current: 414 A Cos phi - power factor: 0.85 Rated speed: 3450 rpm Full load motor efficiency: 82.5 %	Price on request

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

05/07/03 PK1 19:29 FAX 8676687182

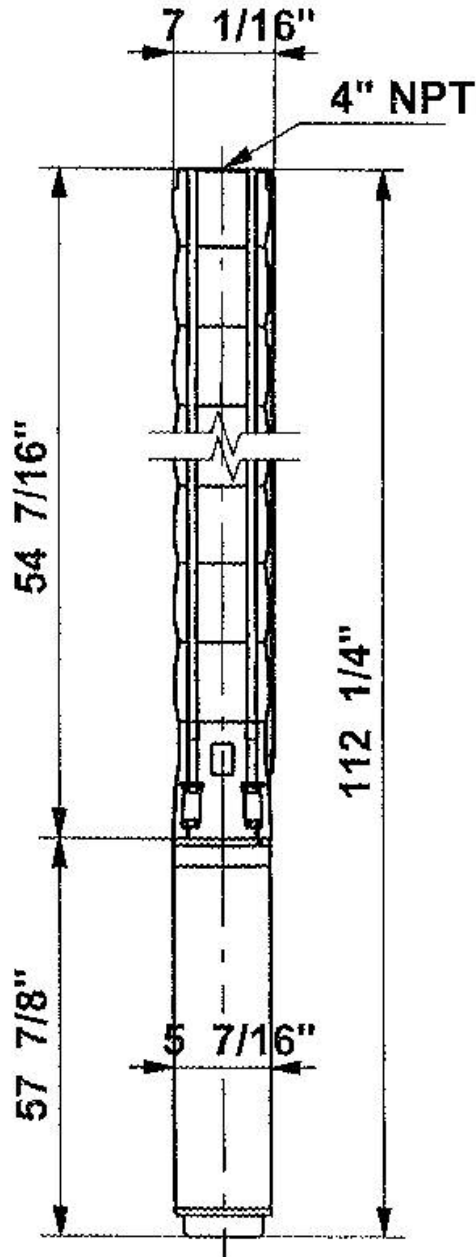
Aqua Tech

004



Phone: 867-668-5544
Fax: 867-668-7182
Date: 3/6/2003
Created by: Bert Albisser

16B73606 385S500-6



Note: All units are in (mm) unless others are stated.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Oct 21 03 12:01p

Bert Albisser

1-867-668-7182

p. 1

123 Copper Road
Whitehorse, Yukon
Y1A 2Z7

Ryan Martin
Project Engineer
EBA
Whitehorse

Dear Ryan Martin:

Re: Equipment Specs for Haines Junction Pump Test

1. Enclosed specifications for FQ11 First Rate Flow Totalizer
2. Calibration Date for the 4" Haliburton Turbine, the repair kit was installed approximately 4 years ago. These kits come calibrated. The K factor for this turbine is 35.77 pulses per imp. gallon
3. Flow Meter Totalizer precision is 0.25% plus/minus. Turbine precision is 1.0% plus/minus
4. The 4" turbine is fitted with 36" of straight pipe on either side of the turbine. The manufacturers recommendation is 5 pipe diameters
5. No information available on temperature gauge
6. No specification is available on pressure gauge.

Bert Albisser

Enclosures



Aqua Tech Supplies & Services
123 Copper Road
Whitehorse, YT Y1A 2Z7
(867) 668-5544 Fax (867) 668-7182
"Your Water Doctor"

Part No. 458.80001

INSTALLATION AND MAINTENANCE INSTRUCTIONS HALLIBURTON TURBINE TYPE FLOW METER

Part No. 458.80001

The calibration tag for each flow meter designating pulses per gallon observed during factory calibration, is attached to the magnetic pickup conduit adapter. This factor is also listed on the packing list (MT). In the event this information is lost or misplaced, the original calibration factor can be obtained from Halliburton Services, Special Products Division, Duncan, Oklahoma. Please supply the flow meter serial number when requesting this information.

**HALLIBURTON SERVICES
SPECIAL PRODUCTS DIVISION
DUNCAN, OKLAHOMA**

**405-251-3442
FAX# 405-251-2154**

PRINCIPLE OF OPERATION:

The Halliburton Turbine Flow Meter is a rugged versatile instrument capable of handling a wide variety of liquids including many types of slurries and suspensions. The Flow Meter contains a rotor secured to a tungsten carbide shaft. The shaft is supported at each end in tungsten carbide bearings. The rotor is made of a magnetic material, while the flow meter body is non-magnetic. A magnetic pickup consisting of a magnet and coil is mounted externally in the body in the same plane as the rotor. Fluid moving through the Flow Meter causes the rotor to rotate at a speed proportional to the fluid velocity. The rotor blades cutting the magnetic field in the vicinity of the magnetic pickup generate a frequency signal proportional to the fluid velocity. This signal is used to represent flow rate and can be accumulated to totalize the volume of liquid passing through the Flow Meter.

Each Flow Meter is calibrated to insure accuracy over the entire recommended flow rate range. Meters are furnished with a calibration factor representing the number of pulses per gallon produced. This information is supplied with the precalibrated rotor and vane kits available for field replacement. Meter and kits are available in either industrial grade with an accuracy of $\pm 0.5\%$ or standard grade with an accuracy of $\pm 1.0\%$.

INSTALLATION:

The Halliburton Turbine Flow Meter may be installed either vertically or horizontally. The direction of flow should correspond to the arrow that appears on the outside of the housing. A minimum straight section with a length of five pipe diameters of the same size as the flow meter is required both upstream and downstream of the meter.

The following precautions should be observed during the installation and operation of the Flow Meter:

1. Clean all upstream lines before installing the Flow Meter.
2. Do not blow out lines with compressed air or gas.
3. Do not slug the Flow Meter with fluid. Initial filling of line with fluid should be done with care.
4. Do not exceed maximum recommended flow rate through the Flow Meter.
5. Avoid hammer blows or other sharp impacts on the Flow Meter; it may break the shaft.
6. The magnetic pickup should be installed per drawing SPI-2B-1830 (Fig. 2). If vibration is present, the locknut should be tightened. A $\frac{3}{4}$ " 12 point deep socket wrench is required. (Part No. 70.60902)

CAUTION:

ALWAYS REASSEMBLE VANE WITH
THE REFERENCE NOTCH IN GROOVE

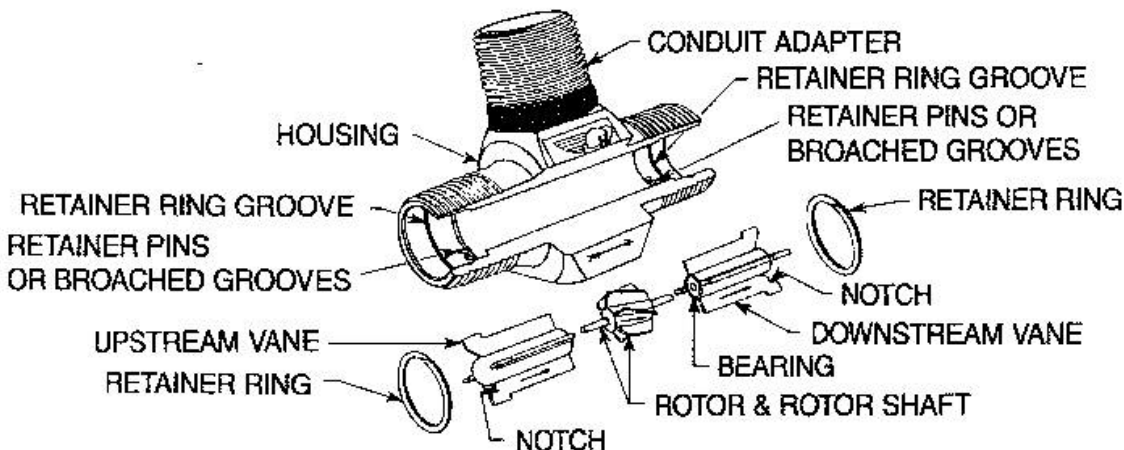


Figure 1

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Oct 21 03 12:01p Bert Albisser

1-867-668-7182

p. 4

SEP 25 '98 11:16AM BARTON INSTRUMENT SYSTEMS
2.0 SPECIFICATIONS

Table 2.1 - Specifications

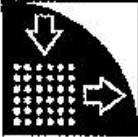
Signal Input	FREQ terminals: 1.0 Hz to 3 kHz Sensitivity: 1 to 80 Hz: 40mV p p min. over 80 Hz: declines at about 6dB/octave CNCT terminals: 1.0 Hz to 20 Hz (voltage free contact inputs) max. allowable contact bounce time: 8 msec
Power Supply	Six 1.5 Vdc "AA" Alkaline cells Battery Life: 1 Year (Alkaline cells) 10 years shelf life, or Two 3.6 to 3.9 Vdc "AA" Lithium cells *, or Six 1.2 Vdc "AA" Nickel-Cadmium rechargeable cells, or External 11.35Vdc with "3W" output option
Temperature	with Alkaline Batteries: -20 to +54 Deg C (Operating and Storage) with Lithium Batteries: -40 to +60 Deg C (Operating) -40 to +82 Deg C (Storage)
Weight	1 Kg (2.2 Lb) without standoff
Dimensions	215mm W x 115 mm D x 145 mm H (8.5" x 4.5" x 5.7")
Display	1/2" high contrast LCD, 8 digit total or 5 digit flowrate
Enclosure	Rugged Polycarbonate/PET blend
Test frequency	21.787 Hz
Accuracy	Total: ± 1 count K factor: 6 digits (including up to 2 decimal places) Flowrate: $\pm 0.25\%$
Options:	
Remote Transformer	for Cable lengths: 4 to 100 ft, FREQ input: 20 Hz to 3 kHz (no CNCT input available)
Pulse Output	Open drain MOSFET (electronic switch) Contact closure time: fixed at 23 ms "Pi" Pulse Interval: programmable from 1 to 255 Flow Total increments Rating: 40 Vdc max., 100mA max. Maximum count rate: 14 Hz, 255 count overflow buffer
Sampler Output	Open drain MOSFET (electronic switch) Contact closure time: programmable as Sampling Pulse Width 1 to 99999 msec rounded to nearest 23 msec interval "Si" Sampling Interval: programmable from 1 to 99999 Rating: 40 Vdc max., 100mA max. Maximum count rate: 5 Hz, 255 count overflow buffer
4-20 mA output	Lift-off Voltage: 8.5V max. Voltage drop across barrier return channel: 2.4V max. Maximum Loop Resistance (barrier, load and cable): 655 Ω @ 24Vdc Calibration Range: 80 Hz min. span, 15 Hz max. elevation 3500 Hz max. span, 700 Hz max. elevation

* Any item containing Lithium must be handled, stored, and shipped in compliance to the Seventeenth Revision (September 15, 1987) of DOT-E 7052 and Transportation Code of Federal Regulations 49 (1985).

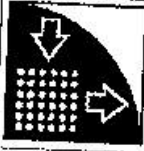
APPENDIX D

PUMP TEST DATA

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

 Waterloo Hydrogeologic, Inc. 180 Columbia St. Unit 1104 Waterloo, Ontario, Phone: +1 519 746		Data	
		Project:	Haines Junction Well 5
		No:	1240049
		Client:	Lessoway Moir Partners
Location: Haines Junction, Yukon		Pumping test:	Well No. 5 Entire step &
		Pumping well:	well 5
Test performed by: Ryan Martin			
at: 20/08/03			
Data observed at:		Depth to static WL: -56.8	
Distance from pumping well: 0 [m]			
	Time [s]	Depth to WL [m]	Drawdown [m]
1	120	20.04	76.84
2	150	23.05	79.85
3	180	25.57	82.37
4	210	27.60	84.40
5	240	29.17	85.97
6	270	30.07	86.87
7	300	32.55	89.35
8	360	35.13	91.93
9	420	36.91	93.71
10	480	37.95	94.75
11	540	38.92	95.72
12	600	39.74	96.54
13	720	40.85	97.65
14	840	41.33	98.13
15	960	41.53	98.33
16	1080	41.64	98.44
17	1200	41.69	98.49
18	1500	41.72	98.52
19	1800	41.85	98.65
20	2100	41.86	98.66
21	2400	41.88	98.68
22	2760	41.94	98.74
23	3000	42.04	98.84
24	3300	42.08	98.88
25	3600	42.15	98.94
26	3660	44.90	101.70
27	3720	49.83	106.63
28	3780	55.65	112.45
29	3840	55.65	112.45
30	3870	56.10	112.90
31	3900	56.70	113.50
32	3960	57.45	114.25
33	4020	57.90	114.70
34	4080	58.61	115.41
35	4140	59.35	116.15

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

 Waterloo Hydrogeologic, Inc. 180 Columbia St. Unit 1104 Waterloo, Ontario, Phone: +1 519 748		Data Project: Haines Junction Well 5 No: 1240049 Client: Lessoway Moir Partners		Page 2
Location: Haines Junction, Yukon		Pumping test: Well No. 5 Entire step &		Pumping well: well 5
Test performed Ryan Martin				
at 20/08/03				
Data observed at:		Depth to static WL: -56.8		
Distance from pumping well: 0 [m]				
	Time [s]	Depth to WL [m]	Drawdown [m]	
36	4200	59.71	116.51	
37	4320	60.02	116.82	
38	4440	60.17	116.97	
39	4560	60.25	117.05	
40	4680	60.33	117.13	
41	4800	61.43	118.23	
42	5100	61.46	118.26	
43	5400	61.47	118.27	
44	5700	61.29	118.09	
45	6000	61.36	118.16	
46	6660	61.45	118.25	
47	6900	61.48	118.28	
48	7200	61.43	118.22	
49	7320	61.45	118.25	
50	7350	65.22	122.02	
51	7380	67.69	124.49	
52	7410	69.30	126.10	
53	7440	70.52	127.32	
54	7500	72.55	129.35	
55	7560	73.75	130.55	
56	7620	74.54	131.34	
57	7680	75.80	132.40	
58	7740	76.50	133.30	
59	7800	77.02	133.82	
60	7880	77.21	134.01	
61	7920	77.31	134.11	
62	8040	77.40	134.20	
63	8160	77.49	134.20	
64	8280	77.41	134.21	
65	8700	76.99	133.79	
66	8820	77.12	133.92	
67	9120	77.17	133.97	
68	9600	77.19	133.99	
69	9960	77.04	133.84	
70	10020	77.05	133.84	

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

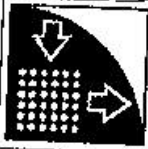
Waterloo Hydrogeologic, Inc.
180 Columbia St. Unit 1104
Waterloo, Ontario,
Phone: +1 519 748

Data
Project: Haines Junction Well 5
No: 1240049
Client: Lessoway Moir Partners
Page 3

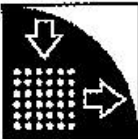
Location: Haines Junction, Yukon Pumping test: Well No. 5 Entire step & Pumping well: well 5
Test performed by: Ryan Martin
at: 20/08/03
Data observed at: Depth to static WL: -56.8
Distance from pumping well: 0 [m]

	Time [s]	Depth to WL [m]	Drawdown [m]
71	10320	76.83	133.63
72	10620	76.67	133.47
73	10920	76.66	133.45
74	11640	76.81	133.62
75	12120	76.84	133.64
76	12720	76.94	133.74
77	13320	76.89	133.69
78	13980	76.91	133.71
79	14640	76.87	133.67
80	18120	77.15	133.95
81	21720	77.00	133.80
82	25320	76.30	133.10
83	28920	76.62	133.42
84	32520	76.66	133.46
85	36120	77.35	134.15
86	39720	77.84	134.64
87	43320	77.67	134.47
88	46920	78.53	135.33
89	50520	78.83	135.43
90	54120	78.58	135.38
91	57720	78.88	135.68
92	61320	78.89	135.69
93	64920	78.75	135.55
94	68520	78.67	135.47
95	72120	78.38	135.18
96	75720	77.76	134.56
97	79320	77.70	134.50
98	82920	77.80	134.60
99	86520	78.50	135.30
100	90120	78.29	135.09
101	93720	79.10	135.90
102	97320	79.21	136.01
103	100920	79.26	136.06
104	104520	79.46	136.26
105	108120	82.19	138.99

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

 Waterloo Hydrogeologic, Inc. 180 Columbia St. Unit 1104 Waterloo, Ontario, Phone: +1 519 748		Data Project: Haines Junction Well 5 No: 1240049 Client: Lessoway Moir Partners	
		Page 4	
Location: Haines Junction, Yukon		Pumping test: Well No. 5 Entire step &	
Test performed: Ryan Martin at: 20/08/03		Pumping well: well 5	
Data observed at:		Depth to static WL: -56.8	
Distance from pumping well: 0 (m)			
	Time [s]	Depth to WL [m]	Drawdown [m]
106	111720	82.38	139.16
107	115320	82.89	139.69
108	118920	83.26	140.06
109	122520	83.46	140.26
110	126120	83.57	140.37
111	129720	83.79	140.59
112	133320	83.71	140.51
113	136920	84.11	140.91
114	140520	84.33	141.13
115	144120	84.30	141.10
116	147720	83.49	140.29
117	151320	83.30	140.09
118	154920	83.07	139.87
119	158520	83.06	139.86
120	162120	82.89	139.69
121	165720	82.90	139.70
122	169320	82.58	139.38
123	172920	82.41	139.21
124	176520	82.33	139.13
125	180120	82.07	138.87
126	183720	82.10	138.90
127	187320	81.98	138.78
128	190920	81.56	138.36
129	194520	81.86	138.66
130	198120	81.79	138.59
131	201720	82.06	138.86
132	205320	82.07	138.87
133	208920	82.46	139.26
134	212520	82.79	139.59

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

	Waterloo Hydrogeologic, Inc. 180 Columbia St. Unit 1104 Waterloo, Ontario, Phone: +1 519 746	Data Project: Haines Junction Well 5 No: 1240049 Page 1 Client: Lessoway Moir Partners	
	Location: Haines Junction, Yukon	Pumping test: Recovery Data	Pumping well: well 5
Test performed Ryan Martin at 21/08/03			
Data observed at:		Depth to static WL: 0 [m]	
Distance from pumping well: 0 [m]			
	Time [s]	Depth to WL [m]	Drawdown [m]
1	78420	7.03	7.03
2	89520	6.33	6.33
3	183120	4.57	4.57
4	194400	4.57	4.57
5	243480	4.22	4.22
6	328740	3.52	3.52
7	353280	3.16	3.16
8	510720	2.81	2.81
9	679080	2.11	2.11
10	765480	1.48	1.48

APPENDIX E

ANALYTICAL RESULTS

ALS Environmental



CHEMICAL ANALYSIS REPORT

Date: July 29, 2003

ALS File No. T1491

Report On: 1240049 Water Analysis

Report To: **EBA Engineering Consultants Ltd.**
Calcite Business Centre
Unit 6 - 151 Industrial Road
Whitehorse, YT
Y1A 2V3

**EBA Engineering
Consultants Ltd.**
WHITEHORSE

AUG 05 2003

RECEIVED

Attention: **Mr. Ryan Martin**

Received: July 15, 2003

ALS ENVIRONMENTAL

per:

Can Dang, B.Sc. - Project Chemist
Natasha Markovic-Mirovic, B.Sc. - Project Chemist

ALS CANADA LTD.
1888 Triumph Street, Vancouver, BC Canada V5L 1K5
Phone: 604-253-4188 Fax: 604-253-6700 Website: www.alsenviro.com

A Campbell Dresser Limited Company

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

REMARKS



The water as represented by the sample submitted met the Canadian Drinking Water Guidelines for all parameters analysed with the exception of pH which is limited for aesthetic purposes rather than health considerations. See the guidelines attached or contact ALS Environmental if you require any additional information.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

RESULTS OF ANALYSIS - Water



Sample ID	Well 5
Sample Date	03 07 12
Sample Time	16:00
ALS ID	7

Physical Tests

Colour	(CU)	<5
Conductivity	(uS/cm)	243
Total Dissolved Solids		178
Hardness	CaCO ₃	10.7
pH		8.78
Total Suspended Solids		<3
Turbidity	(NTU)	2.9

Dissolved Anions

Alkalinity-Total	CaCO ₃	115
Alkalinity-Bicarbonate	CaCO ₃	115
Alkalinity-Carbonate	CaCO ₃	<1
Chloride	Cl	<0.5
Fluoride	F	0.23
Sulphate	SO ₄	15

Nutrients

Nitrate Nitrogen	N	<0.1
Nitrite Nitrogen	N	<0.1

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except for pH, Colour (CU),
Conductivity (umhos/cm), and Turbidity (NTU).
< = Less than the detection limit indicated.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

RESULTS OF ANALYSIS - Water



Sample ID Well 5
Sample Date 03 07 12
Sample Time 16:00
ALS ID 1

Total Metals

Aluminum	T-Al	0.06
Antimony	T-Sb	<0.0005
Arsenic	T-As	0.021
Barium	T-Ba	0.03
Boron	T-B	<0.1
Cadmium	T-Cd	<0.0002
Calcium	T-Ca	3.5
Chromium	T-Cr	<0.002
Copper	T-Cu	<0.01
Iron	T-Fe	0.08
Lead	T-Pb	<0.001
Magnesium	T-Mg	0.4
Manganese	T-Mn	0.003
Mercury	T-Hg	<0.0002
Potassium	T-K	0.3
Selenium	T-Se	<0.001
Sodium	T-Na	57
Uranium	T-U	<0.0001
Zinc	T-Zn	<0.05

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except for pH, Colour (CU),
Conductivity (umhos/cm), and Turbidity (NTU).
< = Less than the detection limit indicated.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

RESULTS OF ANALYSIS - Water



Sample ID Well 5
Sample Date 03 07 12
Sample Time 16:00
ALS ID 1

Dissolved Metals

Aluminum	D-Al	0.01
Antimony	D-Sb	<0.0005
Arsenic	D-As	0.021
Barium	D-Ba	<0.02
Boron	D-B	<0.1
Cadmium	D-Cd	<0.0002
Calcium	D-Ca	3.4
Chromium	D-Cr	<0.002
Copper	D-Cu	<0.001
Iron	D-Fe	0.11
Lead	D-Pb	<0.001
Magnesium	D-Mg	0.4
Manganese	D-Mn	<0.002
Mercury	D-Hg	<0.0002
Potassium	D-K	0.3
Selenium	D-Se	<0.001
Sodium	D-Na	54
Uranium	D-U	<0.0001
Zinc	D-Zn	<0.05

Remarks regarding the analyses appear at the beginning of this report.
Results are expressed as milligrams per litre except for pH, Colour (CU),
Conductivity (umhos/cm), and Turbidity (NTU).
< = Less than the detection limit indicated.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

Appendix 1 - REGULATORY CRITERIA



Health Canada

Summary of Guidelines for Canadian Drinking Water Quality,
April 2002.
All limits are Maximum Acceptable Concentration (MAC) unless
otherwise indicated.
Limits expressed as milligrams per litre except pH, Turbidity,
Colour, and Bacteriological Tests.

		Lower Limit		Upper Limit		Notes
Physical Tests						
Colour	(CU)	-		15	CU	1
Total Dissolved Solids		-		500	mg/L	1
pH		6.5		8.5		1
Turbidity	(NTU)	-		5	NTU	1, 2
Dissolved Anions						
Chloride	Cl	-		250	mg/L	1
Fluoride	F	-		1.5	mg/L	
Sulphate	SO ₄	-		500	mg/L	1, 3
Nutrients						
Nitrate Nitrogen	N	-		10	mg/L	
Nitrite Nitrogen	N	-		1	mg/L	
Total Metals						
Antimony	T-Sb	-		0.006	mg/L	4, 5
Arsenic	T-As	-		0.025	mg/L	4
Barium	T-Ba	-		1	mg/L	
Boron	T-B	-		5	mg/L	4
Cadmium	T-Cd	-		0.005	mg/L	
Chromium	T-Cr	-		0.05	mg/L	
Copper	T-Cu	-		1	mg/L	1, 6
Iron	T-Fe	-		0.3	mg/L	1
Lead	T-Pb	-		0.01	mg/L	6, 5
Manganese	T-Mn	-		0.05	mg/L	1
Mercury	T-Hg	-		0.001	mg/L	
Selenium	T-Se	-		0.01	mg/L	
Sodium	T-Na	-		200	mg/L	1
Uranium	T-U	-		0.02	mg/L	4
Zinc	T-Zn	-		5	mg/L	1, 6

- 1 Aesthetic Objective (AO) (taste, odour, appearance, etc.)
- 2 1 NTU maximum allowed for water entering distribution systems.
- 3 There may be a laxative effect in some individuals when sulphate levels exceed 500 mg/L.
- 4 Interim Maximum Acceptable Concentration (IMAC)
- 5 First drawn water may be high, flush system before sampling.
- 6 At point of consumption.

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

File No. T1491

Appendix 1 - REGULATORY CRITERIA

Health Canada

Summary of Guidelines for Canadian Drinking Water Quality,
April 2002.
All limits are Maximum Acceptable Concentration (MAC) unless
otherwise indicated.
Limits expressed as milligrams per litre except pH, Turbidity,
Colour, and Bacteriological Tests.



		Lower Limit	Upper Limit		Notes
Dissolved Metals					
Antimony	D-Sb	-	0.006	mg/L	1, 2
Arsenic	D-As	-	0.025	mg/L	1
Barium	D-Ba	-	1	mg/L	
Boron	D-B	-	5	mg/L	1
Cadmium	D-Cd	-	0.005	mg/L	
Chromium	D-Cr	-	0.05	mg/L	
Copper	D-Cu	-	1	mg/L	3, 4
Iron	D-Fe	-	0.3	mg/L	3
Lead	D-Pb	-	0.01	mg/L	4, 2
Manganese	D-Mn	-	0.05	mg/L	3
Mercury	D-Hg	-	0.001	mg/L	
Selenium	D-Se	-	0.01	mg/L	
Sodium	D-Na	-	200	mg/L	3
Uranium	D-U	-	0.02	mg/L	1
Zinc	D-Zn	-	5	mg/L	3, 4

- 1 Interim Maximum Acceptable Concentration (IMAC)
2 First drawn water may be high, flush system before sampling.
3 Aesthetic Objective (AO) (taste, odour, appearance, etc.)
4 At point of consumption.

File No. T1491

Appendix 2 - METHODOLOGY



Outlines of the methodologies utilized for the analysis of the samples submitted are as follows

Colour in Water

This analysis is carried out using procedures adapted from APHA Method 2120 "Color". Colour (true colour) is determined by filtering a sample through a 0.45 micron membrane filter followed by analysis of the filtrate using the platinum-cobalt colourimetric method.

Recommended Holding Time:

Sample: 2 days

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Conductivity in Water

This analysis is carried out using procedures adapted from APHA Method 2510 "Conductivity". Conductivity is determined using a conductivity electrode.

Recommended Holding Time:

Sample: 28 days

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Solids in Water

This analysis is carried out using procedures adapted from APHA Method 2540 "Solids". Solids are determined gravimetrically. Total dissolved solids (TDS) and total suspended solids (TSS) are determined by filtering a sample through a glass fibre filter, TDS is determined by evaporating the filtrate to dryness at 180 degrees celsius, TSS is determined by drying the filter at 104 degrees celsius. Total solids are determined by evaporating a sample to dryness at 104 degrees celsius. Fixed and volatile solids are determined by igniting a dried sample residue at 550 degrees celsius.

Recommended Holding Time:

Sample: 7 days

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Conventional Parameters in Water

These analyses are carried out in accordance with procedures described in "Methods for Chemical Analysis of Water and Wastes" (USEPA), "Manual for the Chemical Analysis of Water, Wastewaters, Sediments and Biological Tissues" (BCMOE), and/or "Standard Methods for the Examination of Water and Wastewater" (APHA). Further details are available on request.

File No. T1491

Appendix 2 - METHODOLOGY - Continued



pH in Water

This analysis is carried out using procedures adapted from APHA Method 4500-H "pH Value". The pH is determined in the laboratory using a pH electrode.

Recommended Holding Time:

Sample: 2 hours

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Turbidity of Water

This analysis is carried out using procedures adapted from APHA Method 2130 "Turbidity". Turbidity is determined by the nephelometric method.

Recommended Holding Time:

Sample: 2 days

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Alkalinity in Water by Colourimetry

This analysis is carried out using procedures adapted from EPA Method 310.2 "Alkalinity". Total Alkalinity is determined using the methyl orange colourimetric method.

Recommended Holding Time:

Sample: 14 days

Reference: APHA

For more detail see ALS Environmental "Collection & Sampling Guide"

Dissolved Anions in Water by Ion Chromatography

This analysis is carried out using procedures adapted from APHA Method 4110 "Determination of Anions by Ion Chromatography" and EPA Method 300.0 "Determination of Inorganic Anions by Ion Chromatography". Anions are determined by filtering the sample through a 0.45 micron membrane filter and injecting the filtrate onto a Dionex IonPac AG17 anion exchange column with a hydroxide eluent stream. Anions routinely determined by this method include: bromide, chloride, fluoride, nitrate, nitrite and sulphate.

Recommended Holding Time:

Sample: 28 days (bromide, chloride, fluoride, sulphate)

Sample: 2 days (nitrate, nitrite)

Reference: APHA and EPA

For more detail see ALS Environmental "Collection & Sampling Guide"

File No. T1491

Appendix 2 - METHODOLOGY - Continued



Metals in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 20th Edition 1998 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedures may involve preliminary sample treatment by acid digestion, using either hotplate or microwave oven, or filtration (EPA Method 3005A). Instrumental analysis is by atomic absorption/emission spectrophotometry (EPA Method 7000 series), inductively coupled plasma - optical emission spectrophotometry (EPA Method 6010B), and/or inductively coupled plasma - mass spectrometry (EPA Method 6020).

Recommended Holding Time:

Sample:	6 months
Reference:	EPA
For more detail see:	ALS "Collection & Sampling Guide"

Mercury in Water

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" 20th Edition 1998 published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). The procedure involves a cold-oxidation of the acidified sample using bromine monochloride prior to reduction of the sample with stannous chloride. Instrumental analysis is by cold vapour atomic absorption and/or fluorescence spectrophotometry (EPA Method 7470A/7471A/245.7).

Recommended Holding Time:

Sample:	28 days
Reference:	EPA
For more detail see	ALS Environmental "Collection & Sampling Guide"

This Chemical Analysis Report shall only be reproduced in full, except with the written approval of ALS Environmental.

End of Report

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study



Department of
Earth Sciences
Faculty of Science

University of Waterloo
200 University Avenue West
Waterloo, Ontario, Canada
N2L 3G1

519-685-1211
Fax 519-746-7464

Environmental Isotope Lab
August 7, 2003

Mr. R. Martin
EBA Engineering Consultants Ltd.
Calcite Business Centre Unit 6
151 Industrial Road
Whitehorse Yukon Y1A 2V3

Dear Mr. Martin:

Enclosed please find the results of the testing done on the samples you submitted to our lab recently. I hope you are happy with them. As storage space here is scarce, we can keep these samples for two months (i.e. until October 7, 2003), after which time we will throw them out unless you have given us other instructions.

A bill for these analyses will arrive shortly.

Thank you for sending your samples to our lab.

Yours truly

A handwritten signature in cursive script, appearing to read "Mary Ellen Patton".

Mary Ellen Patton

Village of Haines Junction Geothermal District Heating
Resource Assessment for Heat Potential Study

Client: Martin
EBA Engineering

ISO# 2003451
Location: 1 - B
1 for 18O/2H/E3H
RUSH RUSH

Environmental Isotope Lab
2003-08-07
1 of 1

Sample	Lab#	18O	Result	Repeat	2H	Result	Repeat	E3H	Result
		SMOW							
Well 5 (July 12, 2003)	66179	X	-23.34	-23.22	X	-176.63	-177.93	X	<0.8 +/- 0.5

Tritium is reported in Tritium Units.

1TU = 3.149 Picocuries/L

1TU = 0.11815 Becquerels/L

To Contact EIL:
mepatton@uwaterloo.ca
or phone:
519 888 4732

Robert J. Drimmie
Laboratory Manager
rdrimmie@uwaterloo.ca
519 888 4567 ext 2580