HYDRO
THE POWER OF COMMITMENT

# THE Lower Churchill PROJECT

July 2008

# MF1260 - Assessment of Existing Pumpwell System

prepared by

HATCH™

in association with

RSW inc.

Statnett

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## Executive Summary

The purpose of this WTO was to determine the suitability of the pumpwell system installed in the north spur at the Muskrat Falls site with a view to a life extension of ten years. The review included an on-site inspection of the system to determine the present physical condition and operational characteristics.

In October 2007, an interim report was submitted which described the findings of a site visit during the period from September 9 to 11, 2007 and outlined the requirements of a field program to be undertaken in the autumn of 2007 to obtain additional information to aid in the assessment of the system.

From November 5 to 8, this field program was carried out to perform tests on pumps and piezometers. The dewatering system was shut down for 5 hours each day on November 7 and 8, and the water level recovery in wells and piezometer water elevation were recorded for half of the system each day. Information obtained from these visits was then compared with historical data from prior investigations to assess the performance of the pumpwell system and to determine the required action to allow the system to operate satisfactorily for the next ten years.

The dewatering system has operated continuously since November 1981 and there has been no further major landslide activity on the spur. The purpose of the installation has, therefore, been fulfilled. However, the system is currently 26 years old, and some rehabilitation work is required to ensure its continued operation for the next 10 years.

**Piezometers**

The originally installed piezometers were struck by lightning in 1983. The new standpipe piezometers, installed in 1997, are partially functional. Only 7 of the 10 suggested piezometers were installed and one of these (P-C) is out of order. The recommendations for piezometer upgrades can be categorized as follows:

- Installation of 4 new standpipe piezometers in the narrowest section of the spur (Figure 4):
    - One piezometer on the west of W-4
    - Two piezometers on both sides of W-9
    - One piezometer in the location of the previously proposed P-E
- Installation of data acquisition systems and automatic data transformation for all piezometers and selected wells including: W-2, W-4, W-9, W-13, W-19, and W-22. The specifications and a cost estimate for the instrumentation are provided in Appendix D.

Until such time as the system is automatic, recording of the piezometric elevations should be undertaken on a more frequent basis (e.g. monthly). There are few records in some years; in 2003, the piezometer elevations were recorded only two times, in 2005: three times, and in 2006: three times.

**Wells**

Three of the pumps (W-1, W-2, and W-22) have been decommissioned, and several of the remaining pumps operate less than 100 minutes per annum, while some wells are very active. The continued dependence of the dewatering system on only a few wells, W-4 in the South Block and W-9 and W-10 in Central Block, is not advisable. To maintain and improve the dewatering system at the current level, the following are recommended for immediate implementation (less than four months) and in the very near future (less than twelve months):

- The wells have been in continuous operation for 26 years, and based on an inspection of one well (W-4) in the November 2007 site visit which was seen to be discharging silt and fine sand (and the data of the 1994-1996 site activities) there is a need to repeat the flushing of the wells similar to the activities in 1996. Such flushing should be undertaken by a qualified company with experience in well drilling (immediate).
- It would be also appropriate to consider the use of a television camera to inspect the screen and confirm its integrity. The use of a down-hole test called a $\gamma$-$\gamma$ Test (Radiation Absorption or Density test) is also recommended to allow the inspection of possible voids behind and within the filter given the volume of fines which have passed through both since 1981 (immediate).
- Pumps should be installed in wells W-1, W-2, and W-22 (immediate).
- Until the installation of an automatic data acquisition system, the well water elevations and piezometers readings should be recorded and interpreted manually by plotting the phreatic surfaces in different sections of the spur (immediate).
- All pumps, risers and level sensors should be pulled, inspected and cleaned. All specifications and details of pumps, motors and sensor positions should be recorded and all sensors and relays tested (immediate).
- In order to achieve and maintain maximum lowering of the groundwater in the area, seven new wells should be installed in the very near future in three blocks to replace the existing system:
    - In the Southern Block, 2 wells, close to W-4 and place W-4 into a backup mode
    - In the Central Block, 3 wells, close to W-9, W-10, and W-11 and place W-9, W-10, and W-11 into a backup mode
    - In the Northern Block, 2 wells, close to W-18 and W-20 and place W-19 and W-20 into backup mode
- Consideration should be given to the installation of a flow monitoring device at the collector pipe outlet, the output from which could be transmitted to Goose Bay with pump function data (very near future).

**Electrical Supply**

From the SNC-Lavalin construction report, it was noted that the main 600 V AC line exiting the control shelter was divided into four runs of 600 V AC. The 600 V AC cable runs powered three groups of 6 motors and one group of 4 motors in series. The grouping of motors was not identified. Little is known about the power cables feeding the pumps. It is recommended that all electrical components from the control panel outward be tested to ensure the electrical infrastructure is not deteriorating.

Back-up power should also be provided in the event of a power outage. (While the WTO indicated a generator was on site for this purpose, this is not the case.)

**Data Monitoring and Transfer**

The data collected by Hydro for the pumps appears unreliable due to ON/ON and OFF/OFF sequences. The ON/OFF data originates from the pump level relay and is processed at the MF Control Shelter before being transmitted by VHF radio to Hydro's offices.

Hydro should investigate the cause of the troublesome data with a review of all overload relays and sensors. The remote terminal unit should undergo self testing. To ensure the data being collected is meaningful, a computer should be installed at the shelter to collect the data before transmission. This data would then be compared with the transmitted data to determine whether the errors are caused by the monitoring or the radio transmission components of the system. It is understood that the transmission components have been upgraded in recent years, and if it is concluded that they are still at fault, the following options for data transmission should then be explored:

- Satellite technology.
- Fibre optic/communications cable along the existing pole line to Goose Bay.
- Data transmission over existing power lines.
- Additional upgrades to VHF system.

**General Recommendations**

It is recommended that the following activities be carried out to assist with the ongoing dewatering operation:

- Implement procedures for responding to high-level alarms.
- Provide back-up pump and motor capability at site or at Hydro's facilities in Goose Bay.
- Clear trails to all piezometers (1997 and original standpipes) and weirs, and install safety hand lines as appropriate.
- Re-bury the exposed portion of the outfall pipe and re-grade the slope to prevent further erosion. Repair and/or replace the outfall heater.

# 1. Introduction

Newfoundland and Labrador Hydro (Hydro) is pursuing engineering studies with respect to the development of the hydroelectric potential of the Lower Churchill River at Gull Island and Muskrat Falls. These sites are located downstream 225 km and 285 km respectively from the Upper Churchill hydroelectric facility that was developed in the late 1960s. The total potential capacity at the two sites is approximately 2800 megawatts (MW), the Gull Island site being the larger. In addition to the development of these sites, the overall concept includes various potential transmission arrangements involving combinations of ac and dc lines of various capacities.

Early studies in the late 1970s concluded that the land spur which reaches from the north bank of the Churchill river at Muskrat Falls to the large rock knoll closer to the south bank could be incorporated with a natural embankment dam at this location. In this context the natural spur constituted a considerable capital asset, if it could be maintained. Natural mass wasting processes, however, were quickly eroding the spur but it was determined that these could be arrested with the installation of a pump well system. Such a system was installed in 1981.

The purpose of this WTO was to determine the suitability of the pumpwell system installed in the north spur at the Muskrat Falls site with a view to a life extension of ten years. The review included an on-site inspection of the system to determine the present physical condition and operational characteristics.

In October 2007, an interim report was submitted which described the findings of a site visit during the period from September 9 to 11, 2007 and outlined the requirements of a field program to be undertaken in the autumn of 2007 to obtain additional information to aid in the assessment of the system.

From November 5 to 8, this field program was carried out to perform tests on pumps and piezometers. The dewatering system was shut down for 5 hours each day on November 7 and 8, and the water level recovery in wells and piezometers water elevation were recorded for half of the system each day.

This document presents the findings of the assessment of the system from both field visits and makes recommendations for continued operation.

# 2. Historical and Geological Background

## 2.1 Site Characteristics

The site of Muskrat Falls on the lower Churchill River, located about 30 km upstream from Happy Valley/Goose Bay in Labrador (as shown in Figure 1) , has been recognized as a potential hydro electric development for several decades. At this site, the Churchill River has a drop of about 15 m from el 18 m at the upstream side to el 3 m at the downstream side. Past studies contemplated raising the head to about 40 m.

The prominent features of the site include a rock knoll rising to almost 150 m in elevation. The rock knoll is connected to the left bank by a spur of land about 1 km long, which forms a natural barrier forcing the diversion of the Churchill River into a channel carved out south of the rock knoll. The spur rises to elevation 60 m and has a minimum width of 150 m at the south side, in the upstream - downstream direction.

## 2.2 Geology and Sediments

The Muskrat Falls site is underlain at a maximum depth of about 270 m by crystalline metamorphic rocks composed of granitic gneiss of Precambrian age, with some dark mafic bands and occasional irregular pegmatite stringers. In addition to the rock knoll which rises sharply from the buried valley floor, several exposures are found on the right bank of the river.

The Churchill River valley is preglacial in origin, and was formed largely by river action prior to the Pleistocene epoch. Subsequent widening and reshaping of the valley occurred during the Wisconsin glaciation period, about 13 000 years ago. An estimated thickness of 60 m of a deposit of sand, gravel and boulders filled the lower part of the reshaped bedrock valley during the course of glaciation. As the glacier retreated, the sea level rose and caused submergence of the valley by an estuary extending up to Gull Island. This inundation of the valley by the rising sea resulted in the deposition of marine and estuarine sediments in an environment of saline and brackish water.

Isostatic rise of the land relative to the sea then caused a gradual recession of the estuary and resulted in the deposition of a layer of fine sand, over marine clay sediments.

The sediments in the spur consist of four units.

a) Upper Sand (el 60 to 45 m) covering the terrain and consisting of uniform fine to medium sand approximately 10 to 15 m thick.

b) Stratified Drift (el 50 to -10 m) consisting of a marine clay deposit generally underlain with a varying thickness of sandy materials. The sandy components dominate the southern 250 m long section of the spur against the rock knoll and constitutes an aquifer. The thickness of the upper clay increases toward the north.

   It is noted that primarily these two units in (a) and (b) are engaged in the failure activity of the downstream face of the spur.

c) Lower Marine Clay (el -10 to -60 m) is a stratified impervious silty clay deposit.

d) Lower Aquifer (el -70 to -210 m) composed of pervious sand and gravel, and occupying the lower part of the buried valley.

Gullies and creeks exist along both the upstream and downstream slopes of the spur. The most prominent gully is found in the area of the three lakes in the north side of the spur. Numerous creeks and a small stream were found originating as springs at the sand and clay contact.

Hydrogeologically, there are two aquifers. The water level in the Lower Aquifer is at el +5 m which is considerably higher than the surface of the overlying marine clay unit suggesting confined characteristics. However, it is the hydrogeologic behavior of the upper aquifer which has a dominant effect on bank stability. Recharge into this unit is from the northwest, through the upper sand unit and hydraulic connections in the stratified drift. Along the dewatering system alignment, the water level was originally at about el 30 m at the south side of the spur rising to el 47 m about half way and dropping to about 15 m at the north end.

## 2.3 Bank Instability and Groundwater Control Facilities

The banks of the Churchill River between Gull Island and Goose Bay are scarred by numerous landslides, some of which involve large quantities of overburden. Figure 2 shows an aerial site photo taken in 1988. A common characteristic of these slides, including those located inland, is that they are adjacent to a watercourse. In some instances where the failed mass has been transported by the erosive influence of water, as is the case on the downstream face of the spur, the scars left behind are rather steep. The destructive effect of erosion is most evident in the riverbed immediately downstream from the rapids. Erosion here is extensive and is caused by eddy currents emerging below the falls. Soundings indicate the presence of a local depression in the riverbed of the order of 70 m below river level adjacent to the rock knoll.

Instability has affected the slopes of the spur, particularly the downstream slope, as well as the left bank of the river downstream from the spur. In 1978, a major landslide occurred on the south end of the spur resulting in the loss of a considerable portion of land in the downstream perimeter. Minor failures were further experienced in 1980-81. High piezometric water levels and steep hydraulic gradients in the sediments above river level and tailwater rapid drawdown effects due to the collapse of the downstream ice-dam, have been the major causes contributing to instability.

In order to protect the remaining spur from further instability, a continuously pumped dewatering system was installed along the downstream shoulder of the spur in 1981. At the time of their installation, the system was considered to be "a temporary stabilization measure . . . and not a total defense against mass wasting", Acres (1994). The dewatering system was anticipated to lower the groundwater level in the spur from about el 30 m to at least el 15 m and preferably as low as el 3.5 m.

22 wells were installed in a line spaced at 30 m with an average depth of 63 m close to the edge of the downstream slope of the spur. The drilling diameter was 300 mm with a screen and PVC riser pipe having an internal diameter of 150 mm. All the pumps are connected to a 300 mm diameter collector pipe, with 75 mm of insulation, finally discharging to an existing stream through an exposed portion close to the outfall location. Two level limit switches were installed in each well above the electric submersible pump. The pumps originally were Berkeley model 4BL-2L with a 1.5 hp motor and 60 L/m capacity, but many pumps and/or motors have been subsequently replaced. The records of this equipment replacement are incomplete. On/off sequences of pumps are transmitted over VHF radio to

the Goose Bay office, over the 138-kV power line to Churchill Falls, and then via satellite to St. John's where the data is entered into the Hydro data base. A 25-kV power supply, tapped from the 138kV power line from Churchill Falls to Goose Bay, supplies the pumps. A full reporting of the construction and initial assessment of the system is presented in Report No 11.99.18, dated March 1982, by SNC-Lavalin Newfoundland.

To monitor the groundwater regime, 17 piezometers (vibrating wire) were installed in 1981 but all were lost in 1983 due to a power surge from a lightning strike on the power line. Figure 3 graphically depicts the location of the wells and the former group of piezometers (P-1 to P-17). The system began pumping in November 1981 and has continued essentially uninterrupted. After the power spike in 1983, the site recordings were decreased to pump function, i.e., pumping duration and the number of pumping cycle initiations during a 24-hr period.

In a report by Acres international (Report No. P10932, 1994), it was recommended that the wells be cleaned. Following this report, the wells were inspected, cleaned, and flushed in 1996. The detail of this operation is presented in Acres Report No. P11759.01, 1997. Also, seven manually monitored standpipe piezometers (A (2 tips), B (2 tips), C, D (2 tips), F (2 tips), G, J (2 tips)) were installed in 1997 and have been read subsequently. Report No. P11759.02, dated February 1998, presents the installation report of the piezometers. The recorded piezometers data for the last 10 years are plotted in Section 4.2.

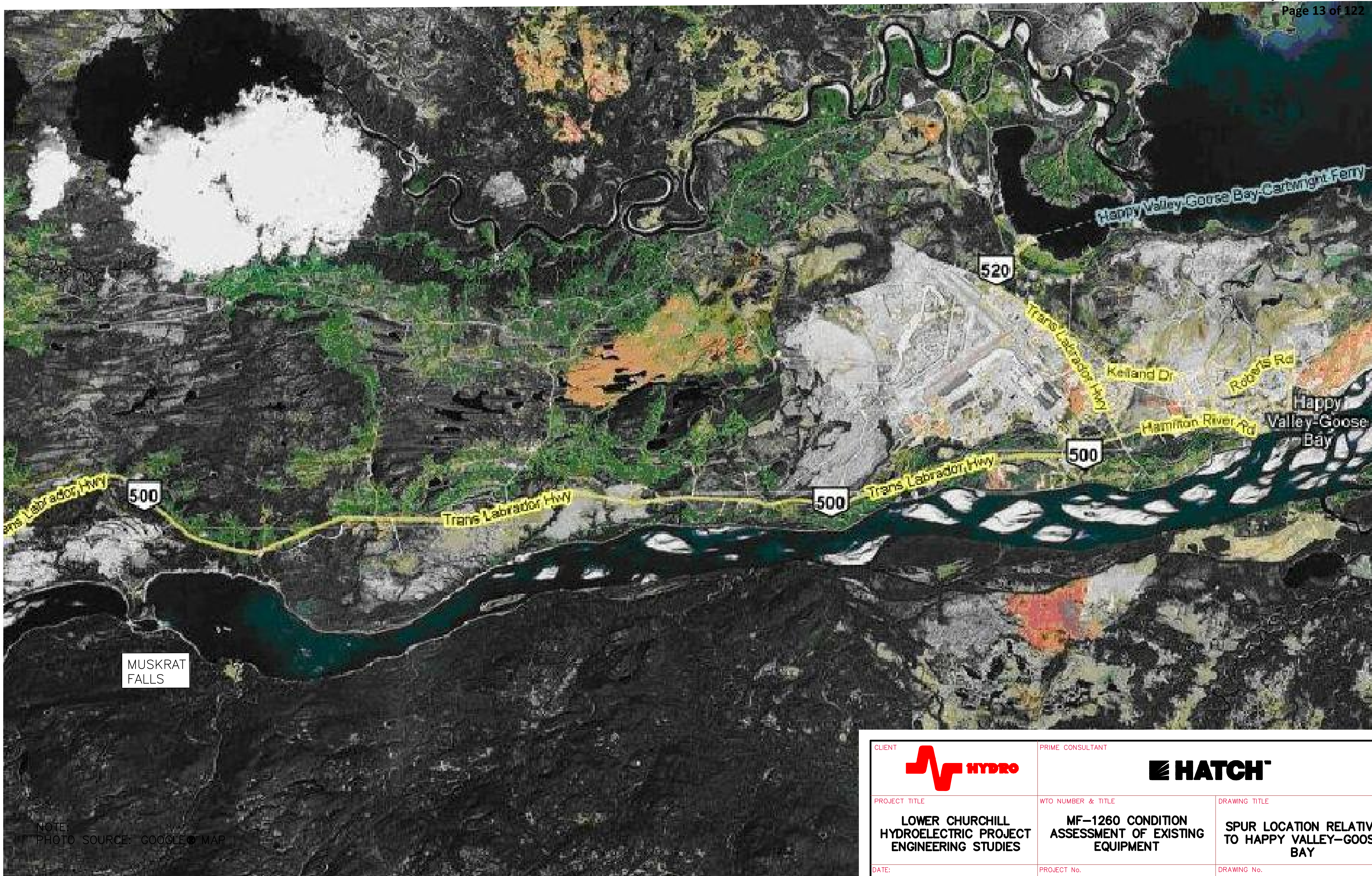
In 1997, 12 standpipe piezometers were installed in 7 boreholes and these continue to be monitored. Subsequent records of operation of the well system have recorded pump functions only, namely pumping duration and the number of pump cycle initiations per day.

Hydro staff carried out formal maintenance inspections in 1994, 1995 and in 1997 at which times and variously, some or all the pumps were retrieved, cleaned and reinstalled or replaced as necessary. The Hydro Goose Bay office retains records of such maintenance activities in varying degrees of detail.

## 2.4 Background Reports

Reports of previous site assessments are available as follows:

- SNC-Lavalin, "Muskrat Falls Dewatering System, Construction Report Operation and Maintenance Information", (1982);
- SNC-Lavalin, "Muskrat Falls Dewatering System, Engineering Assessment", (1982);
- Acres International, "Muskrat Falls Development", (1978);
- Acres International, "Muskrat Falls, Review of Dewatering System", (1994);
- Acres International, "Dewatering System Assessment and Rehabilitation", (1997); and
- Acres International, "Standpipe Piezometer installation Program Report", (1997 and 1998).

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| HYDRO | HATCH | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: SPUR LOCATION RELATIVE TO HAPPY VALLEY-GOOSE BAY |
| DATE: NOVEMBER 2007 | PROJECT No.: H325967 | DRAWING No.: FIGURE 1 |

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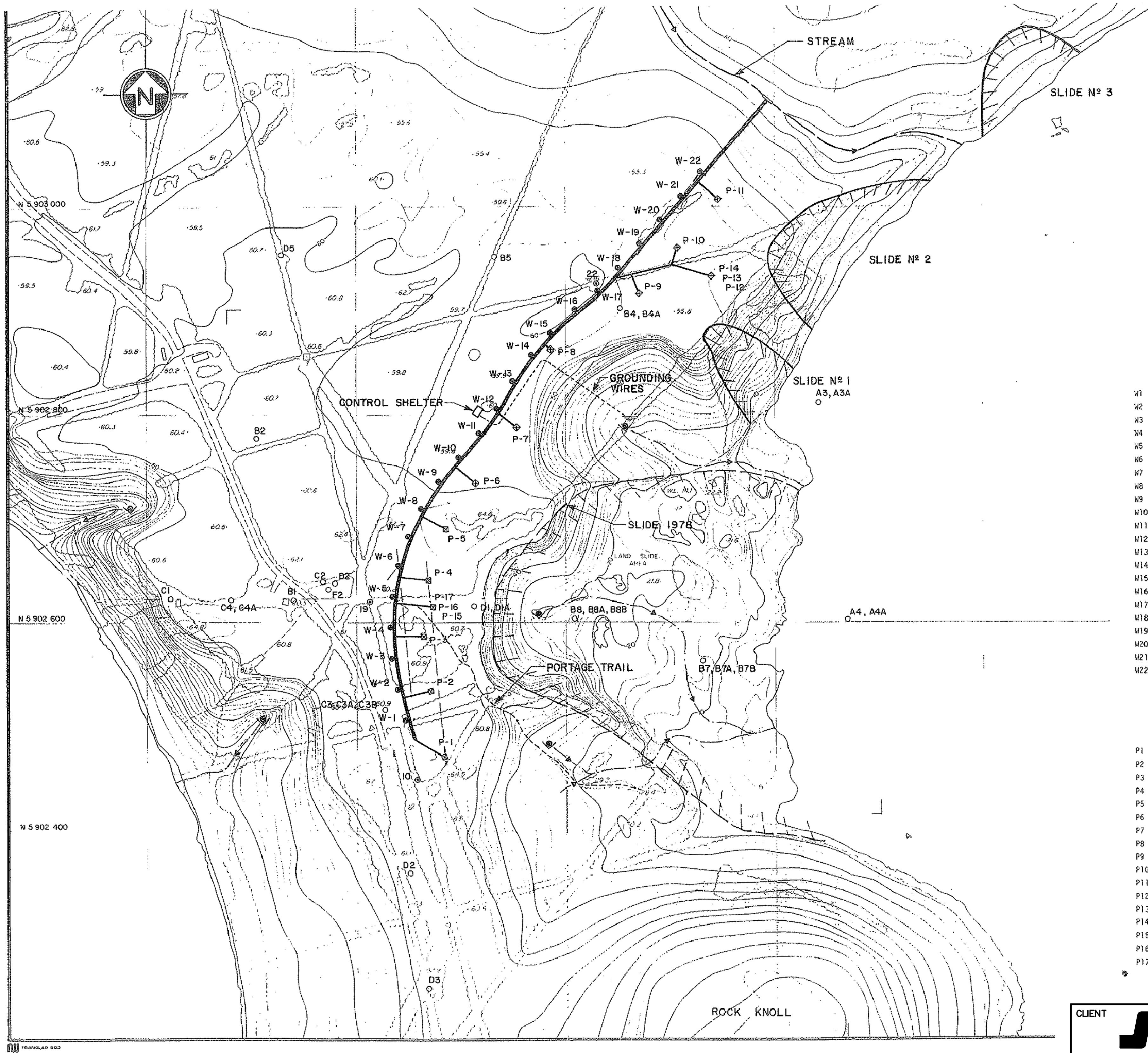
| PROJECT TITLE<br>LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE<br>MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE<br>AERIAL SITE PHOTO 1988 |
| DATE:<br>NOVEMBER 2007 | PROJECT No.<br>H325967 | DRAWING No.<br>FIGURE 2 |




## LEGEND

- ○ BOREHOLE (1979)
- W-1 PUMPING WELL (1981)
- P-1 PIEZOMETER (1981)
- 22 SURVEY STATION
- TRENCH FOR COLLECTOR PIPE AND CABLES
- SPRING
- RECENT LANDSLIDES (1980-1981)
- LANDSLIDE (1978)

## NOTE

FOR SECTIONS SEE PLATE 2

## WELLS

| | N | E |
|---|---|---|
| W1 | 5902 506.5 | 648 246.8 |
| W2 | 5902 535.8 | 648 239.7 |
| W3 | 5902 565.3 | 648 234.3 |
| W4 | 5902 595.2 | 648 232.7 |
| W5 | 5902 625.1 | 648 234.6 |
| W6 | 5902 654.5 | 648 240.3 |
| W7 | 5902 683.1 | 648 249.4 |
| W8 | 5902 710.3 | 648 262.0 |
| W9 | 5902 735.4 | 648 277.8 |
| W10 | 5902 759.2 | 648 296.5 |
| W11 | 5902 782.1 | 648 315.9 |
| W12 | 5902 806.1 | 648 333.3 |
| W13 | 5902 831.9 | 648 349.1 |
| W14 | 5902 857.8 | 648 367.2 |
| W15 | 5902 879.5 | 648 385.8 |
| W16 | 5902 901.9 | 648 408.5 |
| W17 | 5902 918.6 | 648 431.0 |
| W18 | 5902 942.4 | 648 451.6 |
| W19 | 5902 965.3 | 648 471.0 |
| W20 | 5902 988.2 | 648 490.3 |
| W21 | 5903 011.1 | 648 509.7 |
| W22 | 5903 034.0 | 648 529.1 |

## PIEZOMETERS

| | N | E |
|---|---|---|
| P1 | 5902 471.0 | 648 283.8 |
| P2 | 5902 533.2 | 648 271.2 |
| P3 | 5902 587.1 | 648 264.1 |
| P4 | 5902 639.5 | 648 269.3 |
| P5 | 5902 688.3 | 648 285.5 |
| P6 | 5902 732.9 | 648 313.5 |
| P7 | 5902 788.7 | 648 352.3 |
| P8 | 5902 862.5 | 648 384.0 |
| P9 | 5902 916.1 | 648 468.6 |
| P10 | 5902 961.9 | 648 507.4 |
| P11 | 5903 007.7 | 648 546.2 |
| P12 | 5902 932.2 | 648 542.2 |
| P13 | 5902 933.1 | 648 541.1 |
| P14 | 5902 934.1 | 648 539.8 |
| P15 | 5902 616.7 | 648 274.9 |
| P16 | 5902 616.8 | 648 273.8 |
| P17 | 5902 616.9 | 648 272.2 |

0 50 100 m

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| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: WELL AND PIEZOMETER LOCATION PLAN |
| DATE: NOVEMBER 2007 | PROJECT No.: H325967 | DRAWING No.: FIGURE 3 |

# 3. Site Visit Observations

Two site visits were performed for this assessment during September and November 2007. The first site inspection was carried out on September 10 and 11 by Hatch and Hydro representatives. The inspection included a tour of the well installations, the discharge point, the control building, slide area crest, the upstream toe area, and the piezometer locations. On September 10, a helicopter was used for aerial investigation of the spur and the downstream toe as well as to assist in a surface inspection of a portion of downstream toe.

After the first site visit, it was recommended that a second site visit be carried out to perform water level recovery tests on blocks of wells. Accordingly, the second site visit was made from November 5 to 8 by representatives of Hatch, Hydro and a local subcontractor, Minuskat Limited. The details of the tests and the related findings are presented in Section 3.2.

## 3.1 Site Observations – First Visit (September, 2007)

In order to methodically describe the site visit observations, the observations are divided into three sections: general pump operation, geotechnical, and electrical.

### *3.1.1 General Pump Operation*

- During the first site visit, it was observed that 19 submersible electric pumps were on automatic level control.
- Two pumps in Well 1 (W-1) and Well 2 (W-2), close to the narrowest spur section, were decommissioned prior to the 1996 Acres report.
- One pump in W-22 has been recently pulled out as it was found to be malfunctioning.
- The backup generator, as described in the WTO, does not exist.
- Hydro acknowledges anomalies in the data collection of on/off sequencing of the pumps.

### *3.1.2 Geotechnical Observations*

**Wells:**

- During the site visit, the existing pump in W-4 was removed and a new pump was installed by Hydro. The replacement started about 10 am (September 11) and the system returned back to operation around 1 pm.
- Silt and fine sand were produced from W4 (observed in discharged water, the pump riser, and the pump) which may have intensified after 4 months of operation with a weaker pump (0.5 hp pump instead of 1.5 hp).
- The discharge from W4 has been reduced significantly as a result of a weaker pump.
- Silt and fine sand were also produced in Wells 9 and 10.

**Piezometers:**

- Two piezometers, P-B and P-D, each with 2 tips, were read before system shutdown and all of the piezometers were read after the system restoration.
- Generally, the static water levels in the piezometers, before and after system shutdown, were consistent with the water levels read in the past 10 years.
- The water levels in the piezometers changed during interruption of the pumping operation (i.e. for the replacement of the pump in W-4) – the lower piezometer B, which was originally dry, showed a water level after 2.5 hours of the pumping shutdown – this piezometer is close to W-4 which has the most active pump.
- Piezometer C (P-C) has been out of order since March 2007 (riser pipe blockage) and has previously shown little response since installation.
- Three weirs which were recommended in 1997 were not seen – Hydro staff reported that they are accessible only with difficulty.
- Some of the piezometers from the original investigation program (A, B, and C series shown in Figure 3), which were accessible before in 1994 (Acres report), are no longer read or accessible.

**Spur Slopes:**

- Ongoing erosion and sloughing and active springs exist at the downstream toe of the spur.
- The upstream toe was also inspected and no significant erosion was observed.
- Access to the discharge point of the well system was difficult as the area was very overgrown.

**Well W4 Condition:**
Acres (1994) reported that W-4 is responsible for up to 85% of the total dewatering activity. During the first site visit, it was noted that the pump motor installed in W-4 for several months prior to the visit had a capacity of 0.5 hp. During the site visit, this motor was replaced with a 1.5 hp unit. Shortly after replacement of this pump and system restoration, the pump in W-3 went offline, while on the first day, in addition to the pump in W-4 being in operation, the pump in W-3 was also continuously operational. It is important to mention that after system restoration, W-4 also did not operate continuously. This is taken to mean that W-3, or other wells in the vicinity, can not act as a sufficient substitute for W-4 due to either high transmissivity in W-4 or low transmissivity in other adjacent wells, unless sufficient pump capacity exists in all pumps.

### *3.1.3 Electrical Observations*

- The telephone operating via the Hawk 2 VHF radio had heavy static and was unable to transmit a call.
- W-10 relay underwent approximately 10 minutes of continuous switching between operating and high level alarms after power returned to the control panel (subsequent to system shutdown during W-4 replacement).

- Multiple pumps are fed from a single power cable. A similar arrangement exists for the control cables.
- Five sensors were identified at W-4 suggesting that a replacement was installed and the broken sensor was not removed.
- Electrical cables were exposed along the outfall pipe. It is assumed these are the heat trace cables at the outfall, as installed during initial construction.
- The pump function in W-3 was not fully understood as the pump operation signal was on prior to the system shutdown (for the replacement of pump in W-4); however, it did not return to pumping after 2.5 hours, when the pumping system returned on.

## 3.2 Site Observations – Second Visit (November 2007): Recovery Test

The main purposes of this site visit were:

- Understanding the phreatic surface (piezometric surface) in the spur at different sections.
- Defining the correlation between the variations in well water level and the piezometers.
- Measuring the water level recovery in the wells and piezometers after the system shutdown.

In the last 26 years, the performance of the wells has been recorded, both on/off occurrences and on-time minutes. However, as several occurrences of on/on and off/off sequences were observed in the recordings, the current situation of the wells could not be judged by these statistical data. As a result, water level recovery tests were recommended to define the activity of the wells. This would clarify whether any blockage has occurred in the filters or screens of the wells and would confirm the necessity for any remedial action.

### *3.2.1 Original Block Test Plan*

Initially, it was intended to divide the wells into three main blocks as shown in Figure 4. These test blocks were to consist of the following wells and piezometers:

a) Block 1 (Southern Block): Wells 1 to 8 and piezometers P-A, and P-B

b) Block 2 (Central Block): Wells 9 to 15 and piezometer P-D

c) Block 3 (Northern Block): Wells 16 to 22 and piezometers P-F, P-G, and P-J

It was originally intended to shut down the pumps of each block in turn over the three days while all other pumps were running and record the variation of water levels in the block wells, the block piezometers, and the wells in the vicinity. However, the system providing power to the sensors could not be isolated in blocks. For safety reasons, no dip meter could be introduced into the wells while this system was energised. A change was therefore made to the initial plan from block tests to entire system shutdown and block readings on each of two days.

### *3.2.2 Modified Block Test Plan*

In the modified plan, the system was divided into two main blocks: Block 1 and Block 2, as shown in Figure 5:

a) Modified Block 1: W-1 to W-12 and piezometers P-A, P-B, P-D

b) Modified Block 2: W-13 to W-22 and piezometers P-F (2 tips), P-G, P-J (2 tips)

The whole system was shut down and water level variations in each of the modified block wells and piezometers were recorded each day. Each block contained up to 16 reading stations which consisted of both wells and piezometers. To read the levels, every person was assigned 2 reading stations: one primary and one secondary reading point. The primary station was read from initiation at the below noted time intervals for 5 hours (300 min), while the readings at secondary stations were started 15 minutes after the system shutdown. As a result, the proposed time intervals for recording the water level for the two groups stations were:

- Primary station readings after (min): 0, 0.5, 1, 2, 5, 10, 20, 30, 45, 60, 120, 180, 240, 300; and
- Secondary station readings after (min): 15, 25, 35, 50, 65, 125, 185, 245, 305; (or as closely as possible).

Baseline readings were taken on November 6 prior to knowledge of the above noted safety issue. However, zero time readings in the wells were not permitted during the block test plan due to these safety issues.

Primary and secondary reading stations are listed as follows:

- Primary: W-2, W-4, W-6, W-8, W-9, W-10, W-12, W-14, W-16, W-18, W-19, W-20, W-21, P-A1, P-B1, P-D1.
- Secondary: W-1, W-3, W-5, W-7, W-9, W-11, W-12, W-13, W-15, W-17, W-19, W-21, W-22, P-F1, P-F2, P-G, P-J1, P-J2.

#### *3.2.2.1 Baseline Testing – Day 1 (November 6, 2007)*

**Measuring the Water Levels:**

On day 1, prior to system shutdown, the following activities were undertaken:

- Personnel were trained to access and read the piezometers and wells.
- Wells and piezometers were unlocked and made accessible.
- Water levels in the wells and piezometers were read and recorded; these are presented in Table 1.

**Outlet Discharge Measurement and Water Quality:**

On November 6, before system shutdown, the water discharge rate at the outlet was measured by Hydro. The discharge was 22.8 L/min.

The water was noted to be clear with no visible silt.

**Piezometer Conditions:**
The water elevation in piezometers P-D1 and P-G were somewhat higher than the elevations in the other piezometers.

**Table 1**
**Wells and Piezometer Water Elevations – November 6, 2007**

| Well | Pumping Water Elevation (m) * | Piezometer | Piezometer Water Elevation (m) |
|---|---|---|---|
| W-1 | 14.36 | P-A1 | 9.91 |
| W-2 | 12.22 | P-A2 | See note C |
| W-3 | 8.14 | P-B1 | 8.32 |
| W-4 | See note A | P-B2 | See note D |
| W-5 | 8.28 | P-C | See note C |
| W-6 | 11.06 | P-D1 | 23.19 |
| W-7 | 11.96 | P-D2 | See note D |
| W-8 | 9.73 | P-F1 | 12.51 |
| W-9 | 24.04 | P-F2 | 12.29 |
| W-10 | 26.72 | P-G | 18.04 |
| W-11 | 19.8 | P-J1 | 10.07 |
| W-12 | See note B | P-J2 | 11.23 |
| W-13 | 5.79 | | |
| W-14 | 14.97 | | |
| W-15 | 9.25 | | |
| W-16 | 9.26 | | |
| W-17 | 10.3 | | |
| W-18 | 17.53 | | |
| W-19 | 8.81 | | |
| W-20 | 12.26 | | |
| W-21 | See note B | | |
| W-22 | 29.58 | | |

Notes:

* – Water levels obtained prior to safety advisory

A – Due to large water influx the reading was not reliable

B – The well cap was not accessible

C – Blocked, or dry piezometers

D – The elevations derived from these piezometers readings do not match the spur water table and/or adjacent piezometers level

### *3.2.2.2 Block Test 1 – Day 2 (November 7, 2007)*

The pumping system was turned off at 9:30 am on November 7, 2007 by Hydro personnel and the water level rise in the wells and piezometers located in modified block-1 was recorded. The primary and secondary reading stations were set as follows:

- Primary stations: W-2, W-4, W-6, W-8, W-10, P-A1, P-B1, P-D1.
- Secondary stations: W-1, W-3, W-5, W-7, W-9, W-11, W-12.

Water elevations in W-9 were not read as one level meter probe became jammed inside the well. Recorded elevations in W-4 were not reliable because of continuous water influx.

The variations in water elevation for each well or piezometer are plotted versus time in either logarithmic and linear scales and are presented in Appendix C. The pumping system went back into operation after five hours of shutdown.

**Piezometer Drawdown Measurements**

After system restoration at about 2:00 PM, the drawdown of piezometers was recorded for two hours. It was originally intended to measure the well drawdown also; however, this was cancelled due to safety issues associated with measuring while sensors are energized. One level reading was performed early next morning. It was noted that the drawdowns in the piezometer levels were limited (less than 1-2 cm) so this procedure was cancelled for the modified block 2. The results of the drawdown test are presented with the recovery test results in Appendix C (only for piezometers P-A1, P-B1, and P-D1).

**Outlet Discharge Measurement**

After the pumping restoration, the water discharge rate at the collector pipe outlet was measured by known volume container by Hydro twice over a 5-minute interval. The discharges were 57 L/min and 42.6 L/min, respectively.

**Discharge Water Quality**

It was observed that the discharged water was extremely cloudy and included twigs. As several pumps were in the on-situation after the system restoration, it could not be concluded which wells were producing the observed silty water. Further investigation is necessary, either by video inspection or single-well water discharge measurement, to indicate the wells that are responsible for the silty discharge.

Acres (1997) refers to the large buildup of sediment in some wells mostly about 5 to 20 m in thickness. Also, it was reported that the bottom of several sections of most riser pipes were coated with clay and silt. After a further ten years, the same phenomenon is likely to have occurred.

**Pump Activities after System Restoration**

After system restoration, which occurred after more than 5 hours of pumping shutdown, 13 out of the 19 pumps were in the on-situation. It took only 5 minutes to observe that only 5 pumps remained active and after 8 minutes, this reduced to three pumps. The sequence, which was almost repeated on the second day after the test, was recorded in the control room as follows:

0 min: Wells, 4, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 21

1 min: Wells, 4, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 21

2 min: Wells, 4, 9, 10, 12, 13, 15, 16, 17

5 min: Wells, 4*, 10, 12, 15, 19

8 min: Wells, 4, 10, 19

10 min: Wells, 4, 9, 10

20 min: Wells, 4, 10

* W-4 went off at min 6 and returned back into an on-situation shortly, again off at min 12.5 and returned on at min 14.

#### *3.2.2.3 Block Test 2 – Day 3 (November 8, 2007)*

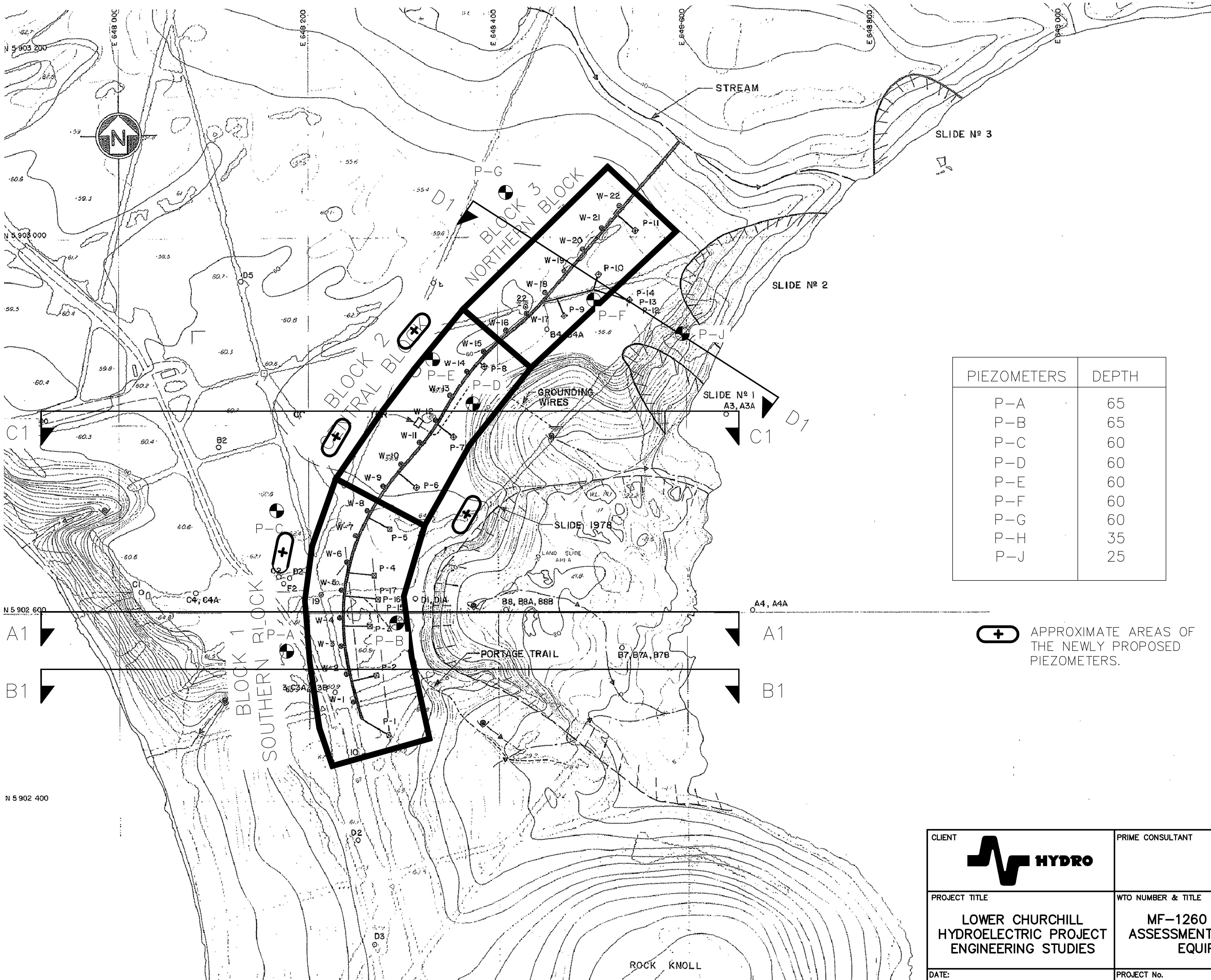
On Day 3, the elevations in the wells and piezometers in modified Block-2 were read after the pumping system was turned off. Also, the water levels in W-4 and W-9 were recorded, as they could not be monitored the first day. On the third day, the primary and secondary reading stations were set as follows:

- Primary stations: W-4, W-9, W-12, W-14, W-16, W-18, W-19, W-20, W-21.
- Secondary stations: W-13, W-15, W-17, W-19, W-21, W-22, P-F1, P-F2, P-G, P-J1, P-J2.

It was noticed that the water elevation in W-4 could be recorded consistently after minute 18; however, the reading in W-9 was very difficult because of the high inflow.

**Piezometers Slow Recovery Rate**

The piezometer readings in P-F, P-G, and P-J indicate that the water levels had already risen as a result of the first day shutdown and had not recovered to the undisturbed situation. The information gathered from these piezometers is plotted and presented in Appendix B; however, little variation was noted on the last day.




| PIEZOMETERS | DEPTH |
|---|---|
| P–A | 65 |
| P–B | 65 |
| P–C | 60 |
| P–D | 60 |
| P–E | 60 |
| P–F | 60 |
| P–G | 60 |
| P–H | 35 |
| P–J | 25 |

(+) APPROXIMATE AREAS OF THE NEWLY PROPOSED PIEZOMETERS.

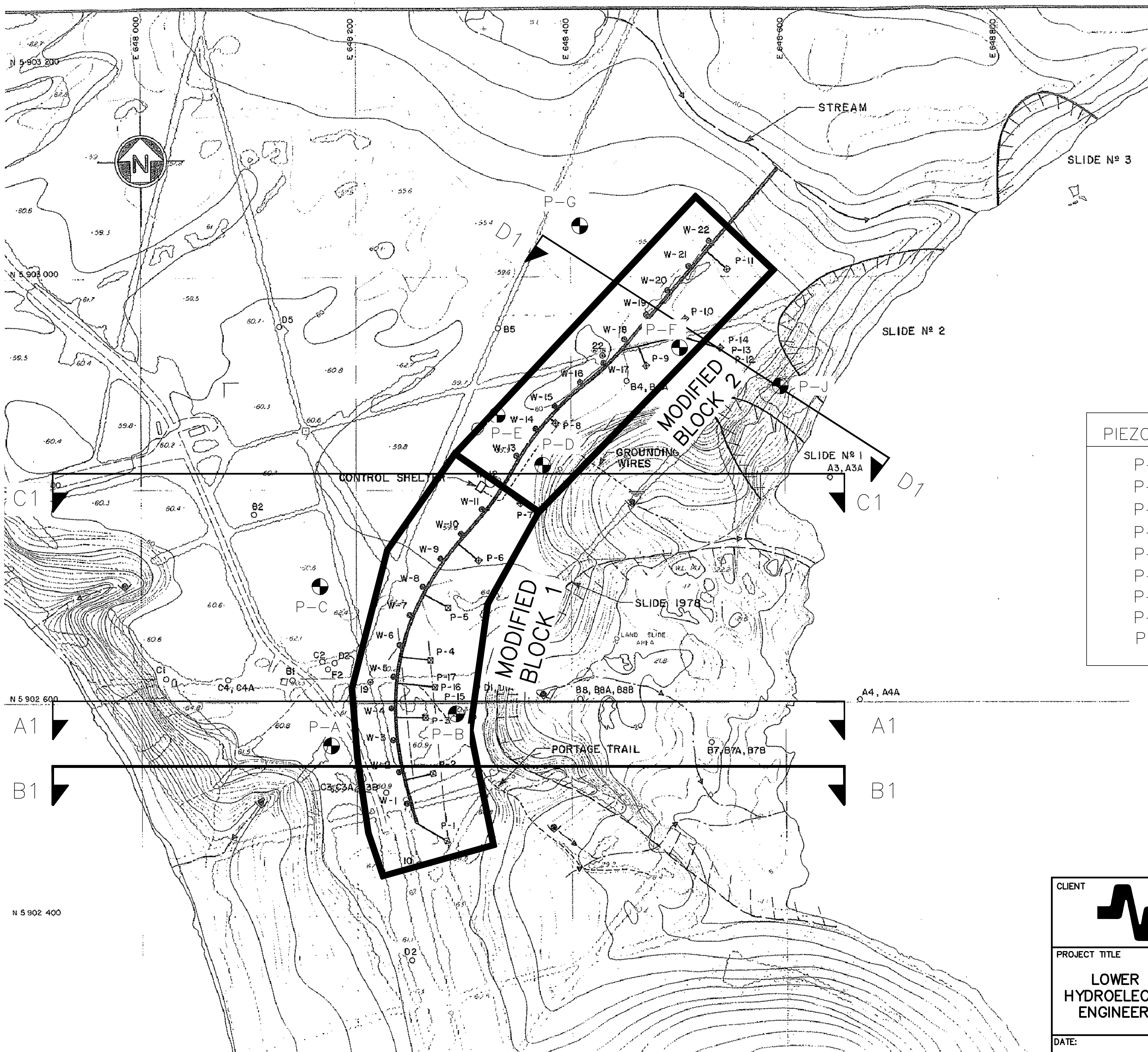
LEGEND

- BOREHOLE (1979)
- W-1 PUMPING WELL (1981)
- P-1 PIEZOMETER (1981)
- 22 SURVEY STATION
- TRENCH FOR COLLECTOR PIPE AND CABLES
- SPRING
- RECENT LANDSLIDES (1980-1981)
- LANDSLIDE (1978)

NOTE

FOR SECTIONS SEE PLATE 2

| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF–1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: ORIGINAL BLOCK TEST PLAN |
| DATE: NOVEMBER 2007 | PROJECT No. H325967 | DRAWING No. FIGURE 4 |




## LEGEND

- BOREHOLE (1979)
- W-1 PUMPING WELL (1981)
- P-1 PIEZOMETER (1981)
- 22 SURVEY STATION
- TRENCH FOR COLLECTOR PIPE AND CABLES
- SPRING
- RECENT LANDSLIDES (1980-1981)
- LANDSLIDE (1978)

| PIEZOMETERS | DEPTH |
|---|---|
| P–A | 65 |
| P–B | 65 |
| P–C | 60 |
| P–D | 60 |
| P–E | 60 |
| P–F | 60 |
| P–G | 60 |
| P–H | 35 |
| P–J | 25 |

## NOTE

FOR SECTIONS SEE PLATE 2

| | | |
|---|---|---|
| CLIENT: HYDRO | PRIME CONSULTANT: HATCH™ | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF–1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: MODIFIED BLOCK TEST PLAN |
| DATE: NOVEMBER 2007 | PROJECT No. H325967 | DRAWING No. FIGURE 5 |

# 4. Groundwater Assessment

In order to assess the pumping system performance, it is necessary to compare the present water table in the spur with the water levels before pump installation and after water drawdown equilibrium. Fortunately the original water table is well documented in a number of reports using several piezometers originally installed in the spur either during early investigation or during system construction. However, most of these piezometers have been destroyed, either struck by lightning (p- series originally recommended by SNC-Lavalin) or lost in vegetation (A- , B- , and C- series installed during early investigation), and defining the current water table is limited to either using the 8 existing standpipe piezometers or the water table inside the wells. The water tables inside the wells are also variable due to pumping; however, they are limited by the high and low elevations of wells sensors. The recovery tests performed during the second site visit were very significant in tracking the water levels and in checking whether the well pumps are performing adequately.

In the following sections, it is intended to compare the current spur water table with the historical values. In addition, some plots describing the variation of the piezometer water elevations, installed and monitored since 1997, are presented. These curves define whether or not there is a significant change in water table in the spur in the last 10 years.

Finally, some other factors which can potentially affect the water table in the spur are discussed.

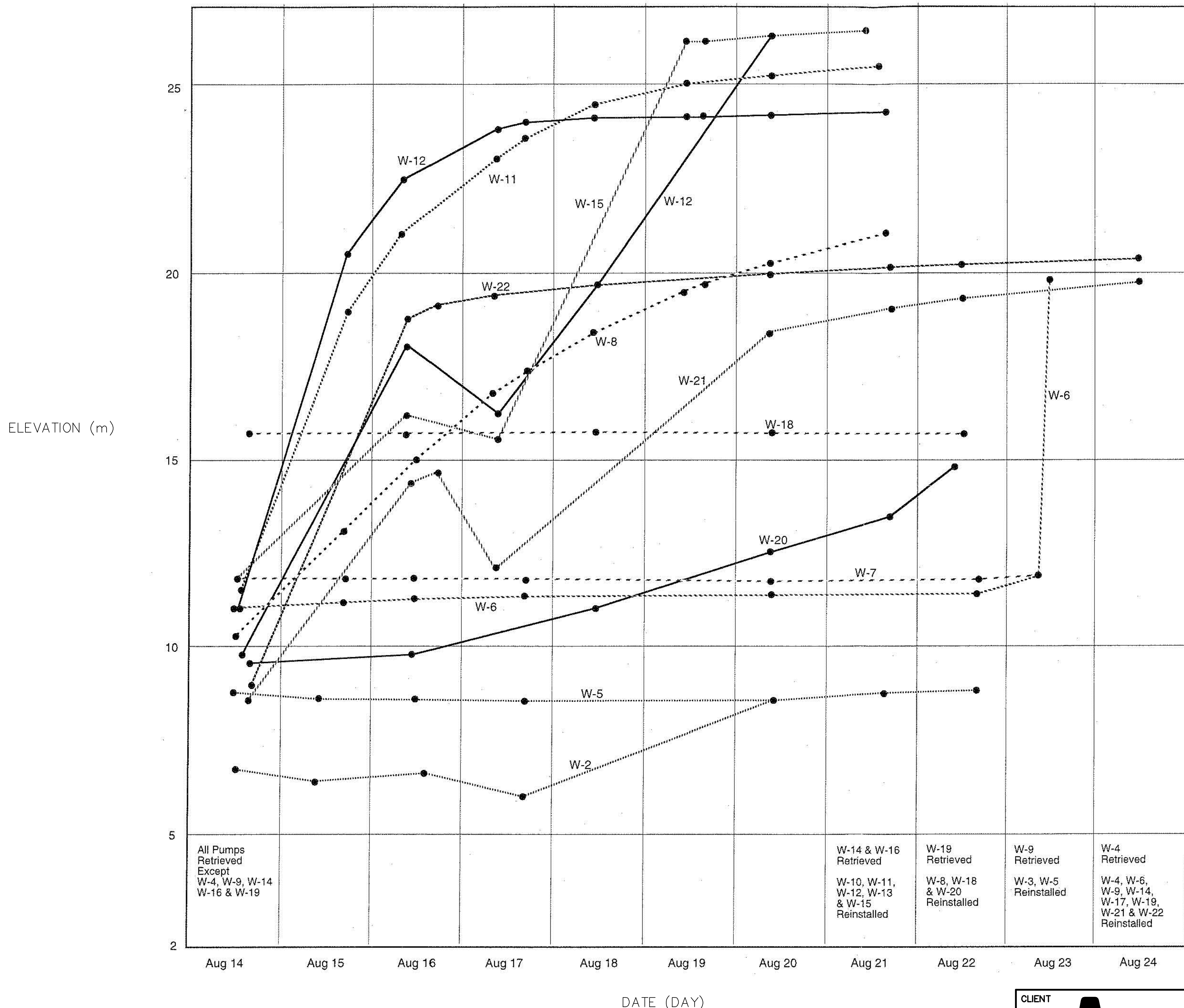
## 4.1 Historical Data

Groundwater assessments were performed after the installation of the pumping system. These assessments were carried out by SNC-Lavalin in 1982 and were used as the initial water levels for this study.

In August, 1996, a series of recovery tests was made by Acres on the pumps for 11 days to study the groundwater regime in the stratified drift unit (between el -10 and 50) and its response to pumping. In that recovery test, all pumps, other than W-4, W-9, W-14, W-16, and W-19, were retrieved and cleaned over a period of 7 days and the water recoveries were recorded accordingly. Since W-4, W-9, W-14, W-16, and W-19 are the most active, they were retrieved and cleaned in one day. Figure 6 describes the variation of the water elevations and the sequence of pumps after reinstallation/retrieval. In addition, Table 2 provides a summary of the characteristics and water level measurements in the wells. This table contains the water elevations in the wells in 1994 and 1995 in addition to the results of the recovery test during the 11 days. It should be mentioned that the pumps in W-4 and W-9 which are the most active wells were not left out of the well overnight.

During the 1996 recovery test, the wells could be divided into three major zones: Southern (W-1 to W-7), Central (W-8 to W-17), and Northern (W-18 to W-22). The major observations of the recovery test can be stated as:

- The sand component of about 50 percent is significant in the downstream south side of the spur near the rock knoll, and decreases in the northerly direction. In other words, the downstream south side contains more pervious sediments and offers better opportunities for dewatering than the northern part.




| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH™ | |
| PROJECT TITLE<br>LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE<br>MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE<br>RECOVERY IN SELECTED WELLS , PERFORMED BY ACRES – 1996. |
| DATE:<br>NOVEMBER 2007 | PROJECT No.<br>H325967 | DRAWING No.<br>FIGURE 6 |

## Table 2
## Summary of Characteristics and Water Level Measurements in Wells in Acres Report – 1996

| Well | Elevation | | | Screen Length | Depth of Well from Top of PVC | Water Elevation | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Top of Steel Pipe | Top of PVC Pipe | Bottom of Well | | | Prior to Pumping Sep 1981 | 1994 | 1995 | 1996 | | | | | | | | | | |
| | | | | | | | | | Aug 14 | Aug 15 | Aug 16 | Aug 17 | Aug 18 | Aug 19 | Aug 20 | Aug 21 | Aug 22 | Aug 23 | Aug 24 |
| W-1 | 59.84 | 59.79 | -3.85 | 30.0 | 63.64 | 30.56 | 19.80 | - | 16.39 | 16.39 | 16.37 | 16.37 | - | - | 16.37 | - | - | - | 16.36 |
| W-2 | 59.82 | 59.66 | -9.77 | 32.0 | 69.43 | 29.49 | - | - | 6.65 | 6.36 | 6.56 | 5.96 | - | - | 8.56 | 8.64 | 8.75 | - | - |
| W-3 | 59.79 | 59.67 | -10.20 | 31.5 | 69.87 | 29.73 | 7.58 | 9.10 | 6.57 | 8.33 | 8.35 | 8.34 | - | - | 8.35 | - | 8.78 | - | - |
| W-4 | 59.78 | 59.67 | -9.51 | 30.0 | 69.18 | 30.43 | 10.07 | 10.90 | - | - | - | - | - | - | - | - | - | - | 11.01 |
| W-5 | 59.71 | 59.55 | -2.89 | 28.0 | 62.44 | 30.57 | 7.54 | 9.10 | 8.73 | 8.61 | 8.57 | 8.54 | - | - | 8.54 | 8.75 | 8.73 | - | - |
| W-6 | 59.68 | 59.33 | -0.07 | 18.5 | 59.60 | 33.27 | 10.51 | 11.30 | 11.03 | 11.19 | 11.23 | 11.29 | - | - | 11.34 | - | 11.39 | 11.83 | - |
| W-7 | 59.67 | 59.51 | -2.69 | 31.5 | 62.20 | 29.94 | 10.00 | 11.80 | 11.78 | 11.73 | 11.71 | 11.79 | - | - | 11.72 | - | 11.76 | 11.81 | - |
| W-8 | 59.63 | 59.46 | -1.54 | 15.0 | 61.00 | 34.91 | 9.46 | 10.80 | 10.28 | 13.10 | 15.02 | 16.78 | 18.39 | 19.47 | 20.26 | 21.04 | - | - | - |
| W-9 | 59.60 | 59.48 | -3.11 | 30.0 | 62.59 | 37.50 | 15.43 | 20.80 | - | - | - | - | - | - | - | - | - | - | 25.92 |
| W-10 | 59.57 | 59.40 | -0.16 | 31.5 | 59.56 | 37.56 | 7.90 | 9.90 | 11.02 | 20.53 | 22.46 | 23.81 | 24.03 | 24.08 | 24.17 | 24.29 | - | - | - |
| W-11 | 59.53 | 59.35 | +2.43 | 31.5 | 56.62 | 37.44 | 11.86 | 12.60 | 11.55 | 18.97 | 21.07 | 23.03 | 24.45 | 25.04 | 25.21 | 25.49 | - | - | - |
| W-12 | 59.45 | 59.29 | -0.77 | 24.0 | 60.06 | 43.91 | 7.78 | 9.10 | 9.71 | - | 18.09 | 16.29 | - | - | 26.21 | - | - | - | - |
| W-13 | 59.36 | 59.27 | -0.96 | 30.0 | 60.23 | 47.37 | 6.69 | 8.70 | 5.51 | - | 4.84 | - | 4.40 | 32.59 | 32.99 | 38.64 | - | - | - |
| W-14 | 59.24 | 59.01 | +2.63 | 30.5 | - | 38.51 | 7.57 | 25.00 | - | - | - | - | - | - | - | - | 26.51 | 31.27 | - |
| W-15 | 58.07 | 58.91 | -0.75 | 23.5 | 59.66 | 41.56 | - | 27.60 | 11..88 | - | 16.16 | 15.54 | - | 26.02 | 26.24 | 26.44 | - | - | - |
| W-16 | 58.92 | 58.76 | -1.23 | 30.0 | 59.99 | 43.20 | 10.75 | 10.10 | - | - | - | - | - | - | - | - | 25.86 | 28.35 | - |
| W-17 | 58.61 | 58.46 | -1.69 | 23.5 | 60.15 | 31.72 | 9.94 | 10.30 | 11.90 | - | 12.76 | - | 13.09 | 13.17 | 13.31 | 13.67 | - | 13.84 | - |
| W-18 | 57.99 | 57.87 | +2.57 | 28.0 | 55.30 | 31.91 | 14.32 | 13.90 | 15.70 | - | 15.67 | - | 15.72 | - | 15.70 | - | 15.64 | - | - |
| W-19 | 56.12 | 57.01 | -2.45 | 36.0 | 59.46 | 43.60 | 12.45 | 14.90 | - | - | - | - | - | - | - | - | - | 18.51 | - |
| W-20 | 56.23 | 56.01 | -5.28 | 30.0 | 61.29 | 21.64 | 8.58 | 8.90 | 9.58 | - | 9.76 | - | 10.96 | - | 12.48 | 13.41 | 14.80 | - | - |
| W-21 | 54.73 | 53.99 | -2.50 | 24.0 | 56.49 | 24.37 | 12.58 | 9.30 | 8.54 | - | 14.37 | - | - | - | 18.40 | 19.03 | 19.29 | - | 19.78 |
| W-22 | 52.42 | 52.26 | -7.52 | 25.5 | 59.78 | 25.59 | 15.77 | 8.70 | 9.10 | - | 18.84 | - | 19.70 | - | 19.97 | 20.13 | 20.18 | - | 20.38 |

- The recharge feeding the aquifer contained in the unit is mostly from upland on the left bank and the groundwater flow is from the northwest. Infiltration occurs in the upper sand unit or cap, and through discontinuities or hydraulic windows in the upper low permeability clay member into the lower and more pervious sand layers hosting the aquifer. The clay furnishes a confining effect, but the sand layers are interconnected to a degree which permits groundwater flow through the interconnections.
- In addition to the recharge from the northwest, the Churchill River upstream at el 18 has an influence on the spur and the groundwater in the rock knoll to a minor degree. The natural groundwater level before pumping was at el 30 m on the south side of the dewatering system and rises to el 47 m near W-13 and decreases to el 24 m on the north towards the existing stream. The piezometric water level at specific points in the formation, approximately along the line of the wells, is generally between el 20 and 30 m.
- The summary of various properties in Table 3 confirms the presence of good drainage at the south side by virtue of greater sand content and higher conductivity compared to central and northern zones. The wells in this southern zone produced the highest yield and least recovery.
- The most significant conclusion from the standpoint of spur stabilization is related to lowering of the water table as a result of the operation of the dewatering system. The greatest drawdown in the spur, in general, is generated in the southern zone where the hydraulic conductivity is highest and the least is in the northern zone where the hydraulic conductivity is lowest.
- The narrowest width of spur, 150 m, from upstream to downstream occurs at the south side. A significant segment of the land mass was lost in a 1978 landslide and the dewatering system is presently about 80 m from the scarp. There are two springs in the slide scarp which were estimated to emerge at about the same elevations as prepumping. Slide debris still occupies a major portion of shoreline with driftwood piled up high. The accumulation of slide debris provides a buffer between the shore and the toe of slope. Growth of vegetation suggests a measure of stability.
- The central section is more than 300 m away from the bay upstream. However, in the area of wells W-11 to W-16 near the control shelter, the downstream slope of the spur is steep and only about 40 m away from the scarp. Moreover, landslides No. 1 and No. 2 mapped in the early 1980s, Figure 3, appear to have become one scarp probably caused by toe erosion. Inspection during the 1996 rehabilitation work indicated that toe erosion was in progress. Also a spring was found on the downstream slope of W-13 probably due to high piezometric levels in the vicinity.
- The northern section of the spur in the area of W-18 to W-22 is wide and the slide scarp on the downstream is about 80 to 90 m from the line of wells. The ravine located north of W-22 is overgrown and the slope is in the order of 1.5H:1V. No sign of instability was noted in the ravine.

**Table 3**
**Summary of Hydrogeological Observations in Acres Report – 1996**

| Observations | Southern Zone | Central Zone | Northern Zone |
|---|---|---|---|
| **Pump Wells in Zone** | **W-1 to W-7** | **W-8 to W-17** | **W-18 to W-22** |
| Proportion of pervious sand and sandy silt layers in stratified drift unit to el 10 m | 55% | 20% except for Wells W-9 and W-14 which are similar to southern zone. | 5% |
| Relative bulk hydraulic connectivity (m/s) | $1 \times 10^{-5}$ | $1 \times 10^{-7}$ to $1 \times 10^{-8}$ | $1 \times 10^{-8}$ |
| Groundwater lowering in 2 years after start of pumping (m) | High of about 15 | Low $<$ 5.5 | Very low $<$ 0.5 |
| Daily operation of pumps | Long, due to steady inflow from pervious layers; pump in W-4 operates 19 hours | Short, generally 1 hour; pumps W-9 and W-14 work longer due to greater pervious thickness | Short, maximum of 1 hour; pumps operate daily |
| Recovery in water level after 10 days of pumps shut down in 1996 | Very small $<$ 2 m | High, about 35 m in Well W-13 equivalent to prepumping level -Steady state reached in about a week | Moderate to about 10 m as in Wells W-21 and W-22 to el 20, equivalent to invert of nearby stream from Kettle Lakes |
| Filling of well casing using 2000 gal of water for flushing | Difficult, unable to cause sediments in Wells W-3, W-4, W-5, and W-7 to rise above top of casing | Easy in all wells except W-9 | Easy in all wells |
| Benefit of continued pumping in groundwater lowering | High | Moderate | Negligible |

## 4.2 Piezometer Water Levels

All the piezometers installed prior to 1996 are either lost in vegetation or considered inactive over the last 10 years. As noted earlier, 6 active piezometers (some with two tips) were located during the site visits: piezometers P-A to P-J. For the purpose of this report, the data has been used whenever it can be substantiated by other indications in neighboring installations, the wells water table, or by other observations.

Figures 7 to 10 plot the variation of piezometer water elevation for the last 10 years. Out of 12 observed tips, the readings of four tips are not consistent with the other installations or historic data. These are: P-A2, P-B2, P-C, and P-D2. In the piezometers which have two tips, the suffixes 1 and 2 refer to lower and higher tips, respectively.

In this section, observations regarding level variations in the piezometers are provided as follows:

- The trends of variation for the levels of piezometers P-A1 and P-B1 are very similar. Geometrically, the distance between the two piezometers is about 100 m; however, they can be considered in one cross sectional plane (perpendicular to the pump line).
- Piezometer P-A1 shows the water level 1.5 m higher than P-B1, which is to be expected, as the location of P-A is in the middle of the spur while P-B is closer to downstream.
- P-A2, which is located at the el 24.35, is dry which was also observed during the September 2007 first site visit.
- P-B2 shows an increasing trend of variation. P-B1 shows a virtually stable condition 15 m lower than P-B2 which suggests a separate and distinct groundwater regime in the areas monitored by the tips. P-B2 shows a unique trend within the spur by constantly increasing over the period 1992 to 2007. All other piezometers show a cyclical or constant trend.
- P-C shows an almost constant head; however, there are some reported spikes, which were also noticed in the 2007 visit (it may be that the piezometer riser pipe is damaged). The piezometer should be flushed and tested.
- P-D1 shows the lowest elevation in 2001 equal to el 21.6 m, which occurred at time when P-A1 and P-B1 experienced their lowest piezometric head. This elevation increased to el 23.8 m in April 2006. The recent readings show the elevation at about el 23 m.
- P-D2 shows an approximately constant value of about 31 m. This value is significantly higher than the value expressed by the lower tip and, similar to the case of P-B2, may show a perched water table in a separate and distinct groundwater regime. A dry condition has occasionally been reported for this piezometer tip.
- P-F1 showed a constant value close to 12 m after installation until 2005. From this time, the water level has increased gradually to a maximum of el 12.80 m, a 0.8 m increase. This value stabilized in 2007 at around 12.70 m.
- P-F2 used to be a dry piezometer. From March 2007, this piezometer indicated that the water level increased about 1.0 m, to a maximum of el 13.17 m in August 2007.
- In P-F, the two tips show the same elevation.
- P-G shows the minimum water elevation in 2004 to be around el 16 m. This value increased to el 19 m in March 2007 which is equivalent to a 3 m increase. At the day of the site visit, the piezometer water elevation decreased to about 18 m. Further readings are important for this piezometer.
- P-J1 shows an approximately constant level of el 10 m. In March 2007, this tip showed the highest elevation of el 10.3.
- P-J2, which is the higher tip, was dry from 2000 to March 2005. From April 2006, the piezometer showed an increase in water elevation of about 0.9 m. In March 2007, this value was equal to el 11.70 m and in September 2007, it was el 11.54 m. In August 2007, the water level was reported as el 14.95 m, which may not be correct and was eliminated from the figure.

- Similar to the two tips of P-F, the two piezometer tips (P-J1 and P-J2) show approximately the same value or a slightly downward gradient.

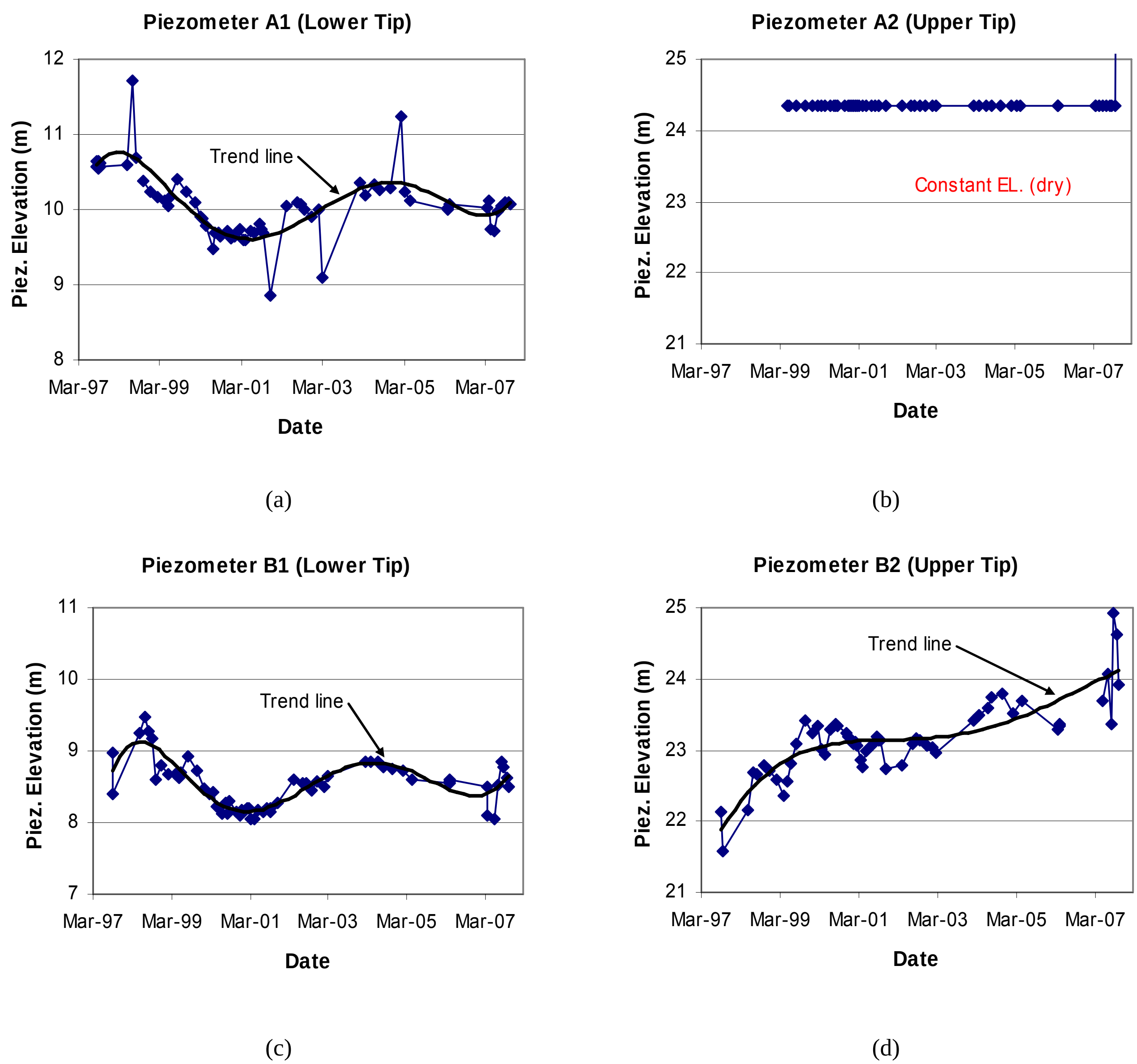
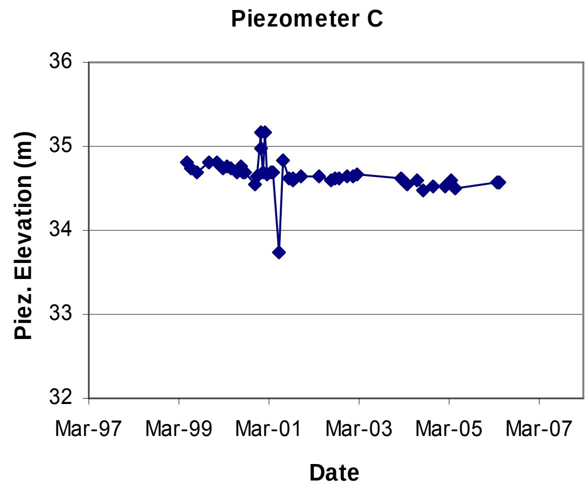
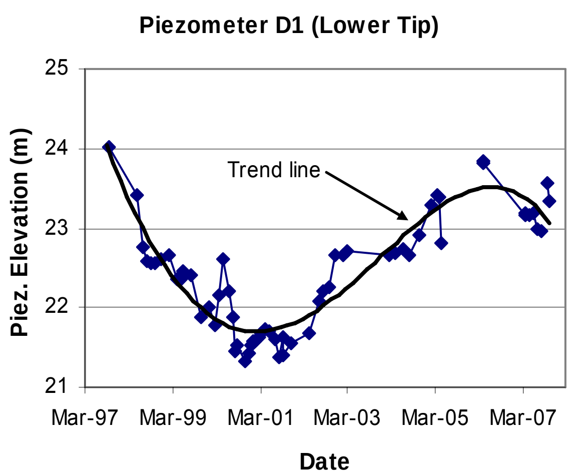


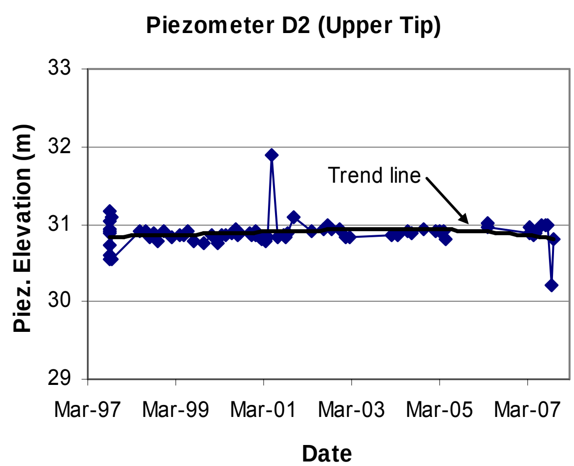

**Figure 7 - Piezometer water level variations from 1997 to 2007: (a) P-A1 lower tip, (b) P-A2 upper tip, (c) P-B1 lower tip, (d) P-B2 upper tip**




(a)




(b)




(c)

**Figure 8 - Piezometer water level variations from 1997 to 2007: (a) P-C, (b) P-D1 upper tip, (c) P-D2 lower tip**

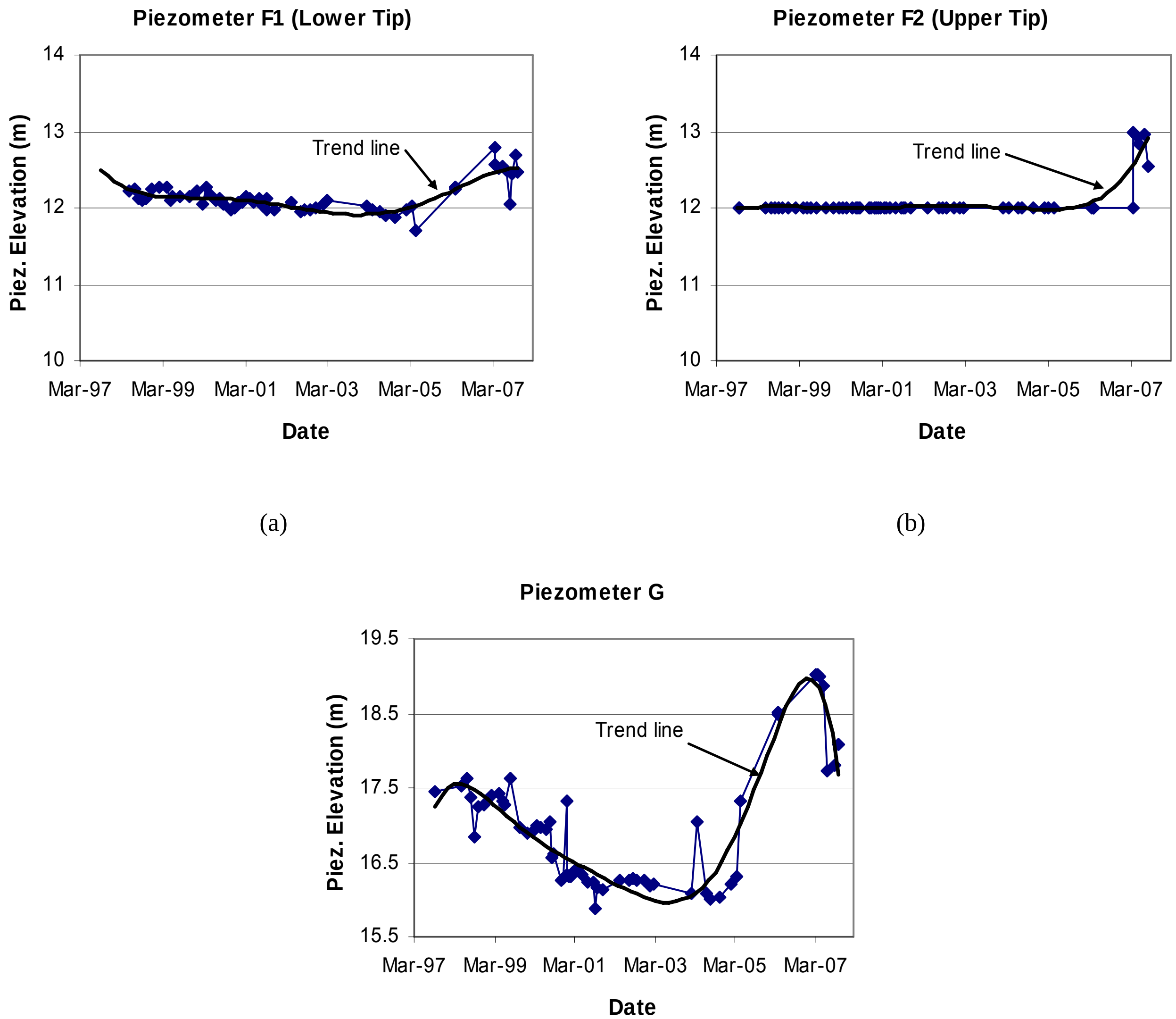
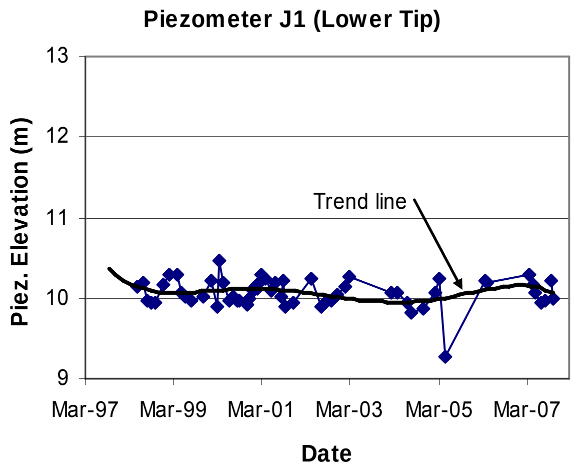
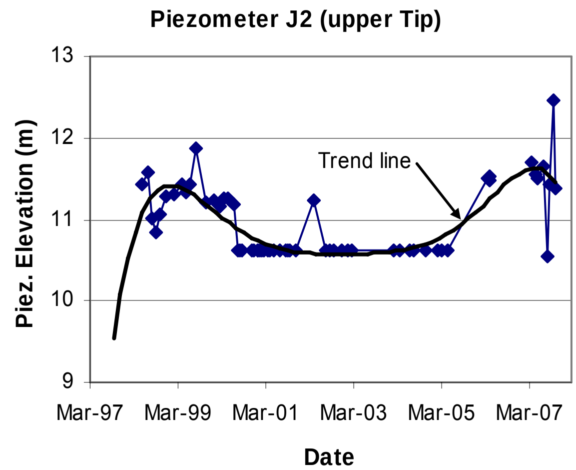



**Figure 9 - Piezometer water level variations from 1997 to 2007: (a) P-F1 lower tip, (b) P-F2 upper tip, (c) P-G**




(a)




(b)

**Figure 10 - Piezometer water level variation from 1997 to 2007: (a) P-J1 lower tip, (b) P-J2 upper tip**

### General Comments about Piezometer Group Behaviour

**Block – 1 (Southern Block):**

Piezometers A and B, which are located at the narrowest width of the spur, show a similar trend. According to these piezometers, the general performance of the dewatering system close to these piezometers has not varied in the last 10 years. However, the piezometers P-A1 and P-B1 show an increasing trend in early 2007, as in early 2003, and should be evaluated to confirm cyclical trend or establish a new regime.

**Block – 2 (Central Block):**

In the middle section of the spur, which is represented only by P-D, the water level in the lower tip has increased about 1.5-2 m since 2001. This indicates that the pumping system efficiency in this section may have deteriorated since 2001 compared with the years from 1997-2001. W-9 to W15 are the wells which are close to P-D.

**Block – 3 (Northern Block):**

P-G, P-F, and P-J can be considered to be located in one cross section. The water levels in all three piezometers have increased since 2005. P-G shows the highest increase equal to 2.5 m and the two other piezometers show an increase of about 1-1.5 m. These values demonstrate that the situation in this area has changed dramatically in the last three years and the performance of the pumps W-17 to W-22 should be checked against the early performances, accordingly.

## 4.3 Well Water Elevations

Table 4 provides the well water levels observed during the Nov. 2007 site visits in addition to some reported values prior to and after pumping system initiation. These elevations are taken from Acres Dewatering System Assessment and Rehabilitation report of 1997.

There is not enough data regarding the wells water elevations in the previous reports, however, there is some information about the wells water elevations reported by Acres (1997). Comparing the collected data from the 2007 elevation observations to the record from 1994 to 1996, it can be concluded that most of the wells have an elevation close to their stabilized elevation with a few exceptions:

- Water elevation in W-2 has increased about 6 m, primarily due to pump decommissioning.
- The block of W-9, W-10, and W-11 has significantly higher elevations compared to their values in the period of 1994 to 1996. These high elevations are also confirmed by piezometer elevations in the vicinity.
- Wells W-18, W-20, W-21, and W-22 are experiencing a higher water elevation in comparison to the similar values in 1994 to1996. W-22 is experiencing a significantly higher water level due to pump decommissioning; however, the other wells also show an increase of between 2 and 5 m. Unfortunately there is no data prior to 1994, neither in wells nor in the piezometers.

**Table 4**
**Well Water Elevations – Old and New Data**

| Well | Prior to Pumping Sep 1981 | 1994 See note C | 1995 See note C | Recovery Test Aug 1996 | Prior to Recovery Test Nov 2007 | Lowest Observed Level in Nov 2007 | Highest Observed Level in Nov 2007 |
|---|---|---|---|---|---|---|---|
| W-1 | 30.56 | 19.8 | - | 16.39 | 14.36 | 14.36 | 14.37 |
| W-2 | 29.49 | - | - | 6.65 | 12.22 | 12.22 | 12.28 |
| W-3 | 29.73 | 7.58 | 9.10 | 6.57 | 8.14 | 8.14 | 8.65 |
| W-4 | 30.43 | 10.07 | 10.90 | 11.01 | See note A | 9.44 | 11.19 |
| W-5 | 30.57 | 7.54 | 9.10 | 8.73 | 8.28 | 8.28 | 8.62 |
| W-6 | 33.27 | 10.51 | 11.30 | 11.03 | 11.06 | 11.02 | 11.06 |
| W-7 | 29.94 | 10.00 | 11.80 | 11.78 | 11.96 | 11.96 | 12.11 |
| W-8 | 34.91 | 9.46 | 10.80 | 10.28 | 9.73 | 9.73 | 11.70 |
| W-9 | 37.50 | 15.43 | 20.80 | 25.92 | 24.04 | 24.04 [a] | 25.38 [a] |
| W-10 | 37.56 | 7.90 | 9.90 | 11.02 | 26.72 | 26.72 | 26.44 |
| W-11 | 37.44 | 11.86 | 12.60 | 11.55 | 19.8 | 19.8 | 21.17 |
| W-12 | 43.91 | 7.78 | 9.10 | 9.71 | See note B | 9.54 | 12.92 |
| W-13 | 47.37 | 6.69 | 8.70 | 5.51 | 5.79 | 5.79 | 11.90 |
| W-14 | 38.51 | 7.57 | 25.00 | 26.51 | 14.97 | 14.97 | 18.84 |
| W-15 | 41.56 | - | 27.60 | 11.88 | 9.25 | 9.25 | 21.01 |
| W-16 | 43.20 | 10.75 | 10.10 | 25.86 | 9.26 | 9.26 | 19.78 |
| W-17 | 31.72 | 9.94 | 10.30 | 11.90 | 10.3 | 10.30 | 13.12 |
| W-18 | 31.91 | 14.32 | 13.90 | 15.70 | 17.53 | 17.51 | 17.53 |
| W-19 | 43.60 | 12.45 | 14.90 | 18.51 | 8.81 | 8.81 | 16.68 |
| W-20 | 21.64 | 8.58 | 8.90 | 9.58 | 12.26 | 11.95 | 12.22 |
| W-21 | 24.37 | 12.58 | 9.30 | 8.54 | See note B | 14.33 | 15.91 |
| W-22 | 25.59 | 15.77 | 8.70 | 9.10 | 29.58 | 29.58 | 29.64 |

Notes: A – Due to water influx the readings should be considered with caution
B – The wells cap were inaccessible
C – Typical random values for comparative reasons

## 4.4 Hydrogeological Sections

An examination of the last 10 years of piezometer data and the recent recovery tests is essential before any commentary can be made with respect to the hydrogeological performance of the spur under the influence of the dewatering system. In order to understand this performance, three additional cross sections, Figures 11 to 14, have been provided in this report each representing one segment of the spur (Figure 11 is an update of previous reports). The cross sections are chosen in such a way that they cover all the piezometers and one typical well in each section including: W-2, W-4, W-12, and W-19. Section locations are illustrated in Figure 4.

Although there is insufficient piezometric data for Sections B1-B1 and C1-C1, to illustrate trends, the data points on the sections provide an apparent comparison between the current water table and the original phreatic surface.

### *4.4.1 Section A1-A1*

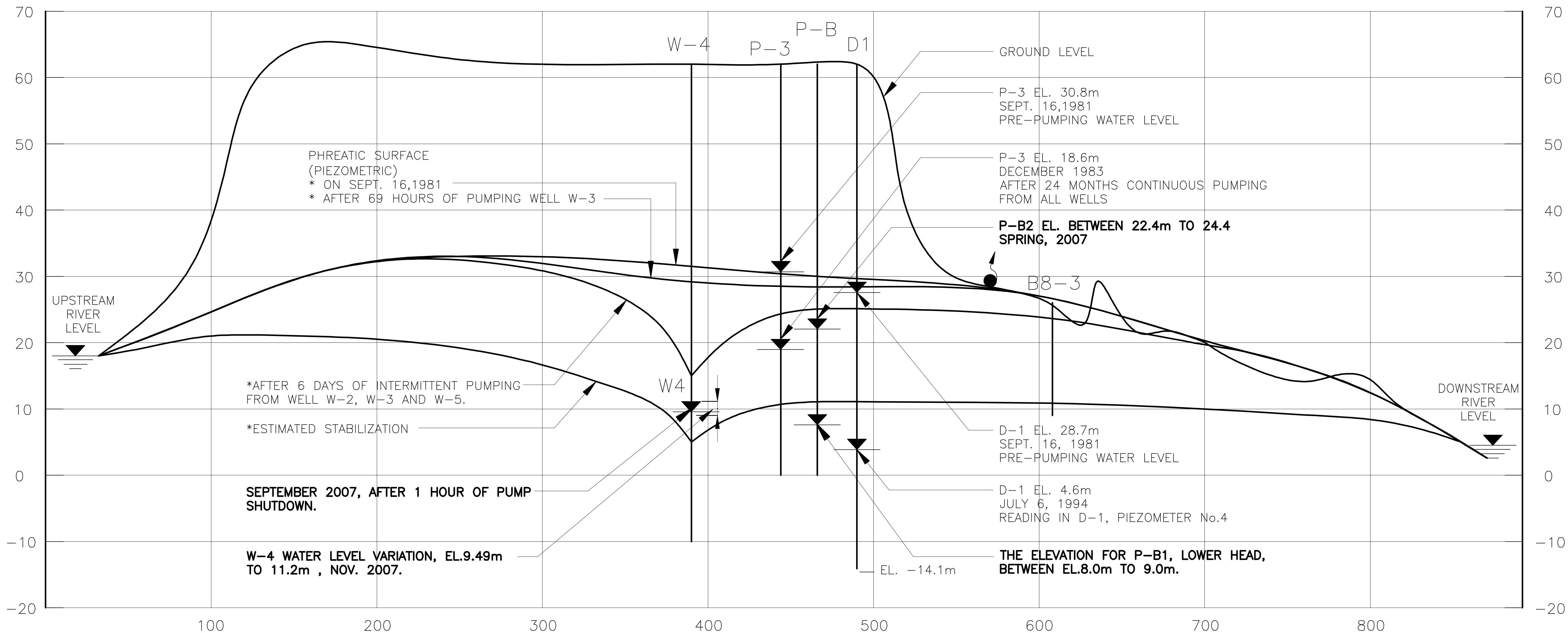
This section, Figure 11, is important because it is close to the narrowest section of the spur, there is a lot of information from other sources, and W-4, which is the most active pump, is located on the section. In the report by Acres International (1994), W-4 is noted to be responsible for 85% of the total dewatering of the system.

Currently, the water levels from P-B1 and W-4 indicate that the water table inside the spur is close to the estimated stabilized water table. P-B2 however, is showing an increasing piezometric level, possibly a perched water table. To confidently draw the current piezometric surface at this cross section, it is necessary to install additional piezometers in the spur, specifically close to the location of the old piezometers, C2, F2, or D2, to the west of W-4 (indicated in Figure 3).

### *4.4.2 Section B1-B1*

This section , Figure 12, is also close to the narrow part of the spur. The original phreatic surface is plotted based on the information provided from SNC-Lavalin report: "Muskrat Falls Dewatering System – Engineering Assessment ", Plate-4. The piezometric line resulted from 69 hours of pumping. Drawdown data points by Pumps 2,3,4, and 5 were also derived from the report.

The water table in the piezometer P2, read in Dec 1983 (original piezometric surface), indicates that the water table had dropped to el 10 m from el 26 m. In Aug 1996, the water level in W-2 was recorded by Acres to be el 8.75 m which is the lowest derived head in this section. This is shown in Figure 12. The two readings in Sept in P-A1 and Nov 2007 in W-2 indicate that the water tables are about el 10.1 and el 12.2 m, respectively. During the recovery test, the water elevation increased in W-2 by only 0.04 m, which is less than the level rise in the adjacent piezometers. This suggests that W-2 may be damaged as suggested by the removal of the pump several years ago. A well video inspection may reveal any problems.



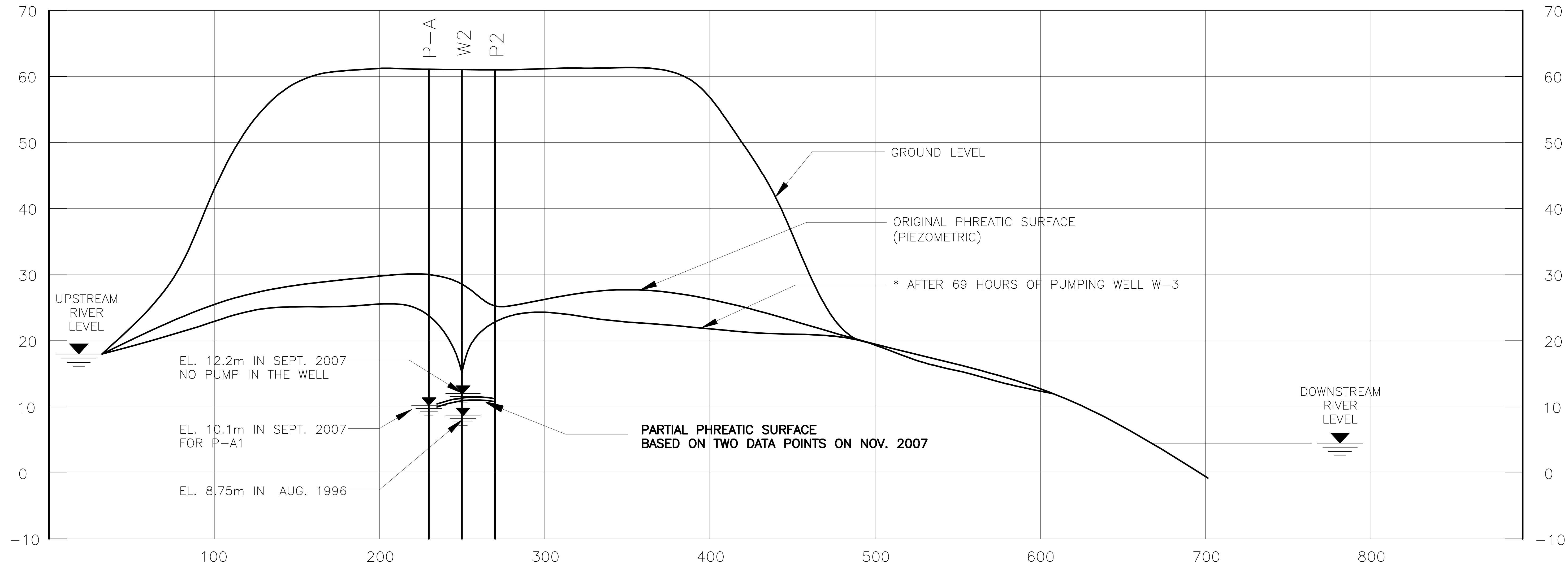

# SECTION A1−A1

NOTE:

DRAWING THE CURRENT PHREATIC SURFACE NOT PRACTICAL WITH ONLY TWO DATA POINTS.

ORIGINAL DRAWING FROM ACRES (1994)

| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH™ | |
| PROJECT TITLE<br>LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE<br>MF−1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE<br>MUSKRAT FALLS HYDROGEOLOGIC SECTIONS SECTION A1−A1 |
| DATE:<br>NOVEMBER 2007 | PROJECT No.<br>H325967 | DRAWING No.<br>FIGURE 11 |




# SECTION B1–B1

NOTE:
DRAWING THE CURRENT PHREATIC SURFACE IS NOT PRACTICAL WITH ONLY TWO DATA POINTS.

| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH™ | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: MUSKRAT FALLS HYDROGEOLOGIC SECTIONS SECTION B1-B1 |
| DATE: NOVEMBER 2007 | PROJECT No.: H325967 | DRAWING No.: FIGURE 12 |

The water table in W-1 is equal to el 14.3 m, 2.1 m higher than W-2 and about 6.0 m higher than W-4. These indicate that the water tables in W-1 and W-2 are significantly higher than W-3 and W-4, indicating that the water table increases towards the south of the spur. Pumping from W-1 and W-2 will decrease these water tables.

### *4.4.3 Section C1-C1*

This cross section passes through W-12 and P-D and former piezometer, P-7, illustrated in Figure 13. Similar to Section B1-B1, the original water table is plotted on this section based on the SNC-Lavalin report. The reported values for P7 show that the water level decreased from el 22.8 to el 16.7 in Dec 1983. However, the original levels of P7 are not consistent with those derived from the phreatic surface for the intermediate aquifer.

Acres reported the W-12 water elevation equal to el 9.1 m in May 1995. This was also read during the recovery test and varied from el 9.5 m to el 13.9 m after five hours of system shutdown.

The upper tip of P-D (P-D2) shows the water level equal to el 30.9 m for this piezometer, which is again even higher than the initial phreatic surface. In this respect, the dewatering system has not influenced this area, and may reflect a local condition.

The lower tip, P-D1, showed a level of el 23.2 m on Nov 6, 2007. This value is significantly higher than the water tables in the wells in the vicinity: W-12, W-13, W-14, W-15. On the other hand , the water elevation in Wells W-9, W-10 and W-11 (from el 19.8 m to el 26.72 m, from Table 4) are more consistent with the value in P-D1 lower tip. These indicate that P-D1 is representing the actual water elevations in the spur close to wells W9 to W-11.

### *4.4.4 Section D1-D1*

There are three piezometers and one well located in this cross section, as shown in Figure 14, which allow a precise illustration of the current stabilized phreatic surface. However, as discussed in Section 4.2, the piezometric surface has risen significantly since 2005.

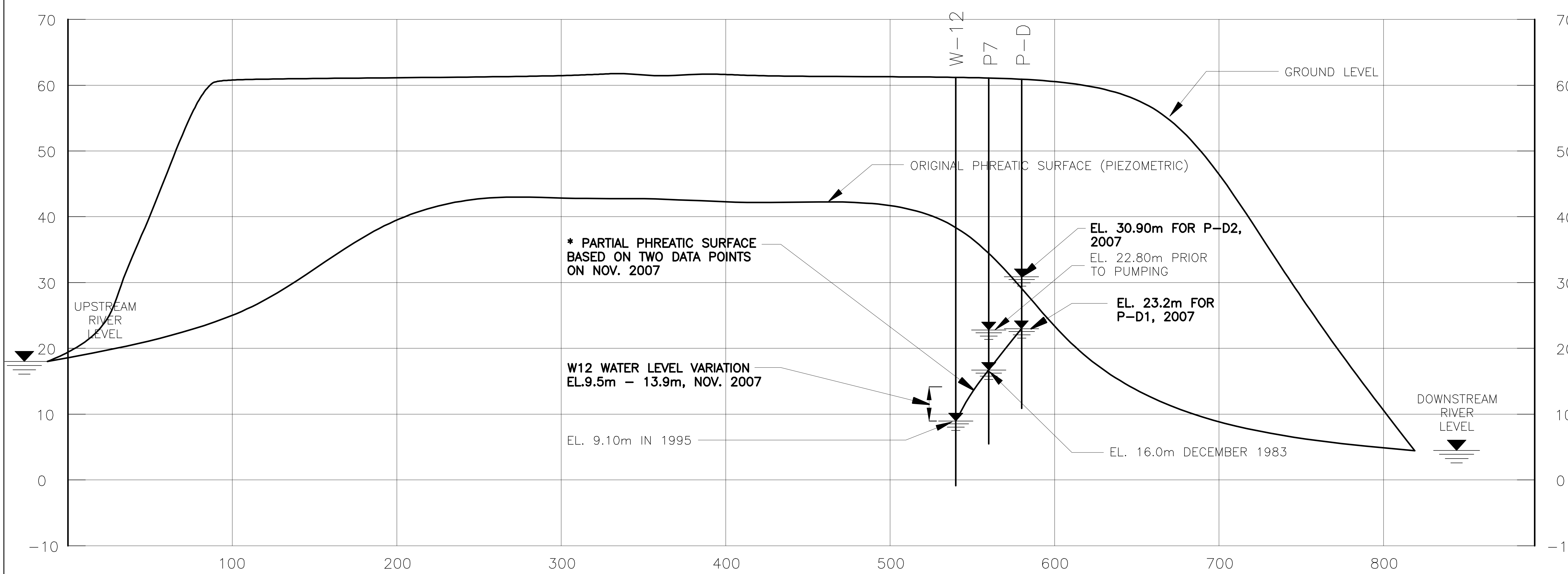
The old piezometer P-10 showed an elevation equal to el 11.39 m in September 1981, prior to pumping, which is significantly lower than the original phreatic surface, around el. 35.0 m and is likely not correct.

The water table in W-19 was at el 40 m, before the system initiation in 1981, and in 1995 Acres showed this value to be at el 14.9 m. The current recovery test indicates that the water table in the well increased from el 8.8 m to el 16.7 m after 5 hours of system shutdown. This confirms that the well is highly active.

The piezometers P-G, P-F, and P-J show the piezometric elevations in Nov 2007 to be el 18.0 m, el 12.3 m , and el 10.1 m, respectfully. These values are consistent with each other and define the water table in this cross section. This cross section can be considered as indicative of the block number 3.

## 4.5 Precipitation, Temperature, and Upstream River Water Level

In this section, the potential interrelationship between piezometric elevations and precipitation, temperature and/or upstream/downstream river water elevations is addressed. As the only continuous water table information in the spur is derived from standpipe piezometers which were installed in 1997, the focus is on the statistical data after 1997.

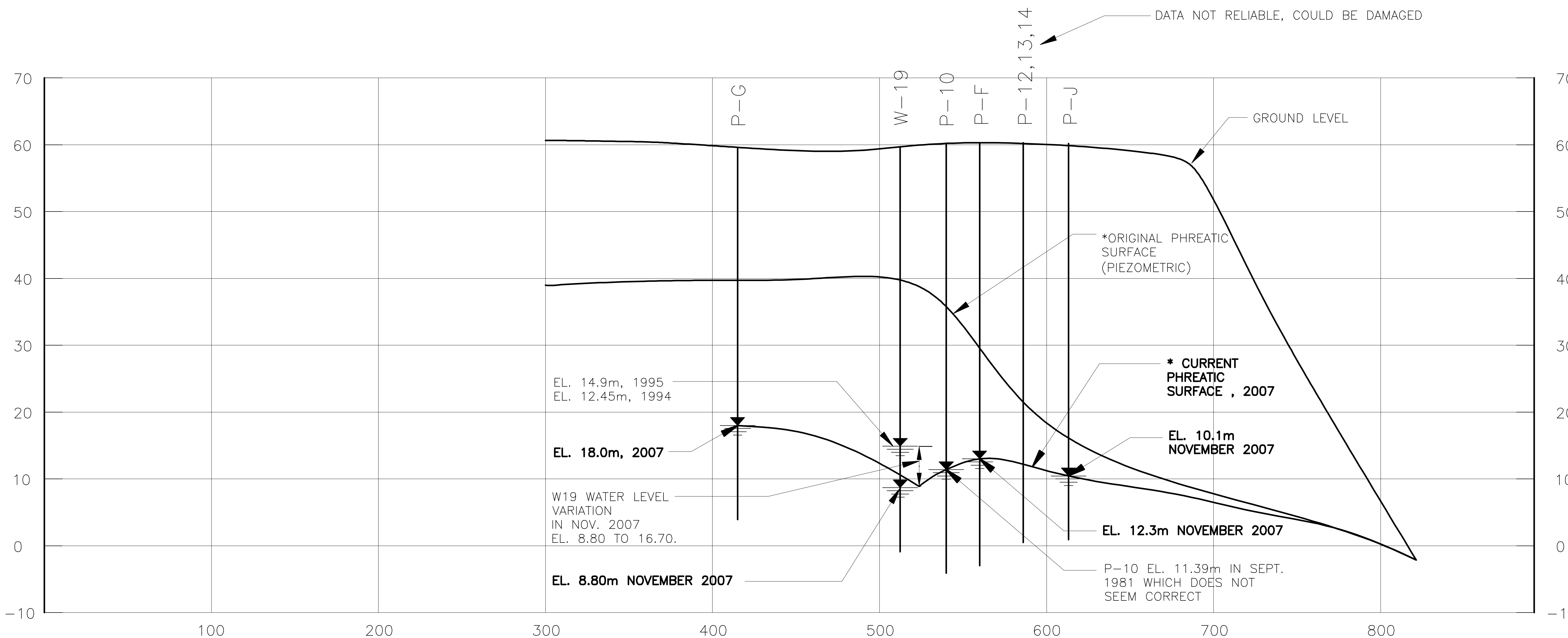



# SECTION C1–C1

NOTE:
1. DRAWING THE CURRENT PHREATIC SURFACE IS NOT PRACTICAL WITH ONLY TWO DATA POINTS.

2. ELEVATION IN P–D IS SIGNIFICANTLY HIGH.

| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF–1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: MUSKRAT FALLS HYDROGEOLOGIC SECTIONS SECTION C1–C1 |
| DATE: NOVEMBER 2007 | PROJECT No. H325967 | DRAWING No. FIGURE 13 |




# SECTION D1-D1

| CLIENT | PRIME CONSULTANT | |
|---|---|---|
| HYDRO | HATCH™ | |
| PROJECT TITLE: LOWER CHURCHILL HYDROELECTRIC PROJECT ENGINEERING STUDIES | WTO NUMBER & TITLE: MF-1260 CONDITION ASSESSMENT OF EXISTING EQUIPMENT | DRAWING TITLE: MUSKRAT FALLS HYDROGEOLOGIC SECTIONS SECTION D1-D1 |
| DATE: NOVEMBER 2007 | PROJECT No. H325967 | DRAWING No. FIGURE 14 |

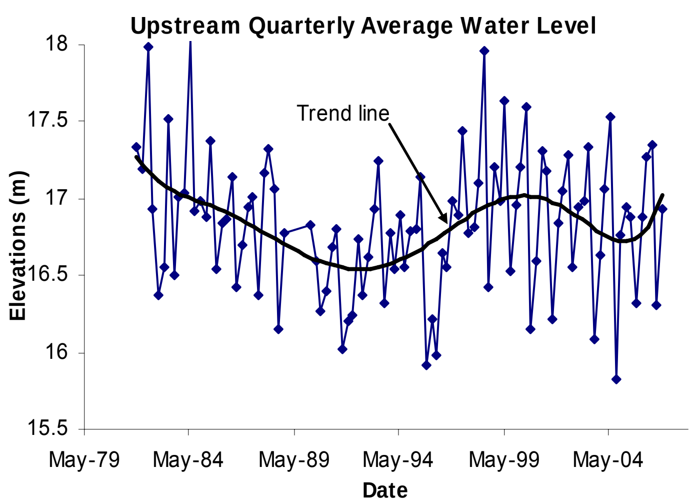
As the piezometric elevations have not been recorded monthly until recently, only quarterly or annual comparisons are provided.

### *4.5.1 River Water Levels*

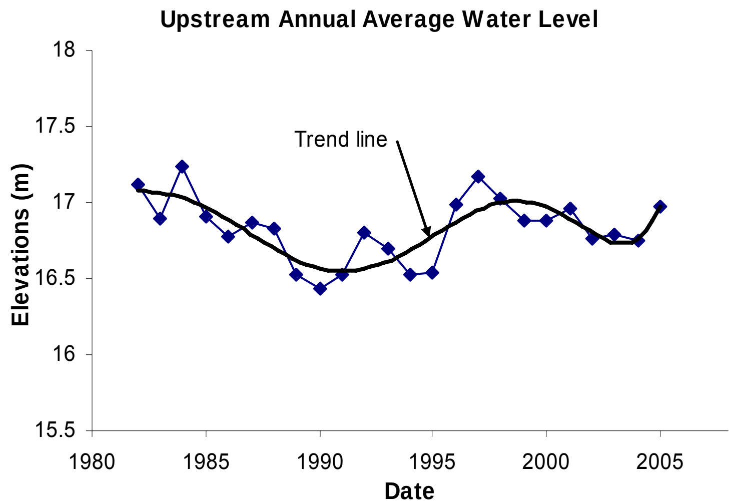
Only upstream river water elevations have been recorded in the last ten years, and information regarding downstream river water level is limited to a few years between 1980 and 1990. Figure 15 shows the variation of upstream water level based on quarterly and annual average values (Water Survey of Canada 03OE001).

The local low values for upstream river water elevation occurred in 1991 and 2004. The range of variation in the elevations for quarterly average data is between el 15.8 and el 18.0 m and for annual values are between el 16.5 and el 17.3 m. The highest quarterly average upstream water level for the last 10 years occurred in June 1998 at el 18.0 m, while the lowest is reported for September 2004 at el 15.8 m.

Comparing the variation of the upstream water levels (showing highest in 1999 and lowest in 2003) with the variation of piezometers P-A , P-B, and P-D, Figures 7 and 8 (which have their lowest elevation in 2001 and the highest value in 2004/5) , it can be concluded that there is no clear correlation between upstream river water level variation and the piezometric elevations.




(a)




(b)

**Figure 15 - Upstream average water level: (a) quarterly average from 1980 to 2007, (b) annual average from 1980 to 2007 (W.S.C. Gauge 03OE001)**

### *4.5.2 Precipitation and Temperature*

Figure 16 depicts total annual precipitation, total rain, and total snow for the last 10 years at the Goose Bay meteorological station (climate station ID: 8501900). As it can be seen, the highest level of precipitation occurred in 1999, while the lowest level was in 2005. However, it can be observed that the overall trend is one of generally decreasing total precipitation.

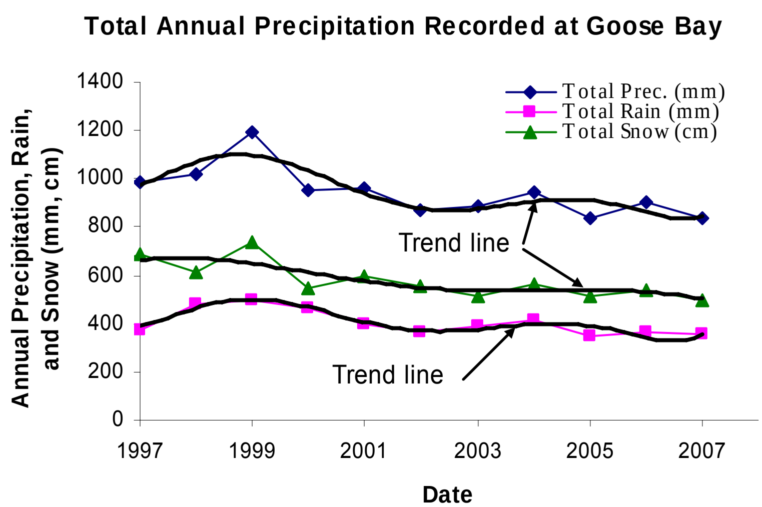



**Figure 16 - Total Annual Precipitation, Rain and Snow at Goose Bay from 1997 to 2007 (from Goose Bay Meteorological Station 8501900)**

This is contrary to the observed piezometric water level variations for P-A1 and P-B1, since for these piezometers, the local peaks occurred in 2005, which shows the lowest precipitation observed for the period of 1997-2006. Furthermore, the total annual precipitation can not explain the recent rises, since 2005, in the piezometric water tables as were observed in the piezometers located in northern block, including: P-F, P-G, and P-J.

Figure 17 shows the variation of mean annual temperature at Goose Bay (climate station ID: 8501900). This figure shows that the highest mean temperature occurred in 2006 followed by 1999. In these years, the spur area would have naturally experienced the fastest melting season in comparison with other years. No other correlation is apparent.

It is believed therefore that the groundwater level regimes in the south and middle segments of the spur should be controlled by both the river flows from upstream to downstream and by regional precipitation infiltration, while the north segment of the spur should be affected primarily by precipitation runoff from the north bank.

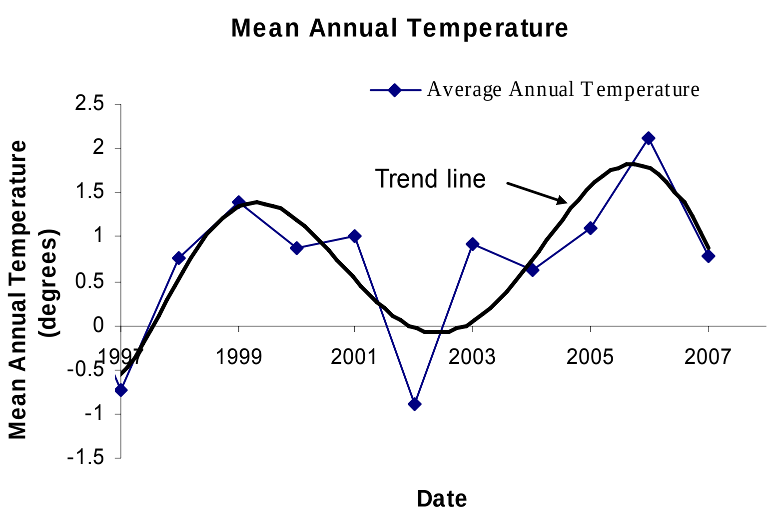



**Figure 17 - Mean Annual Temperature at Goose Bay from 1997 to 2007 (from Goose Bay Meteorological Station 8501900)**

## 4.6 Historical Data on Pump Operation

In order to investigate the performance of the pumping system in the recent years (the last four years), the on-time periods of selected pumps and/or blocks are compared with the on-time values of some randomly selected earlier years. For the following discussion, it should be noted that in some months, there was a problem in the data transmission system so those data are absent from the figures. For instance, in Figure 18, the on-time for pump No. 4, for the duration of July to Aug 2007, is recorded equal to zero, which is very unlikely. It is believed that all the data interpretations related to the on-time should be accompanied with some other data like piezometer and well water elevations. However, discounting the information while there is no better substitute is not justified. Nevertheless, these figures may reveal some valuable data which might otherwise have been recently available with an accurate data recording and transmission system.

Figure 18 demonstrates the total monthly on-time for pump no.4 for the last four years (2004 to 2007) as well as a randomly chosen year, 2001, for comparison purposes. This figure shows that the data are usually well recorded for the first six months of each year. The pump experienced its most active year of the four in 2006; however, the values are significantly lower than in 2001. The pump P-4 in well W-4 was changed in September 2007, and the recorded values show that there is a significant decrease in the on-time Oct and Nov 2007 when compared with Oct and Nov 2004 to 2006. The relatively high on-time throughout 2006 suggests that the pump was not performing satisfactorily during this year, as the well water inflow to the well could not be evacuated fast enough. As a result, pump on-time data might be a useful tool for the purpose of system maintenance. The decreased on-time values in the recent years in comparison to 2001 suggest that P-4 has become less active which should be considered carefully.

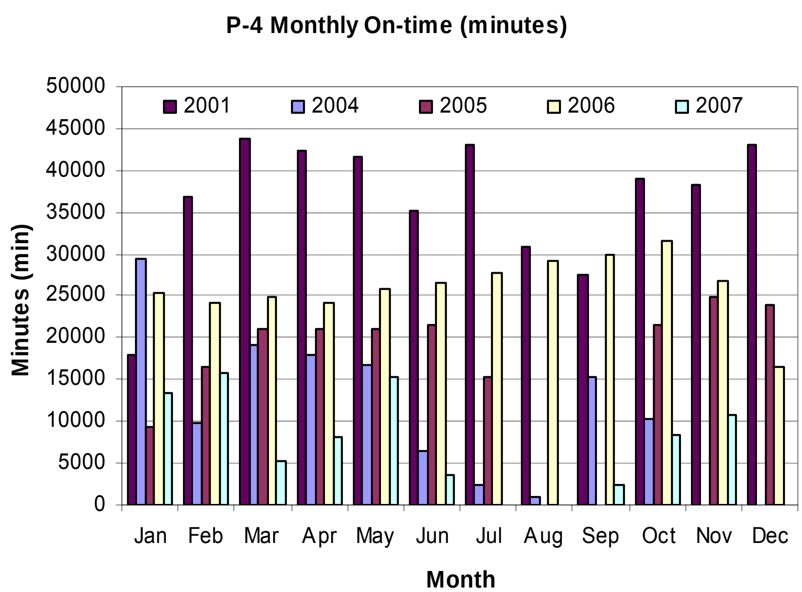



**Figure 18 - Monthly on-time for pump no. 4 (P-4)**

Figure 19 plots the activity of pump no.9 for the years of 2004 to 2007 and also 2001. This shows that the pump on-time is significantly lower than that of pump no.4. The activities in the recent years have not changed meaningfully from 2001.

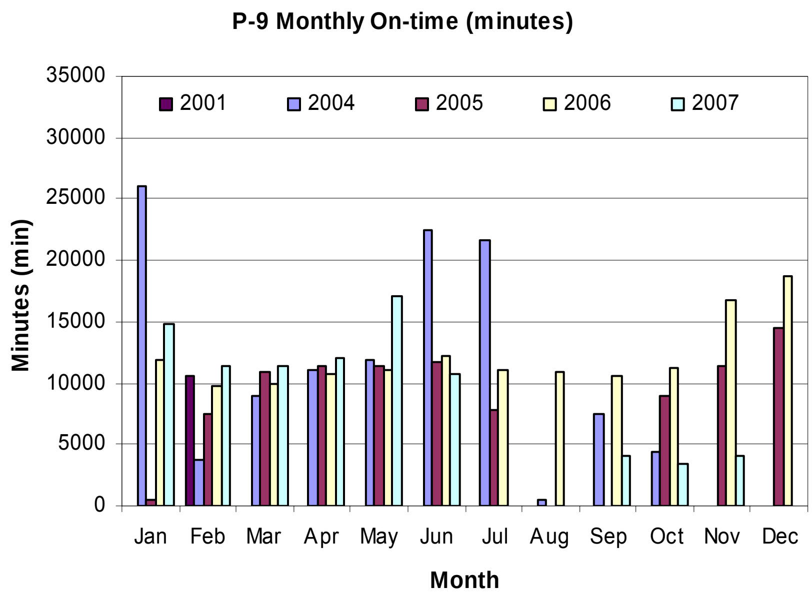



**Figure 19 - Monthly on-time for pump no. 9 (P-9)**

Figure 20 shows the on-time for pump no. 19. This figure suggests that the pump is generally inactive for years after 2005. This pump is located in the northern block where the water table level has significantly increased in the years after 2005.

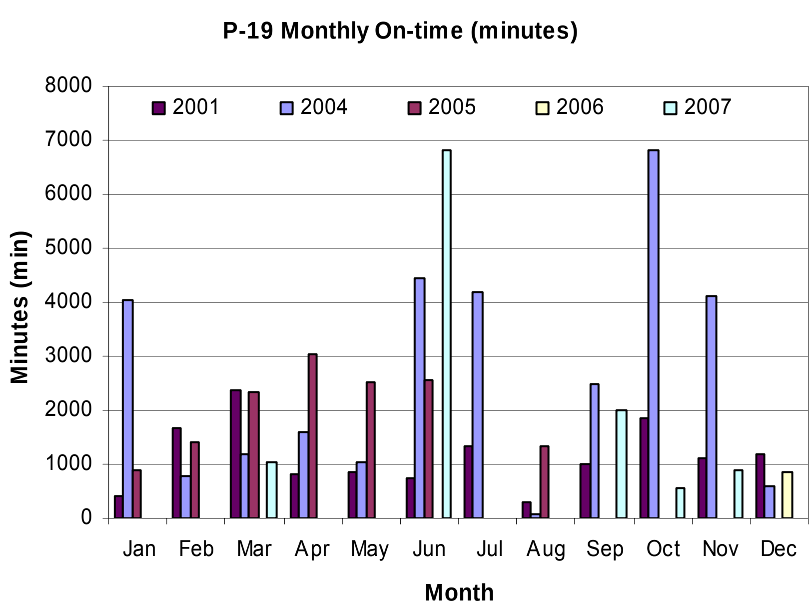



**Figure 20 - Monthly on-time for pump no. 19 (P-19)**

Figure 21 depicts the total monthly on-time for the block 1 (Southern Block). The block experienced its most active time during year 2006, as a result of high pump no.4 activity; however, the on-time values are much less than the year of 2001.

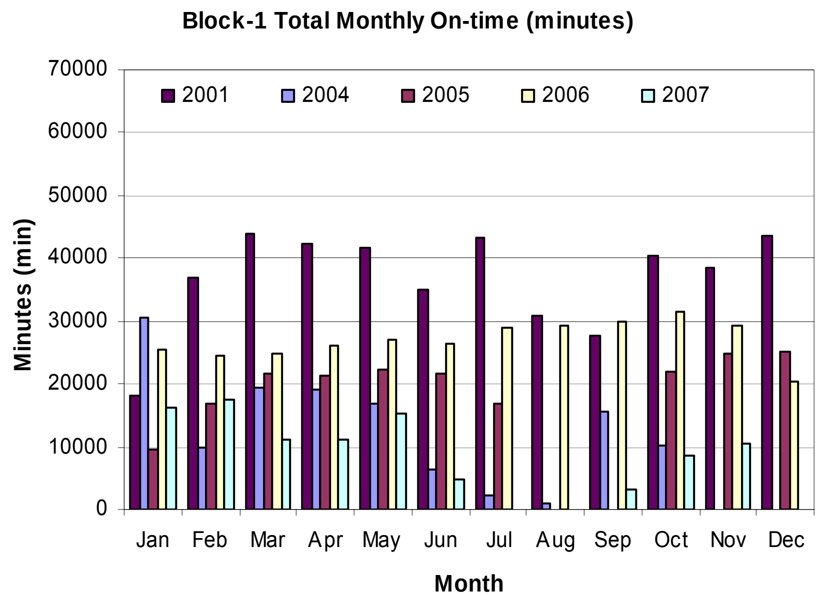



**Figure 21 - Total monthly on-time for Block-1 (Southern Block)**

Figure 22 also shows that Block-2 (Central Block) had its most active month in November 2006.

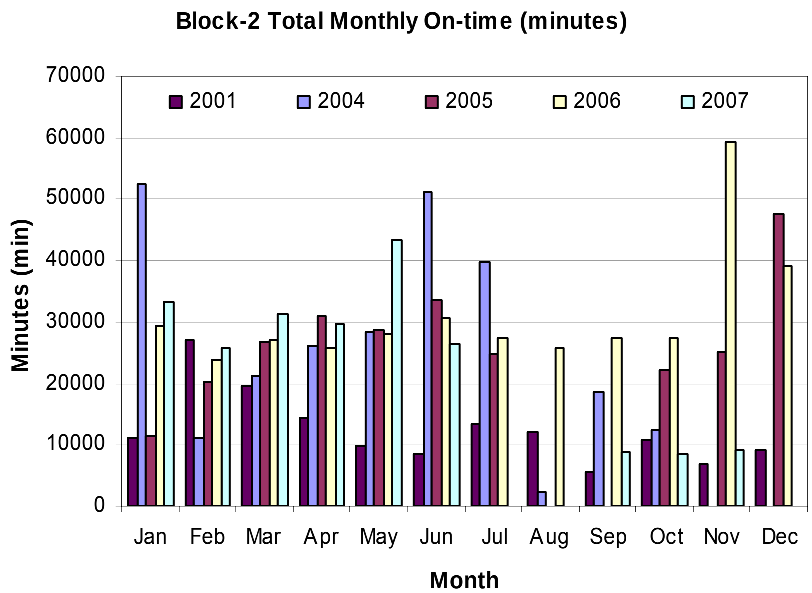



**Figure 22 - Total monthly on-time for Block-2 (Central Block)**

Figure 23 confirms that Block-3 (Northern Block) is generally much less active than the other two blocks. The two monthly on-time values, Jan 2004 and Nov 2006, are significantly higher than the other years. This might be the result of inconsistent recordings of some on-time activities.

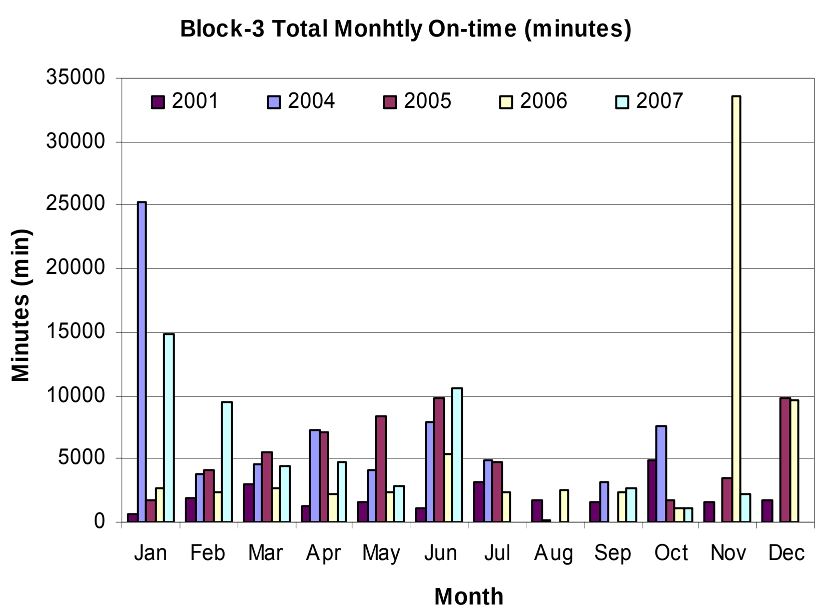



**Figure 23 - Total monthly on-time for Block-3 (Northern Block)**

Figure 24 shows the average monthly on-time for different blocks for the last four years. This figure shows that Block-2 (Central Block) is the most active block in the recent years followed by Block-1. While the on-time of Block-3 has been almost constant over the years, the other two blocks experienced the most active years in 2006 (other than 2001).

All this suggests that the average on-time minutes could be used as a useful source of system control, in future monitoring, but only when considered in conjunction with the well discharge and well efficiency information. In this case, well efficiency is taken to describe the ability of the screen and filter to pass water without significant head loss. Currently no information is available on either discharge or efficiency.

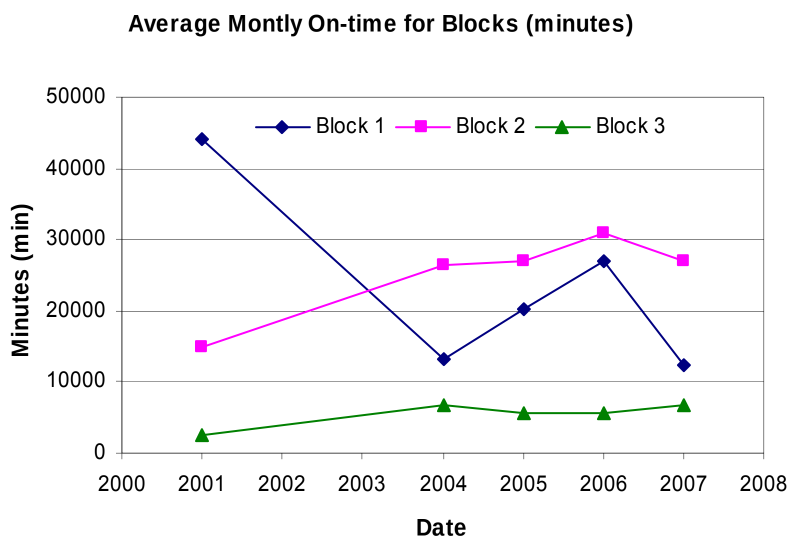



**Figure 24 - Average monthly on-time for different blocks**

## 4.7 Recovery Test Results

Appendix C provides the results of the recovery test for the 8 piezometer tips and the 22 wells. The details of the test procedures are described in Section 3.3.

On the first day, after the system restoration, the readings in the piezometers continued. However, as the water rise in the piezometers was less than 1-2 cm, these observations were not repeated on the second day.

### *4.7.1 Piezometers Recovery Observations*

On the first day of the recovery test, P-A experienced the highest increase equal to 15 cm after 5 hours of system shutdown. P-B had 11 cm of rise in water level and P-D experienced about 5 cm rise.

**Recovery prediction for piezometers**

Shutdown of the pumps might be caused by an unpredictable event such as a problem in power transmission, or well clogging as a result of screen collapse, and so on. In this event, water levels will rise, and the rate of rise is important in the planning of repairs and rehabilitation.

To improve the predictive capability, the experimental results (the recovery test) have been compared with some approximate calculations. The results of the calculations are summarized in Table 5, and the details are presented in Appendix B.

**Table 5**
**Piezometer Water Level Changes - after Appendices B and C – November 6, 2007**

| Piezometer | Calculation Method | Elapsed Time | Water Level Rise in P-A1 (m) | Water Level Rise in P-B1 (m) |
|---|---|---|---|---|
| Water Level Rise | Approximate Calc. Appendix B | 2 hours = 120 min | 0.09 | |
| Water Level Rise | Approximate Calc. Appendix B | 5 hours = 300 min | 0.11 | |
| Water Level Rise | Approximate Calc. Appendix B | 7 days = 10080 min | 0.17 | |
| Max Water Level Rise | Recovery Test Appendices B and C | 7 days = 10080 min | 0.37 | 0.42 |
| Min Water Level Rise | Recovery Test Appendices B and C | 7 days = 10080 min | 0.29 | 0.30 |

### *4.7.2 Well Recovery Observations*

After observing the results of recovery test on the wells, the wells have been categorized into three major groups: highly active, active, and inactive wells. Monitoring the water level rises in the highly active wells was extremely difficult. Some wells (W-4 and W-12) were monitored for a second time on the second day of the site visit; however, it was not practical to reach an ideal and consistent trend of water level variation. The readings of some wells are not reliable but they can be designated as an active well.

The categorization of highly active and active is subjective based on both the on-time for the pump in the well, and the rate of water level rise during the recovery test.

**Inactive Wells (passive wells)**

W-1, W-2, W-6, W-18, and W-22 were observed to be inactive. The pumps of W-1, W-2, and W-22 at the time of site visit have been decommissioned and removed. W-6 and W-18 are off most of the time; however, some activity is logged during some months. W-22 used to be an active well as in Acres (1997) report. It is anticipated that W-2 and W-22 could contribute usefully in the dewatering of the spur if a pump was installed.

**Highly Active Wells**

W-4, W-9, W-10, W-12, W-19 can be considered highly active. Unfortunately, the results of recovery test for W-9 and W-10 can not be considered satisfactory. (A level meter was trapped inside the W-9 for the first day and results of the second day are not satisfactory. For W-10, the observed virtually constant water levels during the test contradict the reported high frequency of pumping starts. Hence, either the pumping on-time information is incorrect or the water levels were not read correctly).

**Active Wells**

The other 12 wells were active and responsive during the recovery test, including: W-3, W-5, W-7, W-8, W-11, W-13, W-14, W-15, W-16, W-17, W-20, and W-21. The active wells experienced some variations in their water level, suggesting that they are passing through an active aquifer and the well, filter, and/or riser pipe are in a satisfactory condition.

For the wells close to W-4 in Block-1, the results of the recovery test suggest that if W-4 fails for any reason, these wells cannot perform as its backup. This is because W-4 appears to be a significantly more active, productive, and efficient well than its neighbor; when considering that while the water level variations for W-3, W-5, and W-7 were limited to 0.41, 0.34, and 0.15m, the water level variation in W-4 (from Min 18 to 300) was 1.75 m. The first site visit observations, noted in Section 3.2.1, also confirm this suggestion.

## 4.8 Pressure Relief Wells – Comments on Potential Service Life

A description of the Muskrat Falls system is presented in Section 2. It is to be noted that no record of the materials used in the well screens was found, only that the riser pipes are polyvinyl chloride (PVC). Similarly, no record is available indicating the slot size or well screen opening. Figure 25 shows a typical pump and well as-built detail as provided by SNC-Lavalin (1982).

Commercially available well screens and riser pipes are available in a variety of materials such as black iron, galvanized iron, stainless steel, brass, bronze, fiberglass, and PVC. The performance of the well materials over time depends on several factors including:

- strength;
- resistance to damage by servicing operations;
- resistance to attack by chemical constituents in the groundwater; and
- maximum depth of well installation.

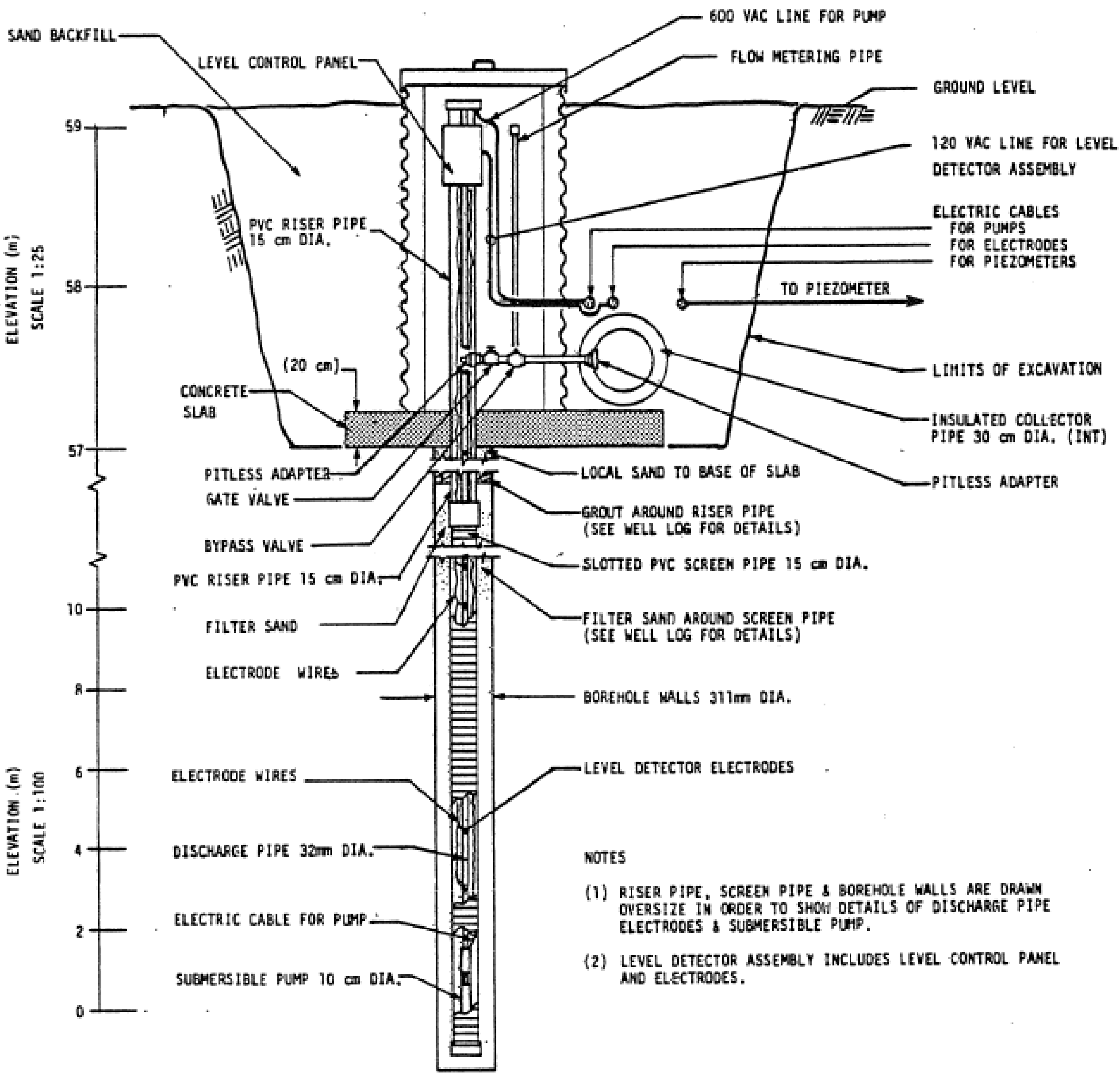



**Figure 25 – Typical pump and well as-built detail provided by SNC-Lavalin (1982)**

### *4.8.1 Screen Materials*

Stainless steel is a very stable material in most environments; however it is relatively expensive. Type 304 stainless steel has excellent corrosion resistance, whereas Type 403 stainless steel has moderate corrosion resistance. Low-carbon steel for use in a wire-wrapped screen may be economical; however it has no corrosion resistance. Brass and bronze are extremely expensive for this use and may not be completely stable in acidic environments. Fiberglass may have some limited use: however, it has not been used in a wide range of environments. PVC appears to be very stable and easy to install; however it is a relatively weak material and can be easily damaged. The combination of ferrous and nonferrous metals such as a brass screen and a steel riser pipe may induce electrolysis and result in deterioration of materials.

### *4.8.2 Selection of Materials*

Generally, pressure relief wells are designed and installed to protect the foundation of structures. As such, the selection of materials should be based on costs and performance over the life of the structure that is being protected. The choice of a well screen for long-term installation will depend on three factors including:

- water quality;
- potential presence of iron bacteria; and
- strength requirements.

A water quality test will provide information on the type of groundwater and whether it is corrosive and/or encrusting. Enlargement of screen openings due to corrosion or abrasion due to suspended fines in groundwater can cause progressive movement of fines into the well. Therefore it is important to ensure that a well screen be fabricated from corrosion-resistant material for installation in corrosive groundwater environments, and similarly if encrusting groundwater is expected, then future treatments may include acidification. If iron bacteria are expected to be present then selection of material should consider repeated chemical treatments. Strength of material needs to be considered for deeper installations, as does maximum compression and tensile forces during installation and potential physical treatments during development and maintenance activities.

A properly designed and installed filter should be considered for long-term performance of a pressure relief well. In order to prevent infiltration of foundation sands and silts into the filter, the filter gradation should meet the stability requirement that the 15 percent size of the filter should not be greater than 5 times the 85 percent size of the foundation materials. Special blends of hard durable particles may be required to maintain long-term performance of permanent relief wells.

Proper development of pressure relief wells, which may include surging and air lifting and pumping, is also necessary to further develop the zone around the well filter. Accumulation of silt in the well may indicate a breakthrough of silt materials in the well filter and as a result, an ineffective filter.

### *4.8.3 General Performance of PVC Pressure Relief Well Systems*

PVC and stainless steel appear to be the most common materials used in the construction of pressure relief well systems. While PVC is generally less costly than stainless steel, other factors should be considered in the selection of the material. Stainless steel and PVC systems have been successfully used for many years and should be expected to last in compatible environments for at least 50 years. The longevity of pressure relief systems may be more dependent on the installation method rather than the type of materials used. In addition to the above-noted chemical concerns associated with various materials, the depth of installation, type of host materials and pressures may also be of concern. The use of PVC materials in coarse alluvial materials at depths greater than 40 m is generally not recommended due to the potential deformation of the pipe and/or screen. At Muskrat Falls, the new wells will be 60 m or deeper. Specific procedures need to be used for the installation of PVC systems such as considering the heat of hydration of cement grouts and the use of chemicals which may degrade PVC materials. For some installations, the use of a stainless steel screen and a PVC riser pipe has been used to combine the best features of both materials.

Pressure relief wells that have been constructed as a temporary measure may not have an installed filter, which may result in the gradual migration of fines into the well. In some cases this type of well can be rehabilitated by redevelopment of the well, surging, etc. Therefore, prior to installation the expected longevity of the wells should be considered in the design.

Our experience with a number of pressure relief systems is that there appears to be more concern associated with the installation of PVC systems; however, this may be due to installation issues rather than material issues and the expected longevity of the system. Some of these systems were designed for a 20-25 year performance life and have been in place in excess of 25 years without any rehabilitation measures.

# 5. Summary and Conclusions - Current Groundwater Regime

In this section, the results of the assessment of the current groundwater regime within the spur are summarized:

- Dividing the spur groundwater regime into three zones or blocks was suggested by Acres (1997): namely southern, central, and northern zones. Historical observations show that these zones are influenced by different water sources and the areas impacted by the dewatering system are different. The greatest drawdown is generated in the southern zone while the lowest drawdown was found in the northern zone.
- The groundwater levels in some wells in the central zone (Block-2), wells W-9 to W-11, are significantly higher than their historical values. These current groundwater elevations are also higher than other wells in the vicinity. The nearby piezometer, P-D, also shows the groundwater at a high elevation which confirms the high water elevation in the block. Recently, the piezometric level in P-D has risen about 2 m in comparison with its lowest value recorded in 2001.
- The piezometers in the northern block indicate that the piezometric elevation in this block has recently increased about 1 to 2.5 m. This increasing trend started in 2005 and most of the piezometric levels have followed this trend.
- Hydrogeological sections show that the water table has decreased from the natural groundwater elevation under the influence of the dewatering system. The groundwater depression in Section C1-C1, located in the central block, is less tangible. In order to gain a complete understanding of the water table in these sections and to be able to monitor the spur piezometric elevation, it is necessary to install additional piezometers.
- The evaluation of precipitation, temperature, and upstream river water level indicates that the recent increases in piezometric levels are independent of natural causes, specifically precipitation, and upstream river water level. Acres (1997) also indicated that the northern block is mainly influenced by groundwater flow from the north valley slope rather than the flow from upstream.
- Considering all the uncertainties in the dewatering system data recording and transmission as mentioned in Section 4.6, historical pump operation data indicates that the pumps in the northern block are generally inactive (Figure 24). The average monthly on-time of the northern block is significantly lower than the other two blocks. This observation is to be compared within an observed rise in groundwater levels in piezometers within this block. Despite the increase in the on-time hours in recent years in comparison to 2001, it is clear that pumping in the north block is inefficient.
- The recovery test and predictive calculations indicate that the effect of a short term system shutdown/interruption on the piezometric elevations is not significant. Nevertheless, the current piezometric elevation especially in the southern block should be maintained. Conversely, a long time is needed to draw down the water table, should level rises occur.
- It is necessary to investigate the reason for decommissioning of pumps in W-2 and W-22 as these wells were reported to be active in Acres (1997) report. It is recommended to reactivate these wells, in addition to W-1.

- The observed fine sand, clay, and twigs in the system discharge water, after total shut down, and the fine sand, silt, and clay witnessed specifically in W-4 suggest that filters and/or screens of several wells and collector pipes are not functioning properly. This is a major concern and indicative of continuing system inefficiency and potential well collapse.

# 6. Final Comments and Recommendations

The dewatering system has operated continuously since November 1981 and there has been no further major landslide activity on the spur. The purpose of the installation has, therefore, been fulfilled. However, the system is currently 26 years old, and some rehabilitation work is required to ensure its continued operation for the next 10 years.

## 6.1 Wells

Three of the pumps have been decommissioned; several of the remaining pumps appear relatively inactive while some pumps are very active. The continued dependence of the dewatering system, which is now 26 years old, on primarily one well, W-4, and on several wells which have been discharging fines through the screen and the filter for many years, is not advisable. As a result of the fines discharge, the existence of cavities beyond the screens cannot be discounted, the collapse of which could damage or destroy one or more wells. To maintain and improve the dewatering system beyond its current level and therefore ensure its continued operation for an additional 10 year period, it is recommended to carry out the following steps:

### *6.1.1 Well Cleaning and Detailed System Evaluation*

- All pumps, risers, and level sensors should be pulled, inspected, and cleaned. All specifications and details of pumps, motors and sensor positions should be recorded and all sensors and relays tested.
- The wells have been in continuous operation for 26 years, and based on an inspection of one well (W-4) during the September 2007 site visit (and the data of the 1994-1996 site activities) there is a need to repeat the flushing of the wells similar to the activities in 1996. Such flushing should be undertaken by a qualified specialist company with experience in well drilling, installation and maintenance.
- It would be also appropriate to consider the use of a television camera to inspect the screen and confirm its integrity. To clarify water in the well and allow better visibility, it may be necessary to use a flocculent agent (Calgon e.g.). The use of a down-hole $\gamma$-$\gamma$ Test (Reactive Absorption or Density Test) is also recommended to allow the detection and an assessment of the extent of possible voids beyond and within the filter given the volume of fines which have passed through the filter and screen since 1981. The $\gamma$-$\gamma$ Test is a standard well logging technique.
- A detailed evaluation should be prepared of the condition of each current well installation and the surrounding ground and conclusions drawn with respect to its individual status and its status within the system as a whole.

### *6.1.2 New Well and Piezometer Installations*

- It is Hatch's current judgement, given the data presently available, that to ensure a satisfactory performance of the dewatering system for the next 10 years and to maintain the physical asset of the Muskrat Falls ridge as a whole, 6 or 7 new stainless steel wells need to be installed together with 4 or 5 new double standpipe piezometers, as mentioned previously (each standpipe in a separate hole). The construction of the wells is estimated to approximately cost $930,000 plus engineering and management fees, as described in Appendix E. There is a mobilization and demobilization cost for both the construction of piezometers and wells which is approximately $90,000, hence the total cost will be in excess of $1 million.

- The above mentioned evaluation and the progressive installation and testing of new wells will indicate the exact number and location of the new wells. After testing the new wells to ensure that they are able to achieve the groundwater levels close to the historical low levels, it may be recommended that the original wells are placed into a backup mode for one or two years whereupon they may be decommissioned. This will increase the reliability of the system and will limit the risk of not reaching the target pumping levels in the new wells. The new wells should be distributed among the three blocks close to the most active wells, as follows:
    - In the Southern Block, 2 wells, close to W-4 and place W-4 into a backup mode
    - In the Central Block, 3 wells, close to W-9, W-10, and W-11 and place W-9, W-10, and W-11 into a backup mode
    - In the Northern Block, 2 wells, close to W-19 and W-20 and place W-19 and W-20 into backup mode

### *6.1.3 Other Recommendations*

- Pumps should be installed in wells W-1, W-2, and W-22
- Until the installation of an automatic data acquisition system, the well water elevations and piezometers readings should be recorded and interpreted manually.
- Consideration should be given to the installation of a flow monitoring device at the collector pipe outlet, the output from which could be transmitted to Goose Bay with pump function data.

## 6.2 Piezometers

The originally installed piezometers were struck by lightning in 1983. The new standpipe piezometers, installed in 1997, are partially functional. Only 7 of the 10 suggested piezometers were installed and one of these (P-C) is believed to be out of order. The recommendations for piezometer upgrades can be categorized into three groups:

- In order to develop a more complete understanding of the phreatic surface and to assist in the creation of hydrogeological cross sections, such as those presented in Section 4.4, and in other sections to be developed in the future, it is suggested to install 4 new double standpipe piezometers. It is estimated that this will cost in the order of $120,000 plus engineering and management fees (Details are provided in Appendix E). The locations of the new piezometers are suggested as follows as shown in Figure 4:
    - One piezometer to the west of W-4 (Section A1-A1)
    - Two piezometers on each side of W-9 (project to Section C1-C1)
    - One piezometer in the location of the previously proposed piezometer P-E (project to Section C1-C1)
- Installation of data acquisition systems and automatic data transmission for all piezometers and several wells converted to standpipe piezometers (W-2, W-4, W-9, W-13, W-19, and W-22)

representing the performance of each well block. The specifications and a cost estimate for the Data Acquisition System and instrumentation are provided in Appendix D.

- Until such time as the system is automatic, recording of the piezometric elevations should continue to be undertaken on a frequent basis (monthly), similar to the readings performed in recent months. It is also suggested to perform well elevation reading a few times every year, taking into account all safety issues. There are few records in some years; (i.e. in 2003, the piezometer elevations were recorded only two times; in 2005, three times; and in 2006, three times).

## 6.3 Electrical Supply

From the SNC-Lavalin construction report, it was noted that the main 600 V AC line exiting the control shelter was divided into four runs of 600 V AC. The 600 V AC cable runs powered three groups of 6 motors and one group of 4 motors in series. The grouping of motors was not identified. Little is known about the power cables feeding the pumps. It is recommended that all electrical components from the control panel outward be tested to ensure the electrical infrastructure is not deteriorating.

Back-up power should also be provided in the event of a power outage (while the WTO indicated a generator was on site for this purpose, this is not the case).

## 6.4 Data Monitoring and Transfer

The data collected by Hydro for the pumps appears unreliable due to ON/ON and OFF/OFF sequences. The ON/OFF data originates from the pump level relay and is processed at the MF Control Shelter before being transmitted by VHF radio to Hydro's offices.

Hydro should investigate the cause of the troublesome data with a review of all overload relays and sensors. The remote terminal unit should undergo self testing. To ensure the data being collected is meaningful, a computer should be installed at the shelter to collect the data before transmission. This data would then be compared with the transmitted data to determine whether the errors are caused by the monitoring or the radio transmission components of the system. It is understood that the transmission components have been upgraded in recent years, and if it is concluded that they are still at fault, the following options for data transmission should then be explored:

- Satellite technology.
- Fibre optic/communications cable along the existing pole line to Goose Bay.
- Data transmission over existing power lines.
- Additional upgrades to VHF system.

## 6.5 General Recommendations

It is recommended that the following activities be carried out to assist with the ongoing dewatering operation.

- Implement procedures for responding to high-level alarms.
- Provide back-up pump and motor capability at site or at Hydro's facilities in Goose Bay.

- Clear trails to all piezometers (1997 and original standpipes), and weirs and install safety hand lines as appropriate.
- Re-bury the exposed portion of the inclined collector pipe and re-grade the slope to prevent further erosion and potential damage. Repair and/or replace the outfall heater and insulation as specified in the original designs. Clear the area of outfall culvert and reinstate the entrance way to the discharge point and provide devices to ensure safe access.

# Appendix A

## Site Visits Photographs

**Downstream slope (Site Visit -1)**

**Downstream slope (Site Visit -1)**

**Erosion at downstream slope toe (Site Visit -1)**

**Pull-out of the pump in W4 (Site Visit -1)**

**Silt and fines in W4 riser pipe (Site Visit -1)**

**Cloudy water from W4, after pump replacement (2.5 hours of system shutdown) (Site Visit -1)**


**Common pump operation before the replacement of pump at W4 (Site Visit -1)**

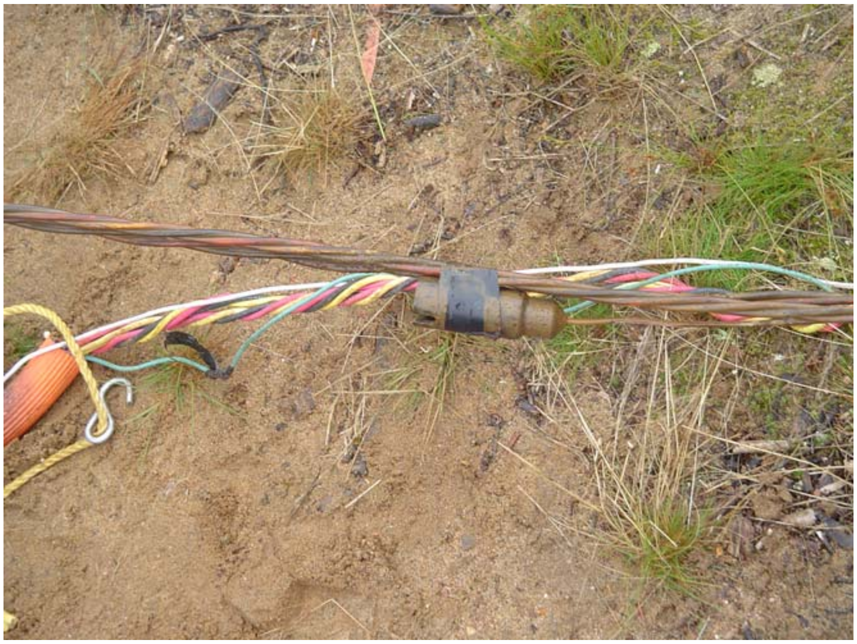

**Control panel after system restoration (Site Visit -1)**

**Decommissioned pumps (Site Visit -1)**

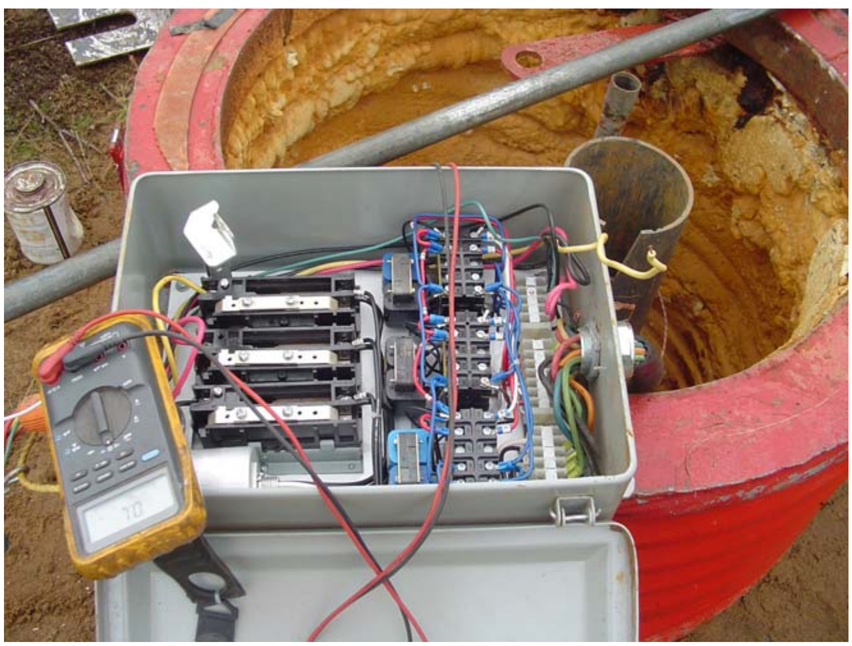
**Discharge water from outfall pipe (Site Visit -1)**

**Shelter room at water outfall (Site Visit -1)**

**25kV Power to Control Shelter (Site Visit -1)**



**Level Electrode removed from W4 (Site Visit -1)**



**Electrical Junction Box in W4 (Site Visit -1)**

**Water quality at outlet – Cloudy with silt and twigs (Site Visit -2)**

**Recovery test (Site Visit -2)**

# Appendix B

## Recovery Prediction for Piezometers

## Recovery prediction for piezometers:

In this Appendix, the experimental results from the recovery test are compared with some approximate calculations. The main purpose of these calculations is to predict the water table rises in the piezometers P-A and P-B, which are 60 m away from W-4, should any interruption occur in pumping in W-4. The graphical data, using the results of the recovery test, is also used for the prediction of water table rises.

**2 hours (120 min) prediction**

P-A and P-B are close to W-4, which is the most active well, about 60 m away. A rough calculation predicts a rise of about 9.3 cm in those piezometers after 2 hours of the pump shutdown. It should be mentioned that these calculations are based on available information like the annual on-time for pump in well W-4 which could be approximate. The accuracy of these calculations should be controlled with in-site observations like the performed recovery tests. The calculations and some assumptions used in this Appendix is based on Groundwater and Wells by F.G. Driscoll (1986 - second edition). The main assumptions and calculations are as follows:

Water discharge rate: $q_4$ = ~ 2.5 (gallon per bucket)*4.55 (L/bucket)/12 (s) = 0.95 L/s

Total on-time for W-4 (2006) = 44409 min

Average on-time/day = 44409 (min) /365 (day) =122 min/day

Average daily discharge = Q = 60 (s/min)*122 (min/day)*.95 (L/s)/1000 ($m^3$/L) = 6.95 $m^3$/day

Observation distance from well r = 60 m, Depth of aquifer = 35 m

$K = 1 \times 10^{-5}$ m/s (compatible with Acres (1994))

Coefficient of transmissivity T = $1 \times 10^{-5} \times 35 \times 86400$ = 30.24 $m^2$/day (assuming aquifer height equal to 35 m)

Coefficient of storage, S (confined) = $10^{-5}$ (Driscoll, 1986)

t = 120 min = 1/12 day

$u = r^2S/4Tt$ (Driscoll, Eq. 9.5a) = $3.6\times10^{-3}$ → W(u) = 5.1 (Driscoll, Appendix 9.E)

Drawdown (here drawback), S = $1/4\pi \times Q/T\, W(u)$ = 9.3 cm (Driscoll, Eq. 9.5)

(This formula is normally used for drawdowns resulting from pumping activities; however, in this section it is utilized for water level increase due to pumping shut down).

**5 hours (300 min) prediction**

In this case, the above calculation can be repeated assuming that the pumping terminates after 7 days, equal to 300 minutes:

t = 300 min = 7 days

$u = r^2S/4Tt = 1.4\times10^{-3}$ → W(u) = 6.0

Drawdown (here drawback), S = $1/4\pi \times Q/T\, W(u)$ = 11.0 cm

**7 days (10080 min) prediction**

Repeating the above and assuming that the pumping terminates after 7 days (10800 minutes):

t = 10800 min = 7 days

u = $r^2S/4Tt = 4.3 \times 10^{-5} \rightarrow W(u) = 9.5$

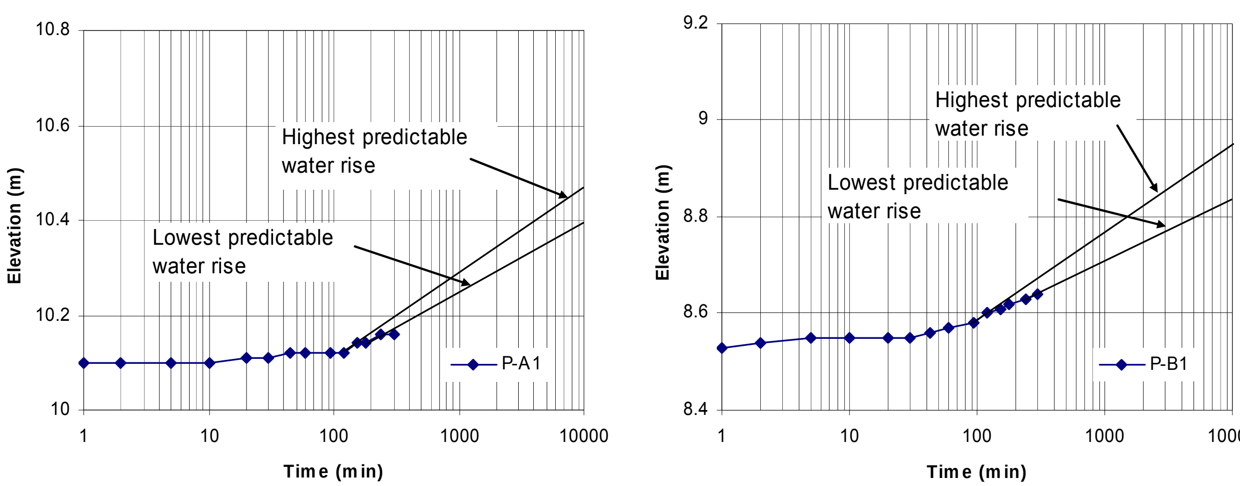
Drawdown (here drawback), S = $1/4\pi \times Q/T\ W(u) = 17.4$ cm

**Graphical estimate for 7 days system shutdown**

Here, it is intended to predict the water rise in piezometers P-A1 and P-B1 using the recovery test results and graphical methods. Figures B1-(a) and B1-(b) show the results of recovery test on piezometers elevation rise versus time for 5 hours (300 min), on a semi-logarithmic scale. Assuming that the level rise in the piezometers is linear versus time in logarithmic scale, the level variation after 7 days (10080 min) can be predicted as:

P-A1: between 0.29 and 0.37 cm

P-B1: between 0.30 and 0.42 cm




(a) (b)

**Figure B1 - Water level rise in piezometers using graphical method (a) P-A1 (lower tip), (b) P-B1 (lower tip)**

It can noticed that the level rise derived from the graphical method is considerably higher than the calculation method, about 1.6 to 2.4 times the graphical method. This is because in the graphical method, it is assumed that the rate of variation in logarithmic scale stays constant; however, as the water rises, hydraulic gradient decreases accordingly. It is recommended to consider the experimental results as conservative values as the experiments were performed for only 5 hours, which may not be considered long enough for a 7-day prediction.

**Results of recovery test on piezometer elevations on second day of recovery test**

The reading of three piezometers: P-F (2 tips), P-G, and P-J (2 tips), were left for the second day of the recovery test. The water level in most of these piezometers increased during the first day shutdown period, and unfortunately were not read gradually in the first day. It was noticed that the water level increased in these piezometers to some extent in the first day and did not return to its original level after about 19 hours of pumping. Table B1 shows the level variations for the three piezometers and the 5 tips.

**Table B1**
**Variations in Piezometer Water Elevations – November 7 and 8, 2007†**

| Piezometer | Distance from Pumping Line (m) | Original Water Elevation (m) | Water Elevation after the end of the First Day Recovery Test (m) | Water Elevation after the Second Day Recovery Test Relative to the First Day (m) |
|---|---|---|---|---|
| P-F1 | 40 | 12.51 | 12.62 ( + 0.11 m) | 12.61 (- 0.01 m) [a] |
| P-F2 | 40 | 12.29 | 12.58 ( + 0.19 m) | 12.46 (-0.12 m) |
| P-G | 90 | 18.04 | 18.08 ( + 0.04 m) | 18.05 (- 0.03 m) |
| P-J1 | 125 | 10.07 | 10.08 ( + 0.01 m) | 10.08 (- 0.00 m) |
| P-J2 | 125 | 11.23 | 11.31 ( + 0.08 m) | 11.33 (+0.02 m) |

† P-A1, P-B1, and P-D were not read during the second day of the northern block of wells

[a] The negative level increase during the second day of recovery test is negligible and is due to the probe successive wetting in a 9 mm tube.

P-J is about 125 m away from the wells line and experienced the lowest water table variation among all piezometers. P-F2 had the highest rise in water level among all piezometers; however, the magnitude is similar to P-A rise, 0.15 m, or P-B, 0.11 m. Considering that P-F2 is much closer to the pumping lines, this higher value is understandable. These results suggest that the piezometer variation curve in semi-logarithmic scale would be similar to Figure B1.

# Appendix C

## Recovery Test Results for Wells and Piezometers

### C1 – Nov 7 Readings

### C2 – Nov 8 Readings

# C1 – Nov 7 Readings

## Newfoundland and Labrador Hydro - Muskrat Falls

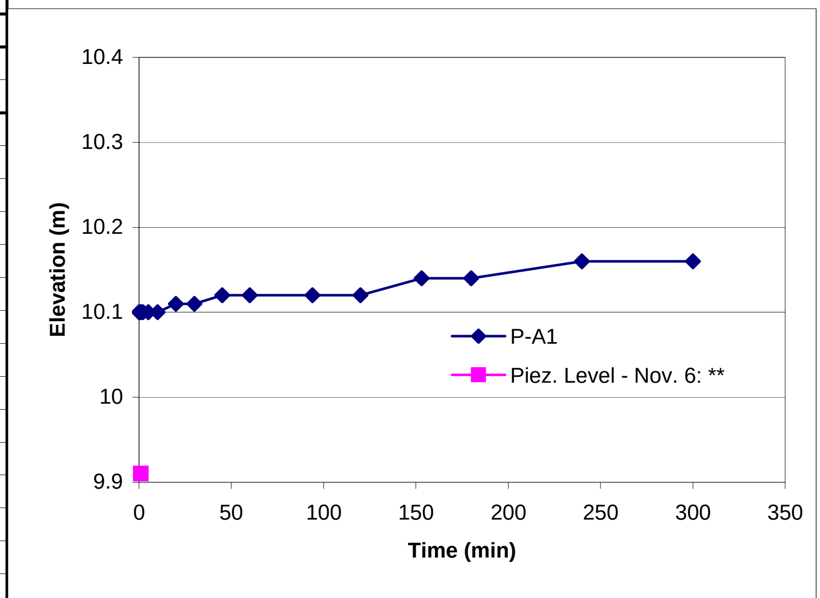
### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

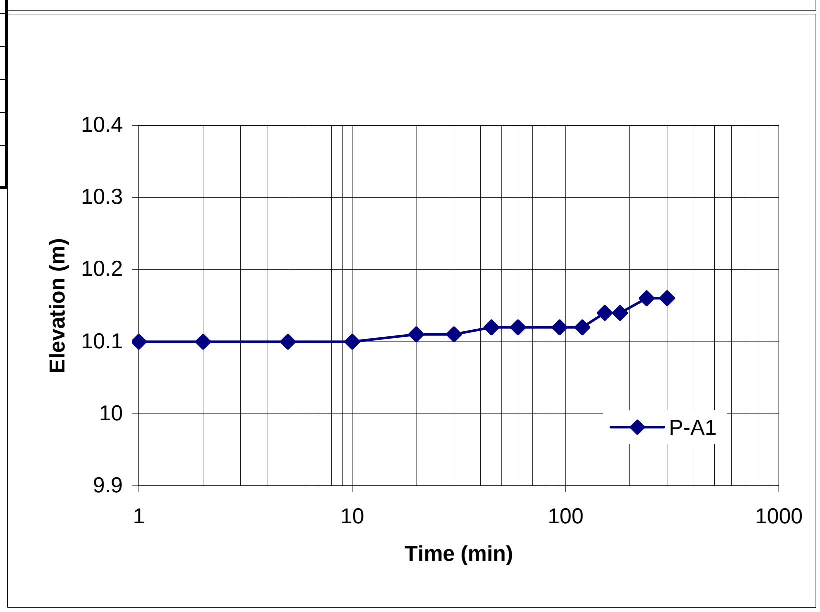
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-A1 | **Date:** | Nov. 7th 2007 | **Case El.:** | 61.81 |
| **Read By:** | P. BroomField | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-A1 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: ** | | |
| 0 | 51.9 | 9.91 |
| Nov 7, Recovery test: | | |
| 0 | 51.71 | 10.1 |
| 0.5 | 51.71 | 10.1 |
| 1 | 51.71 | 10.1 |
| 2 | 51.71 | 10.1 |
| 5 | 51.71 | 10.1 |
| 10 | 51.71 | 10.1 |
| 20 | 51.7 | 10.11 |
| 30 | 51.7 | 10.11 |
| 45 | 51.69 | 10.12 |
| 60 | 51.69 | 10.12 |
| 94 | 51.69 | 10.12 |
| 120 | 51.69 | 10.12 |
| 153 | 51.67 | 10.14 |
| 180 | 51.67 | 10.14 |
| 240 | 51.65 | 10.16 |
| 300 | 51.65 | 10.16 |
| | | |
| | | |
| | | |




* Relative to the top of casing

** The source of difference in the elevations at the two days is unknown. May be as a result of a different reference point at the first day.

## Newfoundland and Labrador Hydro - Muskrat Falls

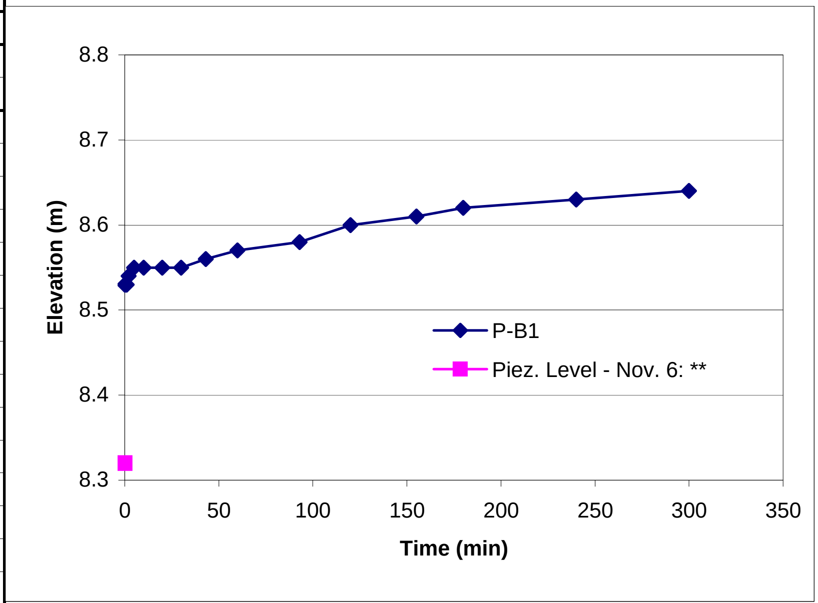
### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

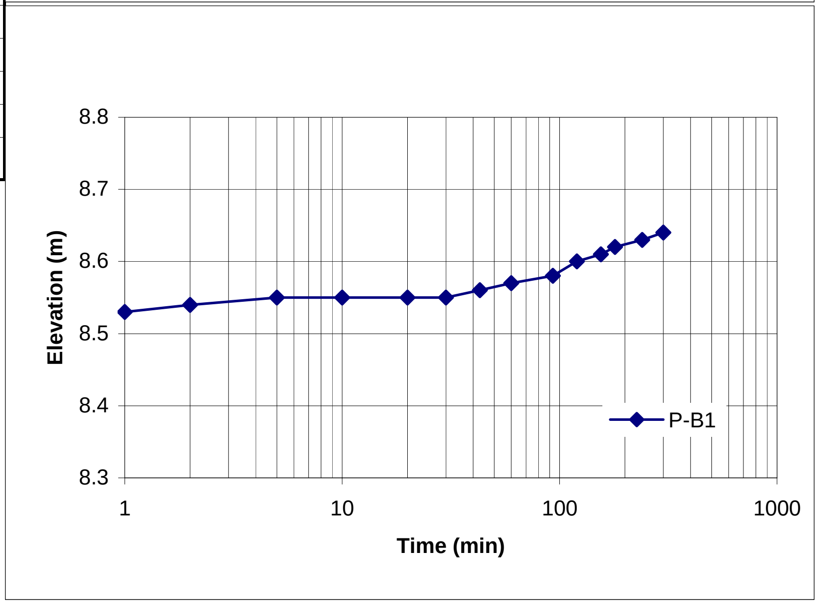
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-B1 | **Date:** | Nov. 7th 2007 | **Case El.:** | 60.22 |
| **Read By:** | P. Ashayer | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-B1 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: ** | | |
| 0 | 51.9 | 8.32 |
| Nov 7, Recovery test: | | |
| 0 | 51.69 | 8.53 |
| 0.5 | 51.69 | 8.53 |
| 1 | 51.69 | 8.53 |
| 2 | 51.68 | 8.54 |
| 5 | 51.67 | 8.55 |
| 10 | 51.67 | 8.55 |
| 20 | 51.67 | 8.55 |
| 30 | 51.67 | 8.55 |
| 43 | 51.66 | 8.56 |
| 60 | 51.65 | 8.57 |
| 93 | 51.64 | 8.58 |
| 120 | 51.62 | 8.6 |
| 155 | 51.61 | 8.61 |
| 180 | 51.6 | 8.62 |
| 240 | 51.59 | 8.63 |
| 300 | 51.58 | 8.64 |
| | | |
| | | |
| | | |




* Relative to the top of casing

** The source of difference in the elevations at the two days is unknown. May be as a result of a different reference point at the first day.

# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

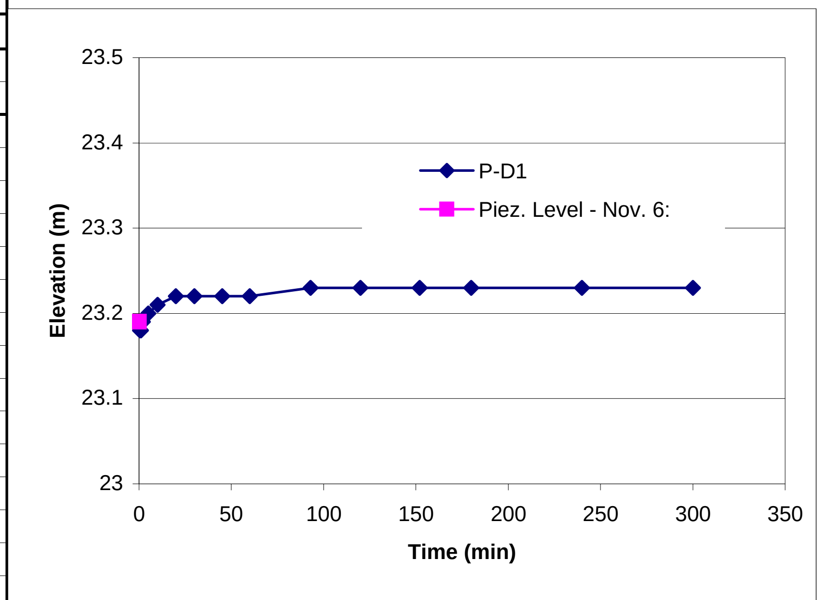
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-D1 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.7 |
| **Read By:** | D. O'Driscoll | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

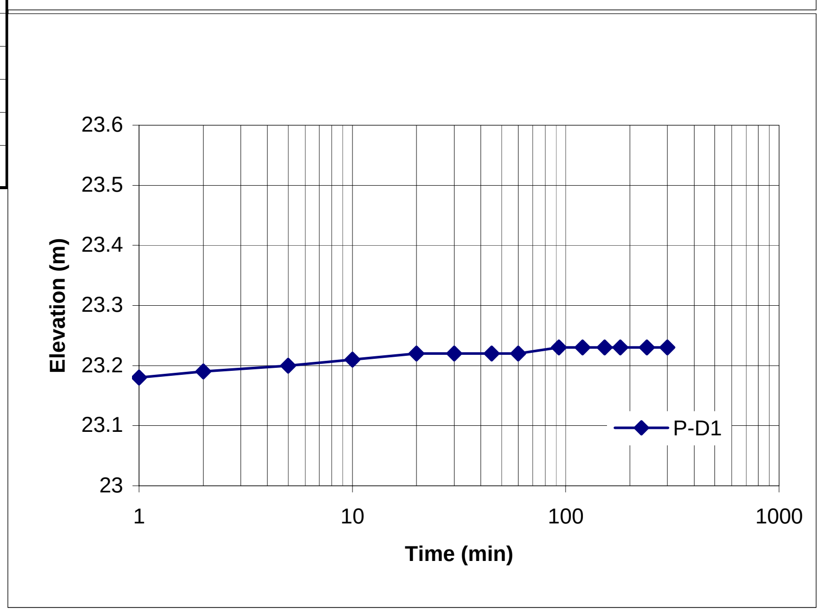
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-D1 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: | | |
| 0 | 36.51 | 23.19 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 0.5 | 36.52 | 23.18 |
| 1 | 36.52 | 23.18 |
| 2 | 36.51 | 23.19 |
| 5 | 36.5 | 23.2 |
| 10 | 36.49 | 23.21 |
| 20 | 36.48 | 23.22 |
| 30 | 36.48 | 23.22 |
| 45 | 36.48 | 23.22 |
| 60 | 36.48 | 23.22 |
| 93 | 36.47 | 23.23 |
| 120 | 36.47 | 23.23 |
| 152 | 36.47 | 23.23 |
| 180 | 36.47 | 23.23 |
| 240 | 36.47 | 23.23 |
| 300 | 36.47 | 23.23 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

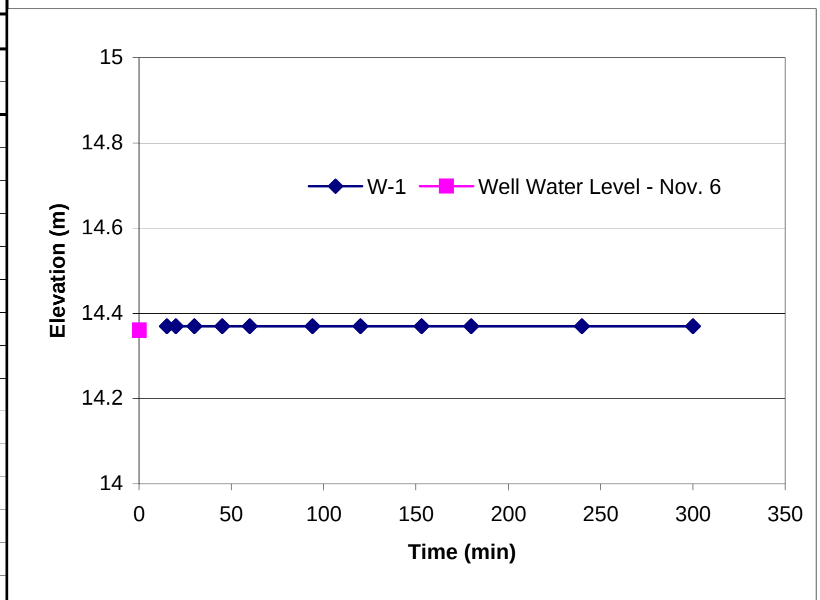
### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

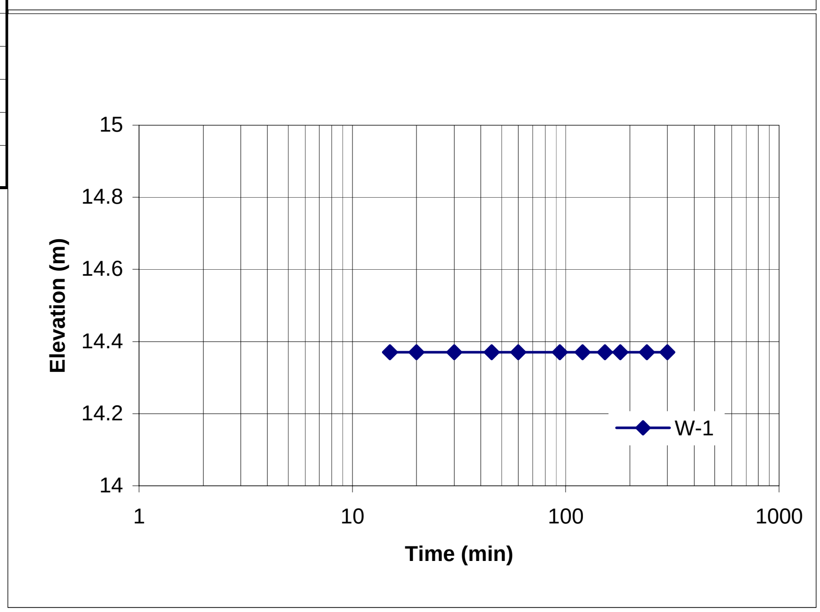
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-1 | **Date:** | Nov. 7th 2007 | **Case El.:** | 57.79 |
| **Read By:** | P. BroomField | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-1 Reading (m)* | W-1 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | 43.43 | 14.36 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 43.42 | 14.37 |
| 20 | 43.42 | 14.37 |
| 30 | 43.42 | 14.37 |
| 45 | 43.42 | 14.37 |
| 60 | 43.42 | 14.37 |
| 94 | 43.42 | 14.37 |
| 120 | 43.42 | 14.37 |
| 153 | 43.42 | 14.37 |
| 180 | 43.42 | 14.37 |
| 240 | 43.42 | 14.37 |
| 300 | 43.42 | 14.37 |
| | | |
| | | |
| | | |




* Relative to the top of casing

## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

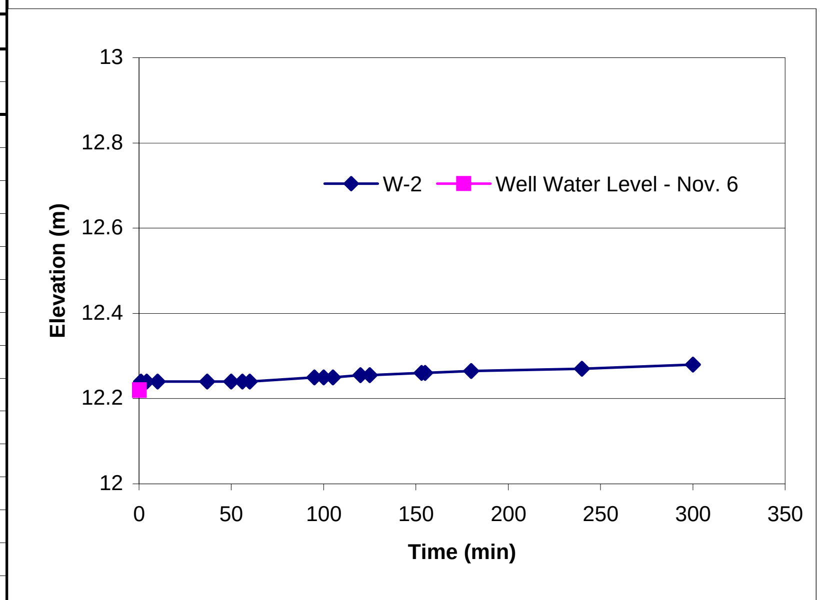
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-2 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.66 |
| **Read By:** | J. Mitchell | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

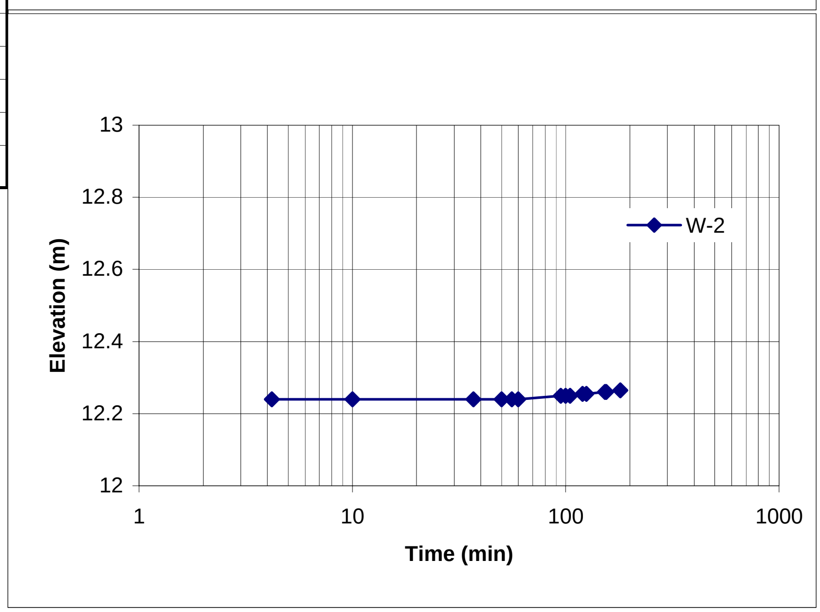
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-2 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 47.44 | 12.22 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 1 | 47.42 | 12.24 |
| 4.2 | 47.42 | 12.24 |
| 10 | 47.42 | 12.24 |
| 37 | 47.42 | 12.24 |
| 50 | 47.42 | 12.24 |
| 56 | 47.42 | 12.24 |
| 60 | 47.42 | 12.24 |
| 95 | 47.41 | 12.25 |
| 100 | 47.41 | 12.25 |
| 105 | 47.41 | 12.25 |
| 120 | 47.405 | 12.255 |
| 125 | 47.405 | 12.255 |
| 153 | 47.4 | 12.26 |
| 155 | 47.4 | 12.26 |
| 180 | 47.395 | 12.265 |
| 240 | 47.39 | 12.27 |
| 300 | 47.38 | 12.28 |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

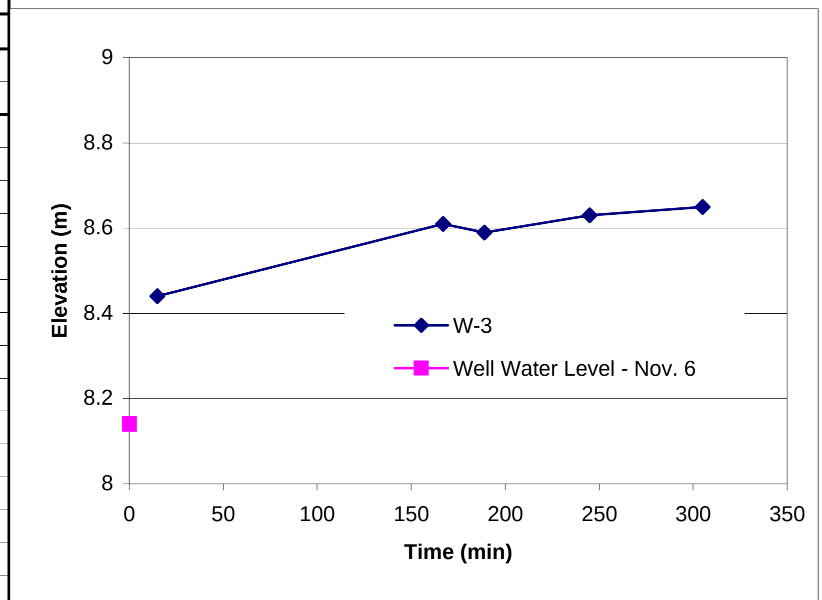
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-3 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.67 |
| **Read By:** | J. Mitchell | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

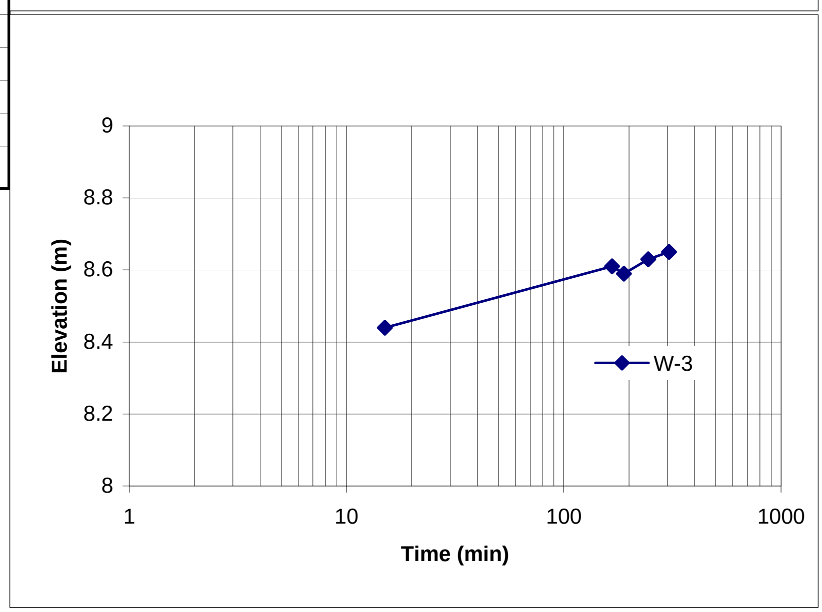
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-3 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 51.53 | 8.14 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 15 | 51.23 | 8.44 |
| 167 | 51.06 | 8.61 |
| 189 | 51.08 | 8.59 |
| 245 | 51.04 | 8.63 |
| 305 | 51.02 | 8.65 |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

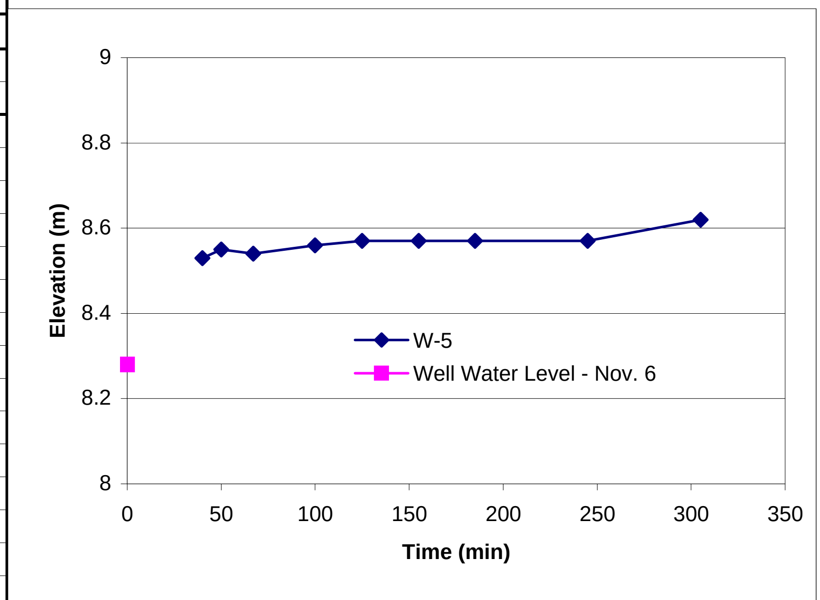
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-5 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.55 |
| **Read By:** | N. Jette | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

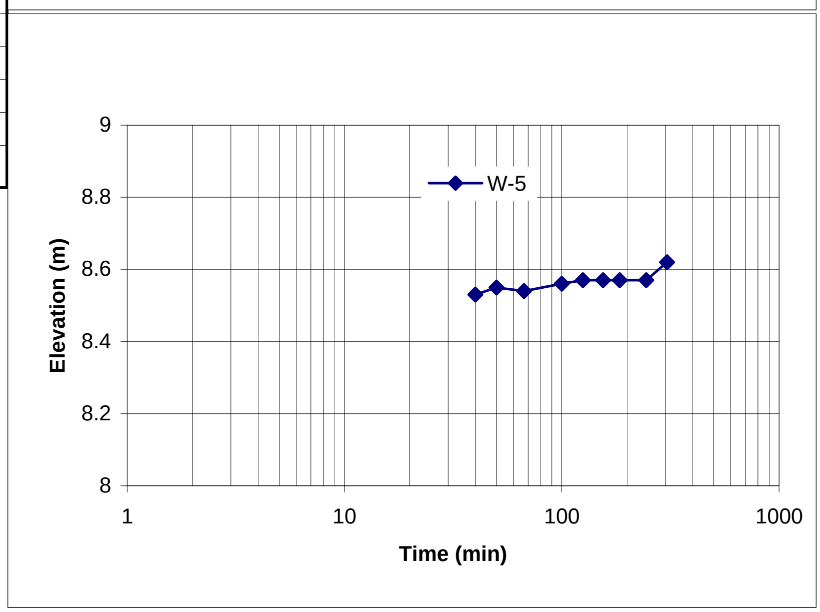
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-5 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 51.27 | 8.28 |
| Nov 7, Recovery test: | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| 40 | 51.02 | 8.53 |
| 50 | 51 | 8.55 |
| 67 | 51.01 | 8.54 |
| 100 | 50.99 | 8.56 |
| 125 | 50.98 | 8.57 |
| 155 | 50.98 | 8.57 |
| 185 | 50.98 | 8.57 |
| 245 | 50.98 | 8.57 |
| 305 | 50.93 | 8.62 |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

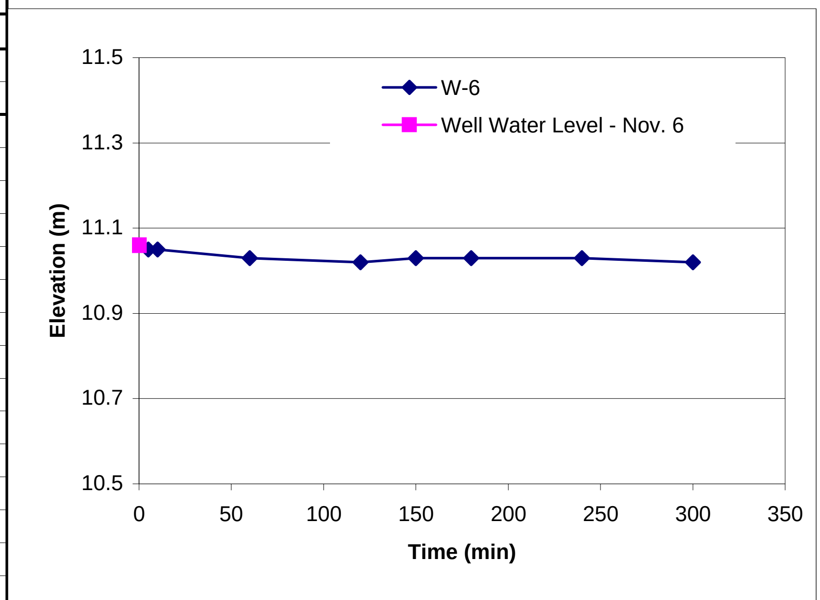
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-6 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.53 |
| **Read By:** | L. Rich | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

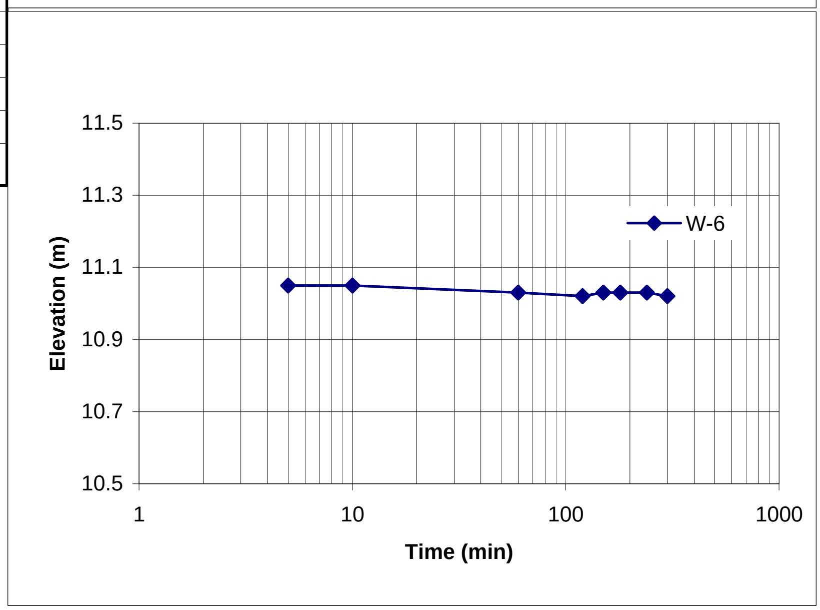
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-6 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 48.47 | 11.06 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 5 | 48.48 | 11.05 |
| 10 | 48.48 | 11.05 |
| 60 | 48.5 | 11.03 |
| 120 | 48.51 | 11.02 |
| 150 | 48.5 | 11.03 |
| 180 | 48.5 | 11.03 |
| 240 | 48.5 | 11.03 |
| 300 | 48.51 | 11.02 |

* Relative to the top of casing



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

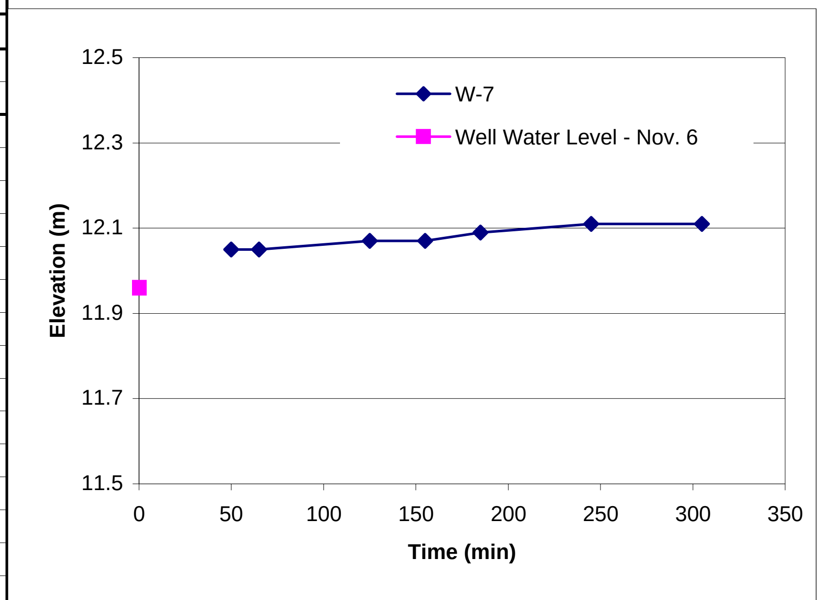
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-7 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.51 |
| **Read By:** | L. Rich | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

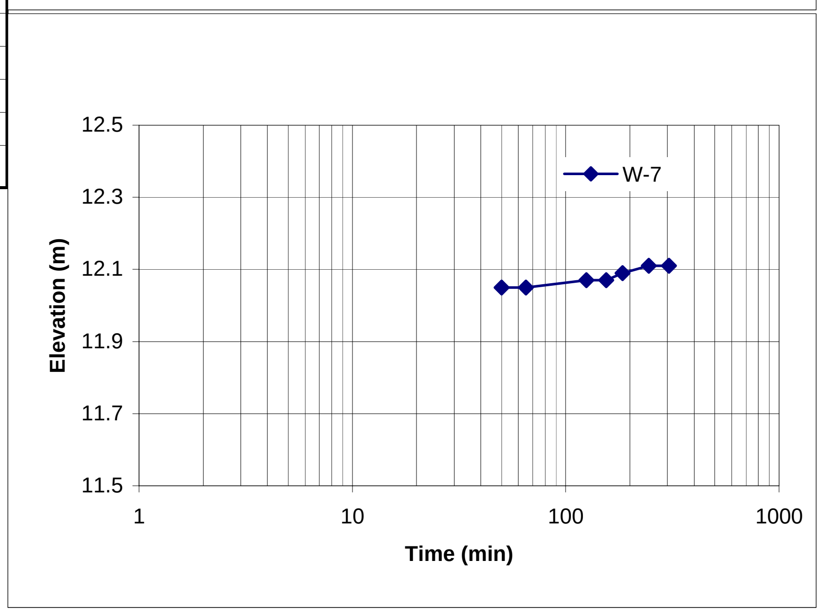
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-7 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 47.55 | 11.96 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 50 | 47.46 | 12.05 |
| 65 | 47.46 | 12.05 |
| 125 | 47.44 | 12.07 |
| 155 | 47.44 | 12.07 |
| 185 | 47.42 | 12.09 |
| 245 | 47.4 | 12.11 |
| 305 | 47.4 | 12.11 |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

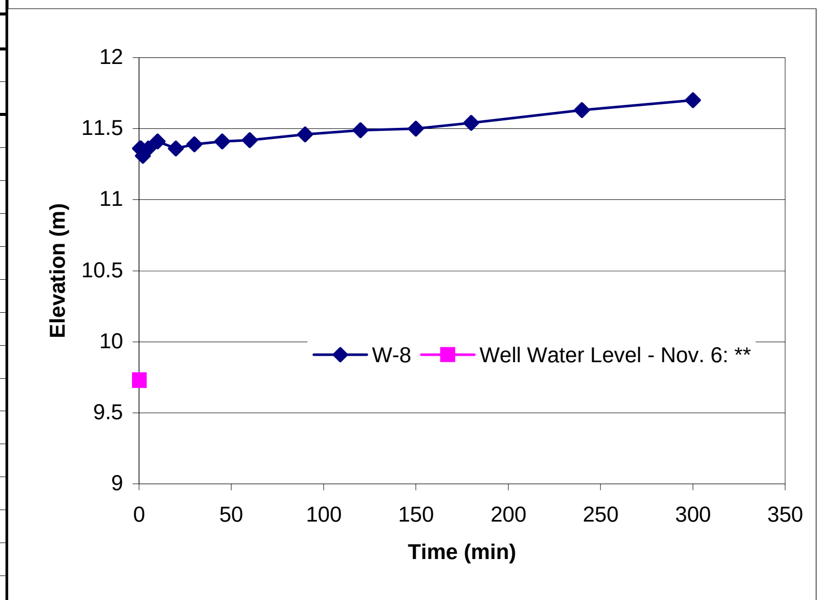
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-8 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.46 |
| **Read By:** | B. Crowe | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

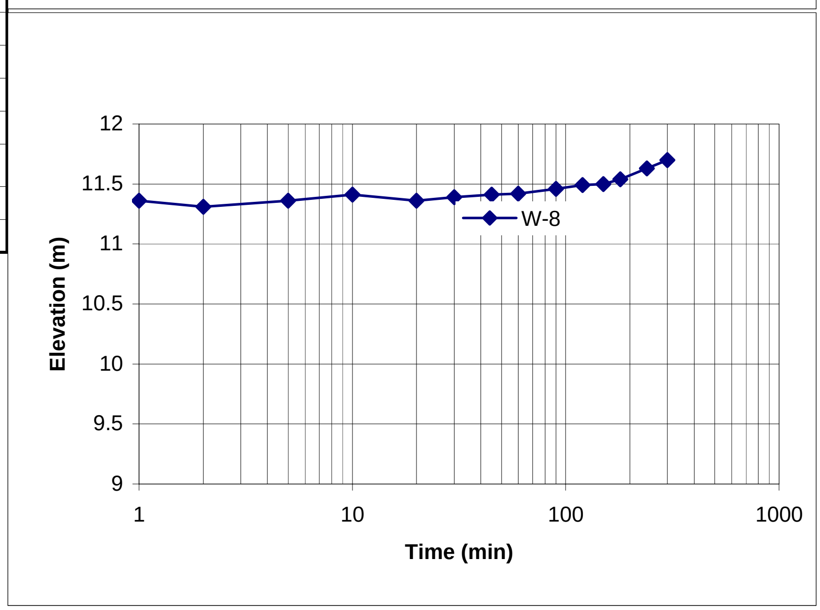
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-8 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6: ** | | |
| 0 | 49.73 | 9.73 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 0.5 | 48.1 | 11.36 |
| 1 | 48.1 | 11.36 |
| 2 | 48.15 | 11.31 |
| 5 | 48.1 | 11.36 |
| 10 | 48.05 | 11.41 |
| 20 | 48.1 | 11.36 |
| 30 | 48.07 | 11.39 |
| 45 | 48.05 | 11.41 |
| 60 | 48.04 | 11.42 |
| 90 | 48 | 11.46 |
| 120 | 47.97 | 11.49 |
| 150 | 47.96 | 11.5 |
| 180 | 47.92 | 11.54 |
| 240 | 47.83 | 11.63 |
| 300 | 47.76 | 11.7 |
| | | |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing
** Variation in elevations is due to high variations in well water level.



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

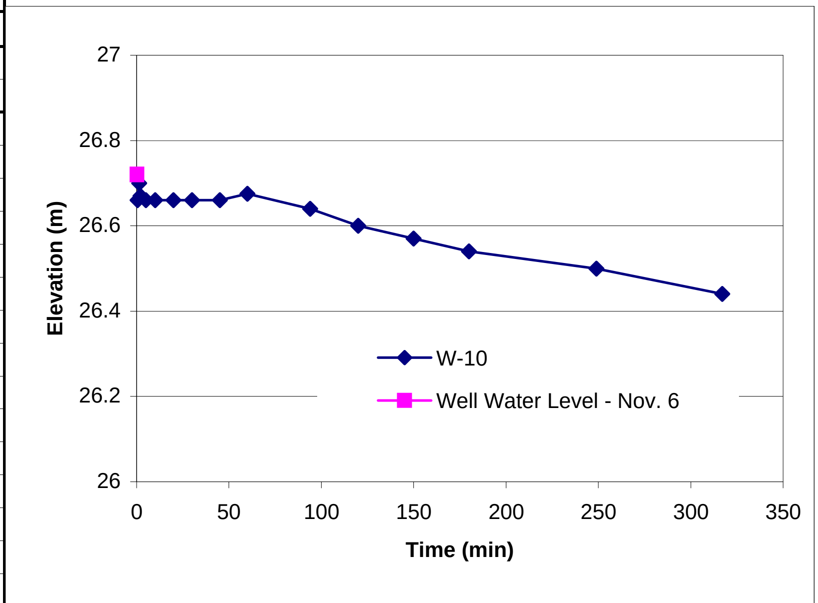
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-10 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.4 |
| **Read By:** | L. Evans | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

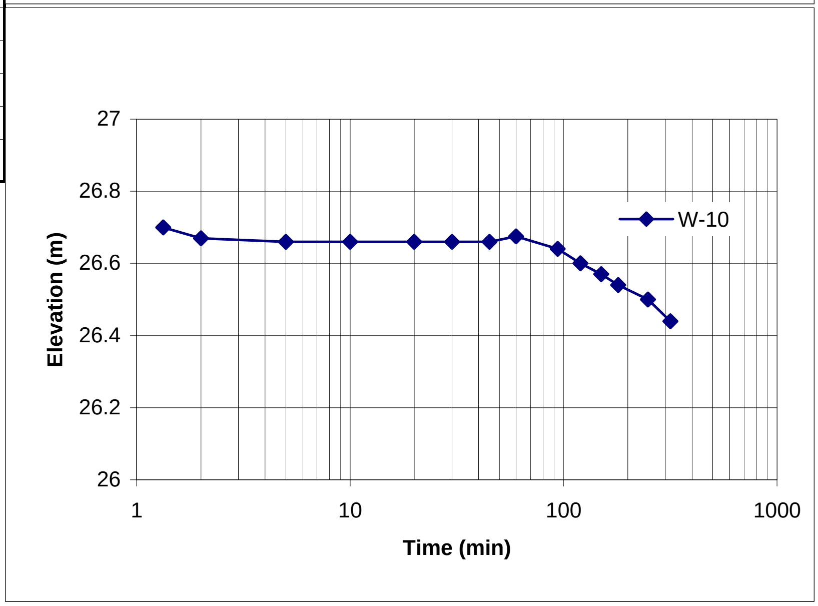
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-10 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 32.68 | 26.72 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 0.5 | 32.74 | 26.66 |
| 1.33 | 32.7 | 26.7 |
| 2 | 32.73 | 26.67 |
| 5 | 32.74 | 26.66 |
| 10 | 32.74 | 26.66 |
| 20 | 32.74 | 26.66 |
| 30 | 32.74 | 26.66 |
| 45 | 32.74 | 26.66 |
| 60 | 32.725 | 26.675 |
| 94 | 32.76 | 26.64 |
| 120 | 32.8 | 26.6 |
| 150 | 32.83 | 26.57 |
| 180 | 32.86 | 26.54 |
| 249 | 32.9 | 26.5 |
| 317 | 32.96 | 26.44 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

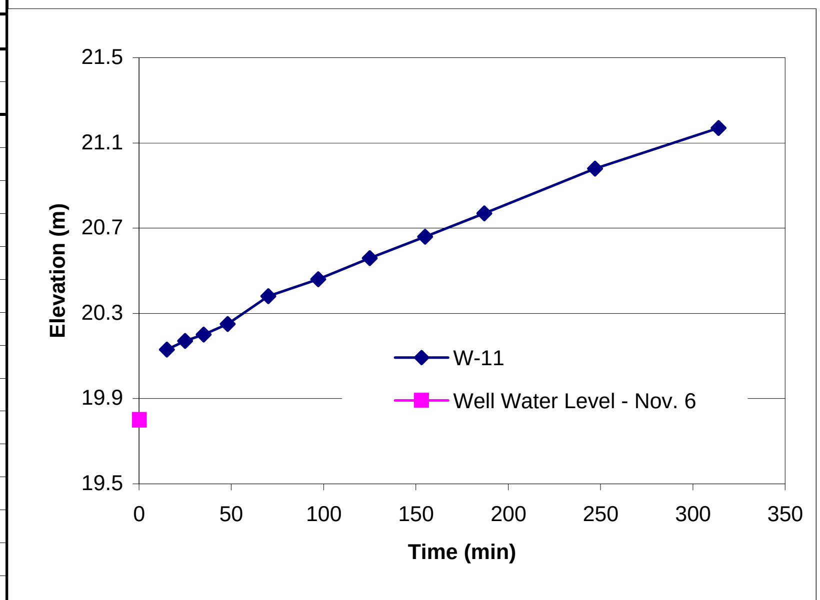
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-11 | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.35 |
| **Read By:** | L. Evans | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

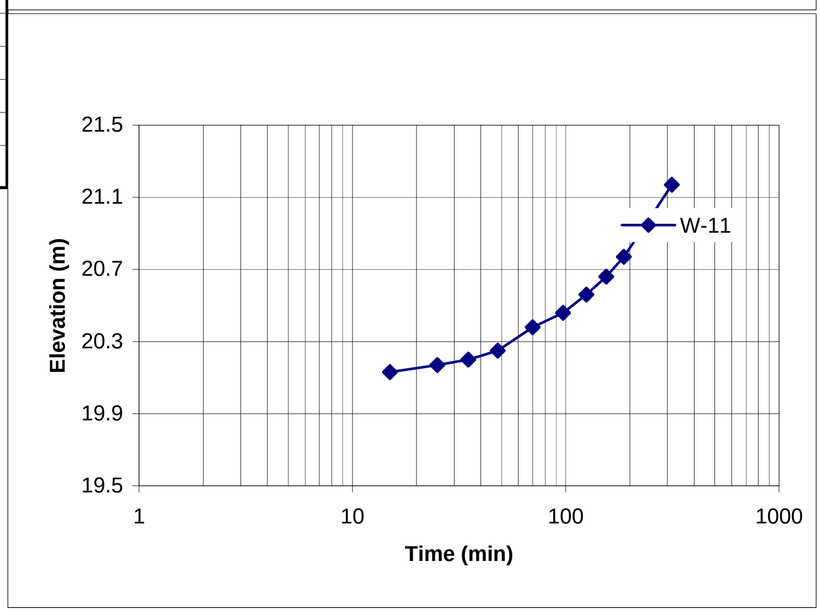
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-11 Reading (m)* | W-11 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | 39.55 | 19.8 |
| Nov 7, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1.33 | | |
| 2 | | |
| 5 | | |
| 15 | 39.22 | 20.13 |
| 25 | 39.18 | 20.17 |
| 35 | 39.15 | 20.2 |
| 48 | 39.1 | 20.25 |
| 70 | 38.97 | 20.38 |
| 97 | 38.89 | 20.46 |
| 125 | 38.79 | 20.56 |
| 155 | 38.69 | 20.66 |
| 187 | 38.58 | 20.77 |
| 247 | 38.37 | 20.98 |
| 314 | 38.18 | 21.17 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

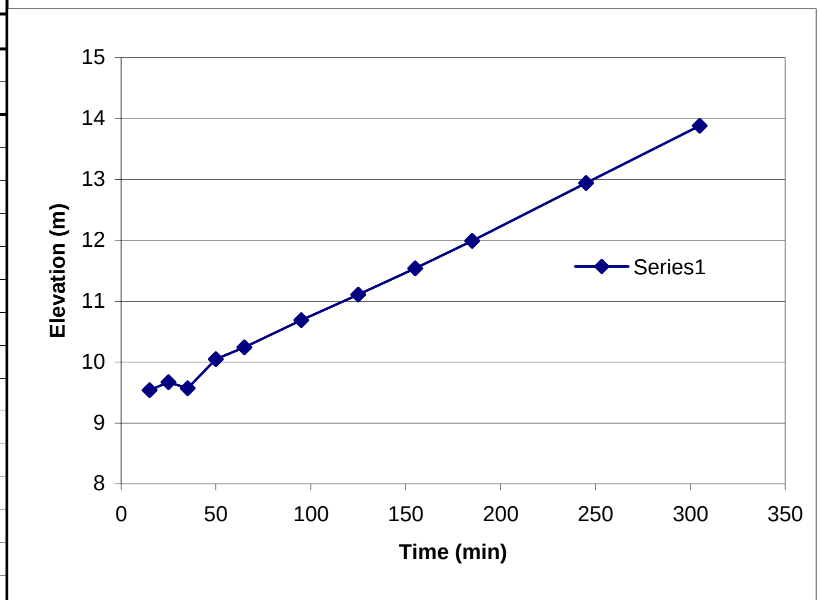
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-12 (Reading-1) | **Date:** | Nov. 7th 2007 | **Case El.:** | 59.29 |
| **Read By:** | L. Rich | **Temperature:** | -5 to +5 | | |
| **Block No:** | 1 | **Weather Condition:** | Rainy with snow periods | | |

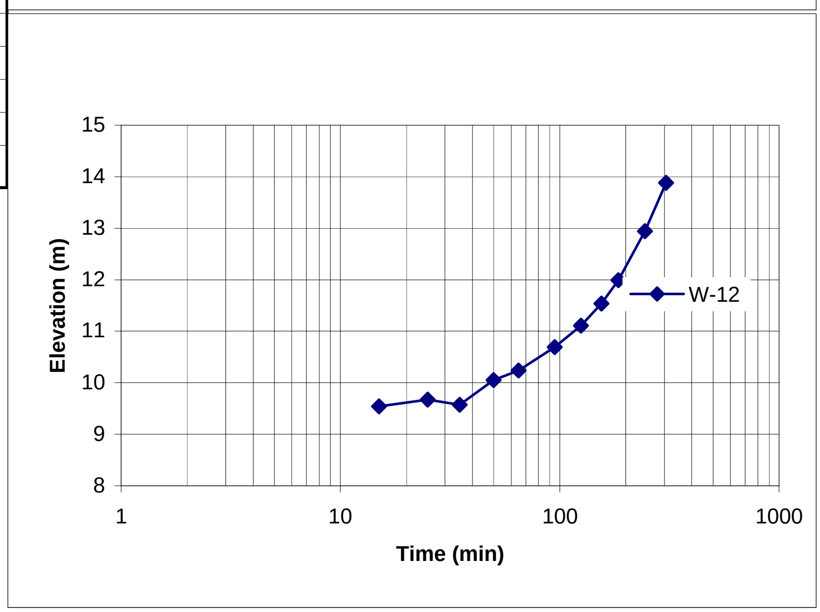
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-12 Reading (m)* | W-12 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | | |
| Nov 7, Recovery test: | | |
| 0 | - | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 49.75 | 9.54 |
| 25 | 49.62 | 9.67 |
| 35 | 49.72 | 9.57 |
| 50 | 49.24 | 10.05 |
| 65 | 49.05 | 10.24 |
| 95 | 48.6 | 10.69 |
| 125 | 48.18 | 11.11 |
| 155 | 47.75 | 11.54 |
| 185 | 47.3 | 11.99 |
| 245 | 46.35 | 12.94 |
| 305 | 45.41 | 13.88 |
| | | |
| | | |
| | | |

* Relative to the top of casing



# C2 – Nov 8 Readings

# Newfoundland and Labrador Hydro - Muskrat Falls

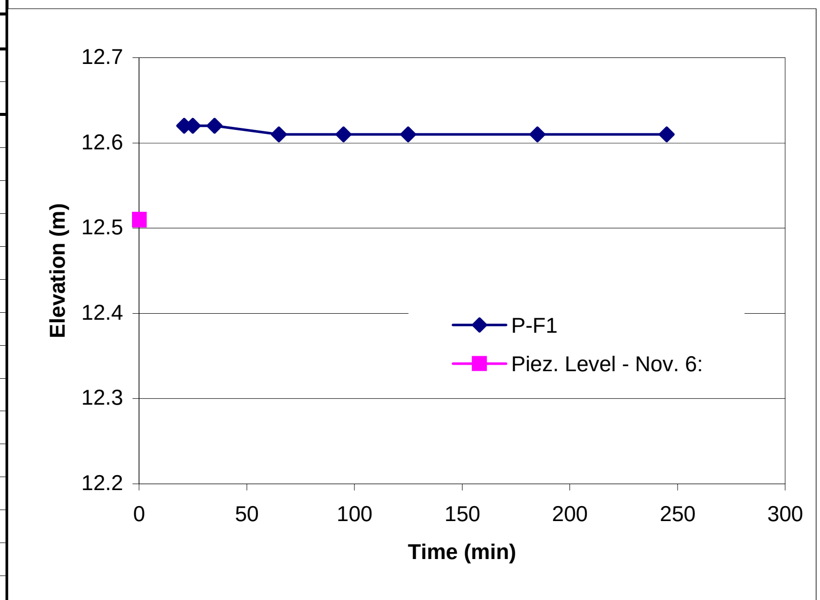
## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

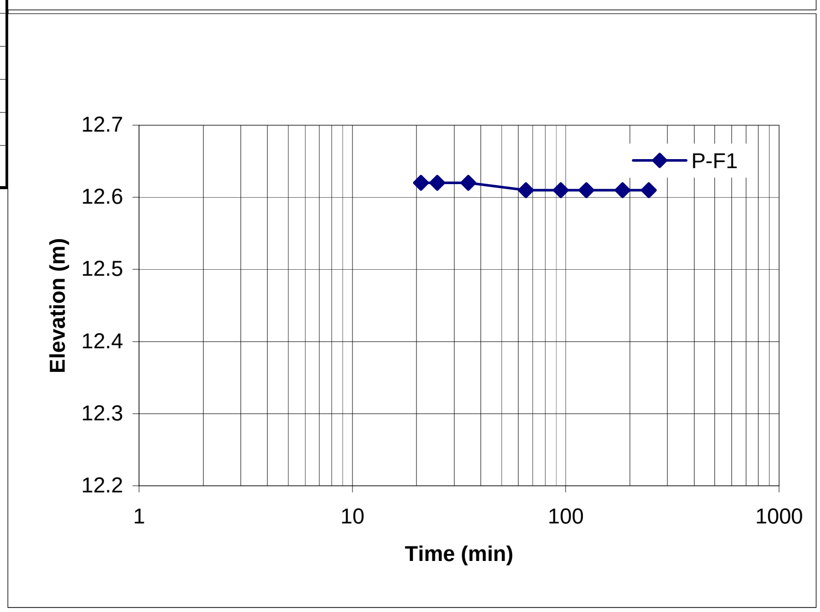
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-F1 | **Date:** | Nov. 8th 2007 | **Case El.:** | 56.38 |
| **Read By:** | D. O'Driscoll | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-F1 Reading (m)* | P-F1 Elevation (m) |
|---|---|---|
| Piez. Level - Nov. 6: | | |
| 0 | 43.87 | 12.51 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | | |
| 21 | 43.76 | 12.62 |
| 25 | 43.76 | 12.62 |
| 35 | 43.76 | 12.62 |
| 65 | 43.77 | 12.61 |
| 95 | 43.77 | 12.61 |
| 125 | 43.77 | 12.61 |
| 185 | 43.77 | 12.61 |
| 245 | 43.77 | 12.61 |
| | | |
| | | |
| | | |
| | | |
| | | |




* Relative to the top of casing

## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

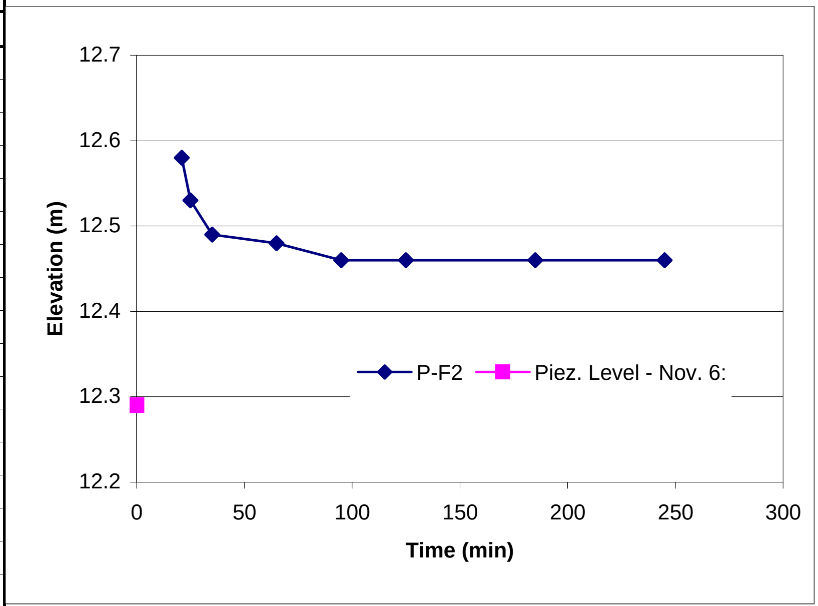
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-F2 | **Date:** | Nov. 8th 2007 | **Case El.:** | 56.38 |
| **Read By:** | D. O'Driscoll | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

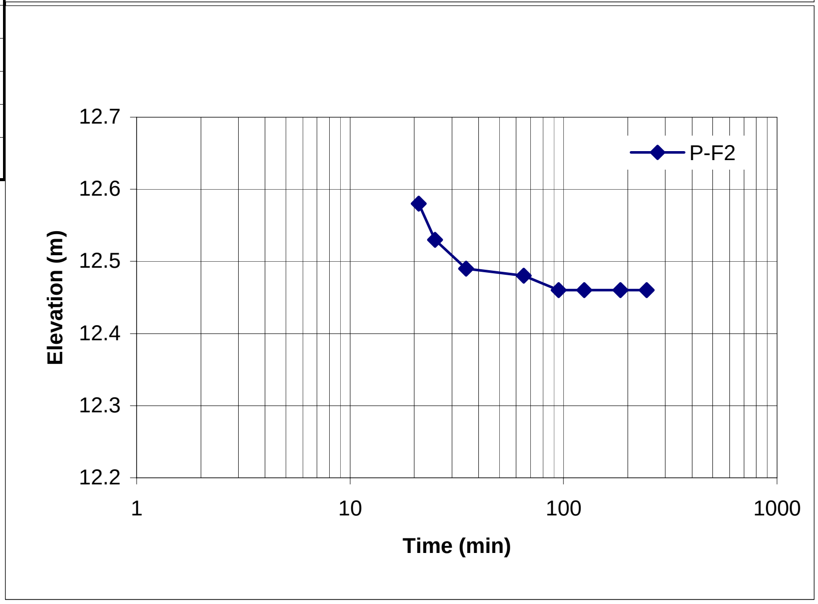
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-F2 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: | | |
| 0 | 44.09 | 12.29 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | | |
| 21 | 43.8 | 12.58 |
| 25 | 43.85 | 12.53 |
| 35 | 43.89 | 12.49 |
| 65 | 43.9 | 12.48 |
| 95 | 43.92 | 12.46 |
| 125 | 43.92 | 12.46 |
| 185 | 43.92 | 12.46 |
| 245 | 43.92 | 12.46 |
| | | |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

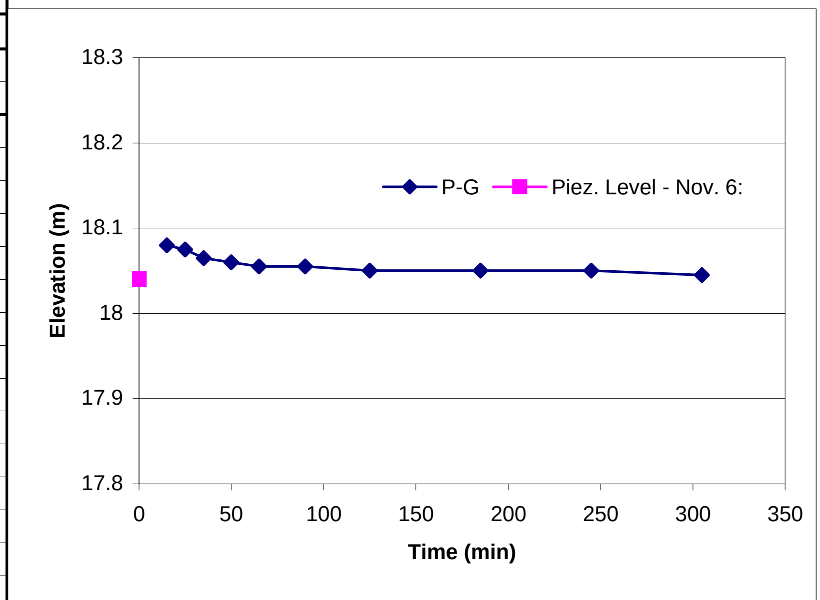
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-G | **Date:** | Nov. 8th 2007 | **Case El.:** | 55.35 |
| **Read By:** | P. BroomField | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

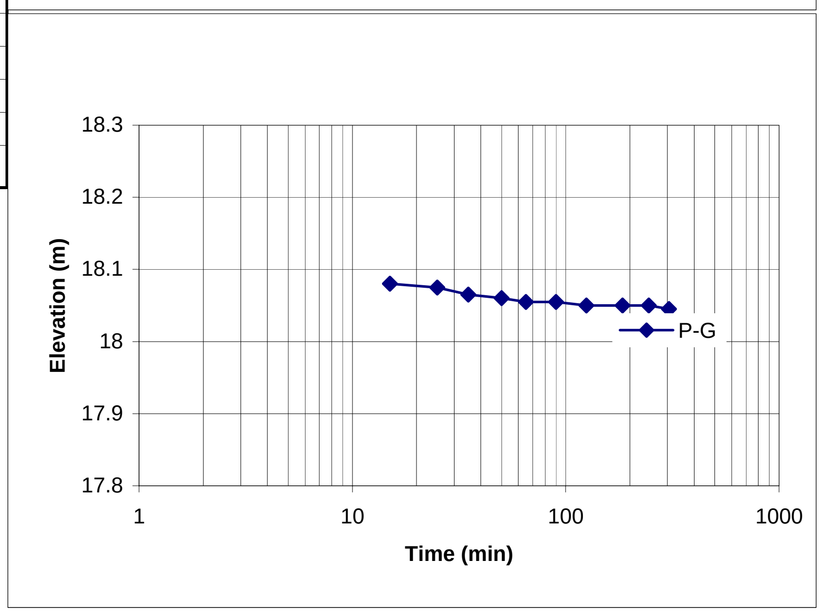
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-G | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: | | |
| 0 | 37.31 | 18.04 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 37.27 | 18.08 |
| 25 | 37.275 | 18.075 |
| 35 | 37.285 | 18.065 |
| 50 | 37.29 | 18.06 |
| 65 | 37.295 | 18.055 |
| 90 | 37.295 | 18.055 |
| 125 | 37.3 | 18.05 |
| 185 | 37.3 | 18.05 |
| 245 | 37.3 | 18.05 |
| 305 | 37.305 | 18.045 |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-J1 | **Date:** | Nov. 8th 2007 | **Case El.:** | 54.36 |
| **Read By:** | P. Ashayer | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-J1 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: | | |
| 0 | 44.29 | 10.07 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 44.28 | 10.08 |
| 25 | 44.29 | 10.08 |
| 35 | 44.28 | 10.08 |
| 50 | 44.28 | 10.08 |
| 65 | 44.28 | 10.08 |
| 90 | 44.28 | 10.08 |
| 125 | 44.28 | 10.08 |
| 185 | 44.28 | 10.08 |
| 245 | 44.28 | 10.08 |
| | | |
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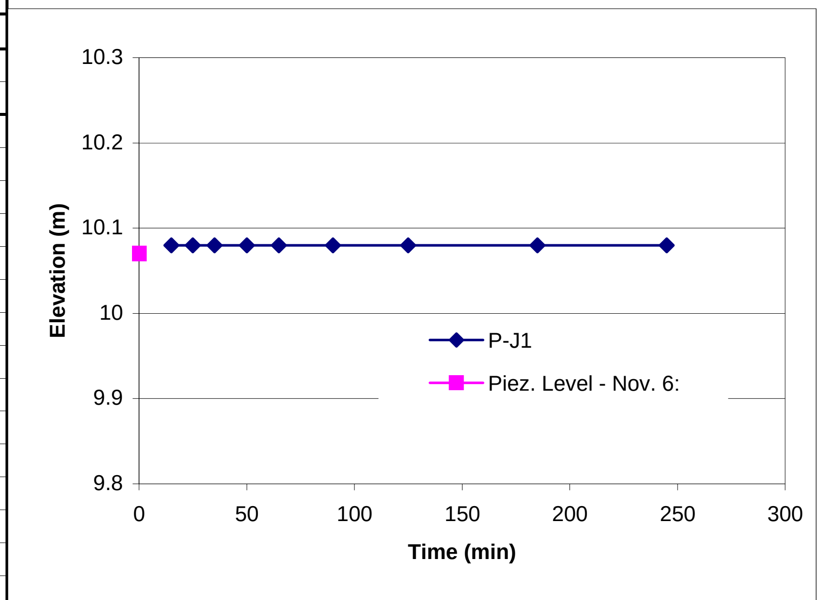
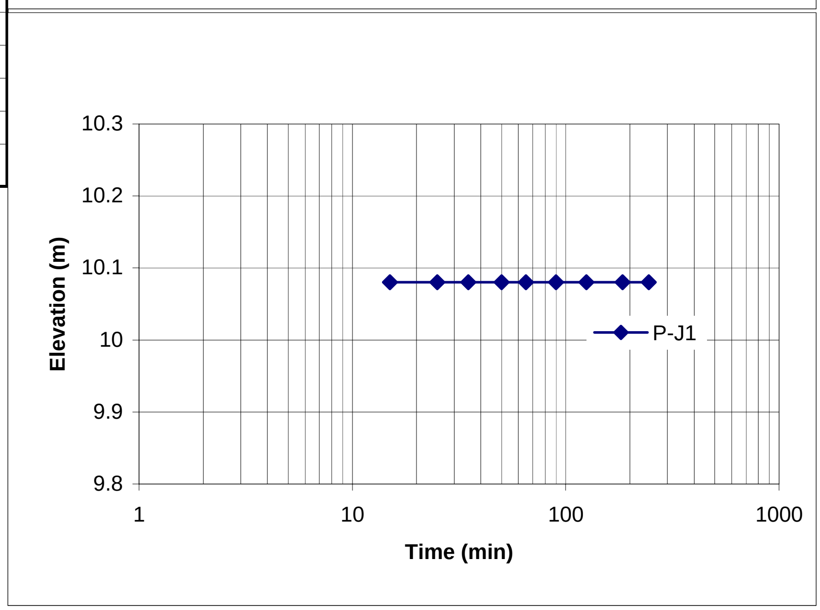
* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | P-J2 | **Date:** | Nov. 8th 2007 | **Case El.:** | 54.36 |
| **Read By:** | P. Ashayer | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | P-J2 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Piez. Level - Nov. 6: | | |
| 0 | 43.13 | 11.23 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 43.05 | 11.31 |
| 25 | 43.03 | 11.33 |
| 35 | 43.03 | 11.33 |
| 50 | 43.03 | 11.33 |
| 65 | 43.03 | 11.33 |
| 90 | 43.03 | 11.33 |
| 125 | 43.03 | 11.33 |
| 185 | 43.03 | 11.33 |
| 245 | 43.03 | 11.33 |
| | | |
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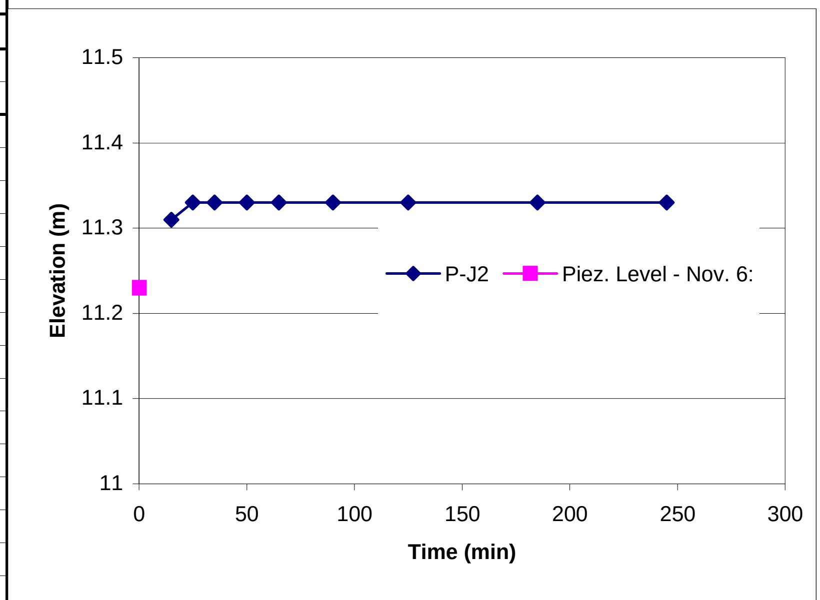
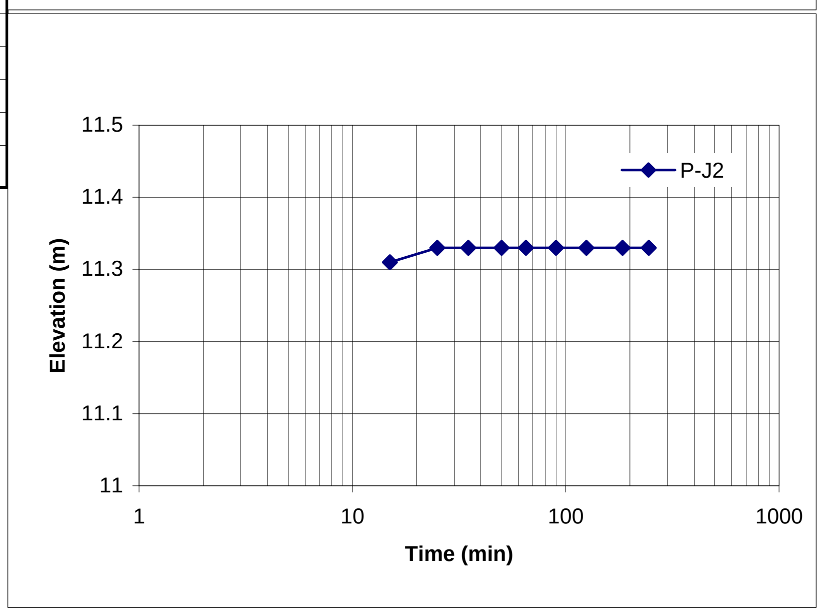
* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

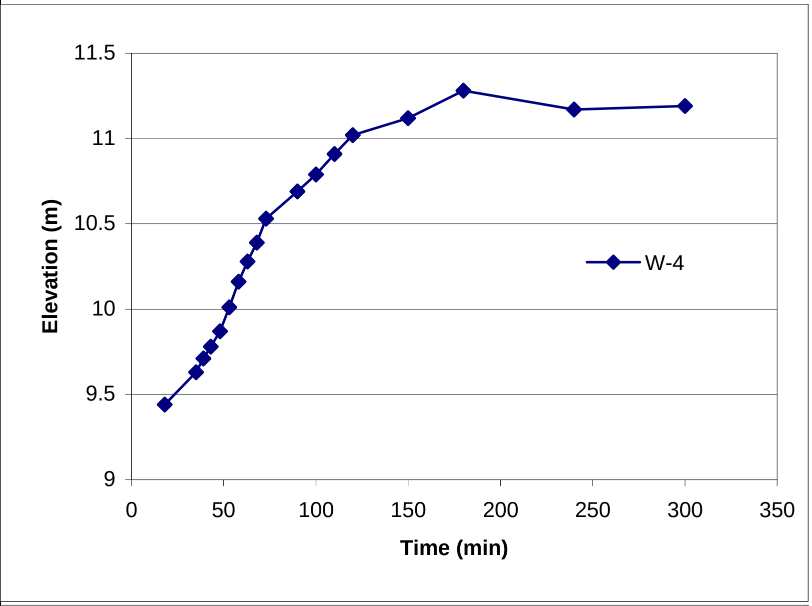
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-4 | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.67 |
| **Read By:** | N. Jette | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

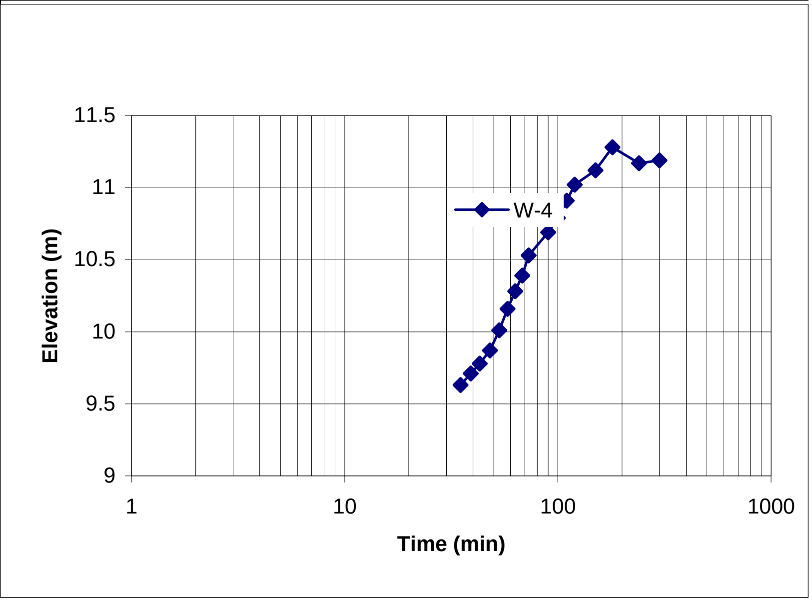
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-4 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | | |
| Nov 8, Recovery test: | | |
| 0 | | |
| 18 | 50.23 | 9.44 |
| 35 | 50.04 | 9.63 |
| 39 | 49.96 | 9.71 |
| 43 | 49.89 | 9.78 |
| 48 | 49.8 | 9.87 |
| 53 | 49.66 | 10.01 |
| 58 | 49.51 | 10.16 |
| 63 | 49.39 | 10.28 |
| 68 | 49.28 | 10.39 |
| 73 | 49.14 | 10.53 |
| 90 | 48.98 | 10.69 |
| 100 | 48.88 | 10.79 |
| 110 | 48.76 | 10.91 |
| 120 | 48.65 | 11.02 |
| 150 | 48.55 | 11.12 |
| 180 | 48.39 | 11.28 |
| 240 | 48.5 | 11.17 |
| 300 | 48.48 | 11.19 |
| | | |
| | | |

* Relative to the top of casing



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

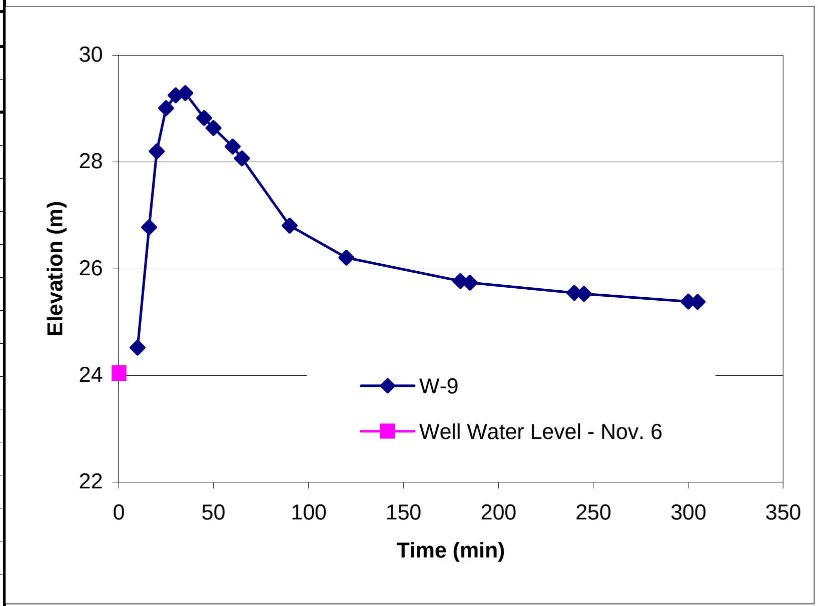
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-9 | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.48 |
| **Read By:** | B. Crowe | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

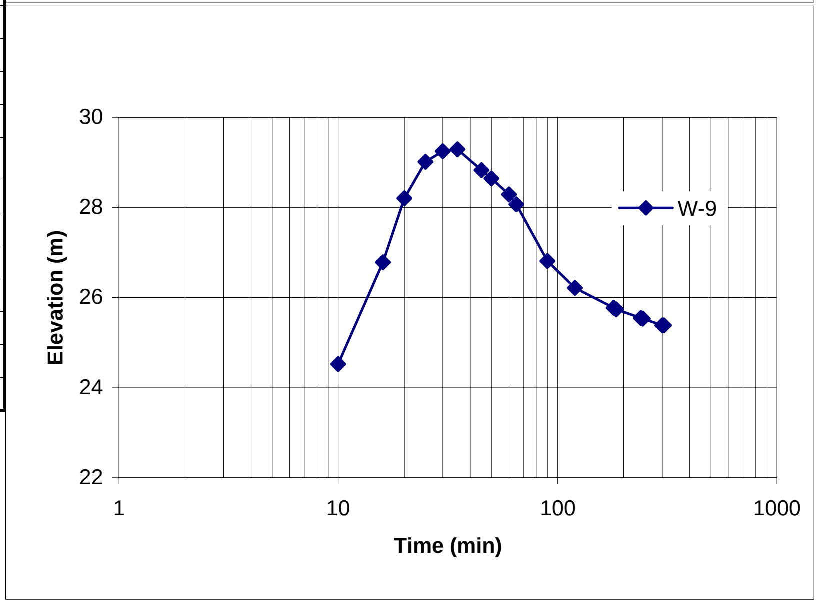
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-9 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 35.44 | 24.04 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 10 | 34.96 | 24.52 |
| 16 | 32.7 | 26.78 |
| 20 | 31.28 | 28.2 |
| 25 | 30.47 | 29.01 |
| 30 | 30.23 | 29.25 |
| 35 | 30.19 | 29.29 |
| 45 | 30.655 | 28.825 |
| 50 | 30.84 | 28.64 |
| 60 | 31.19 | 28.29 |
| 65 | 31.41 | 28.07 |
| 90 | 32.67 | 26.81 |
| 120 | 33.27 | 26.21 |
| 180 | 33.71 | 25.77 |
| 185 | 33.74 | 25.74 |
| 240 | 33.935 | 25.545 |
| 245 | 33.95 | 25.53 |
| 300 | 34.095 | 25.385 |
| 305 | 34.1 | 25.38 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-12 (reading 2)* | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.29 |
| **Read By:** | L. Rich | **Temperature:** | -3 to +1 | | |
| **Block No:** | 1 | **Weather Condition:** | Cloudy | | |

* Test repeated on the second day of the site visit as a primary station.

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-12 Reading (m)* | W-12 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | | |
| Nov 7, Recovery test: | | |
| 0 | - | |
| 0.5 | 53.7 | |
| 1 | 53.7 | |
| 2 | 50.65 | 8.64 |
| 5 | 50.66 | 8.63 |
| 10 | 50.6 | 8.69 |
| 20 | 50.47 | 8.82 |
| 30 | 50.32 | 8.97 |
| 45 | 50.11 | 9.18 |
| 60 | 49.9 | 9.39 |
| 90 | 49.48 | 9.81 |
| 120 | 49.06 | 10.23 |
| 180 | 47.19 | 12.1 |
| 240 | 47.31 | 11.98 |
| 300 | 46.37 | 12.92 |
| | | |
| | | |
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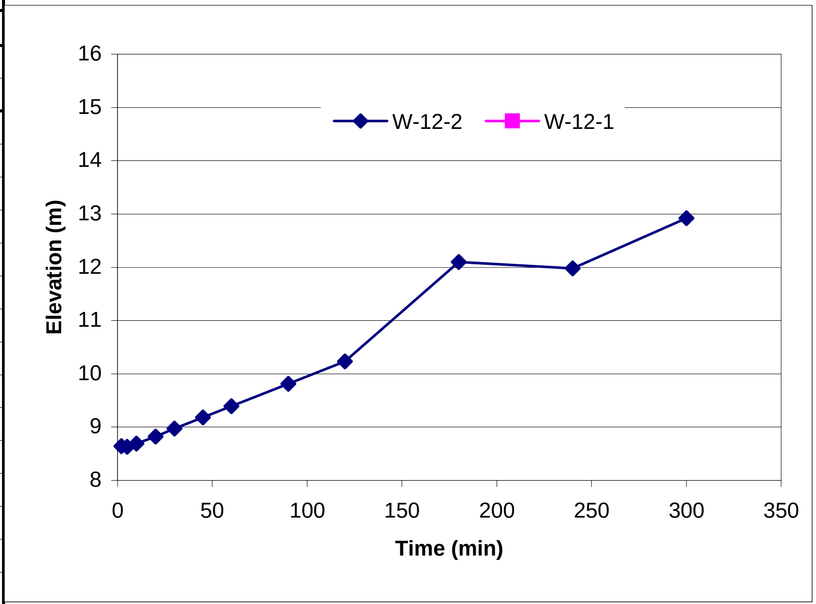
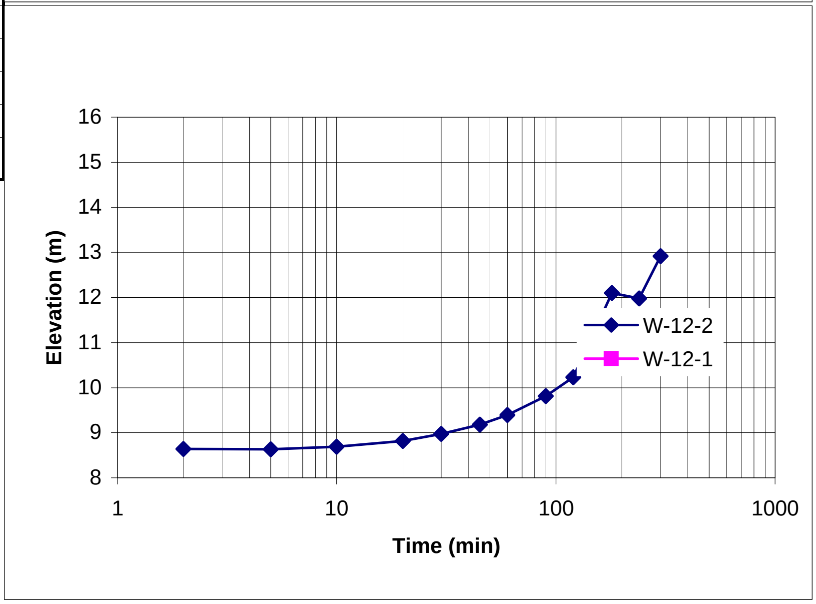
* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

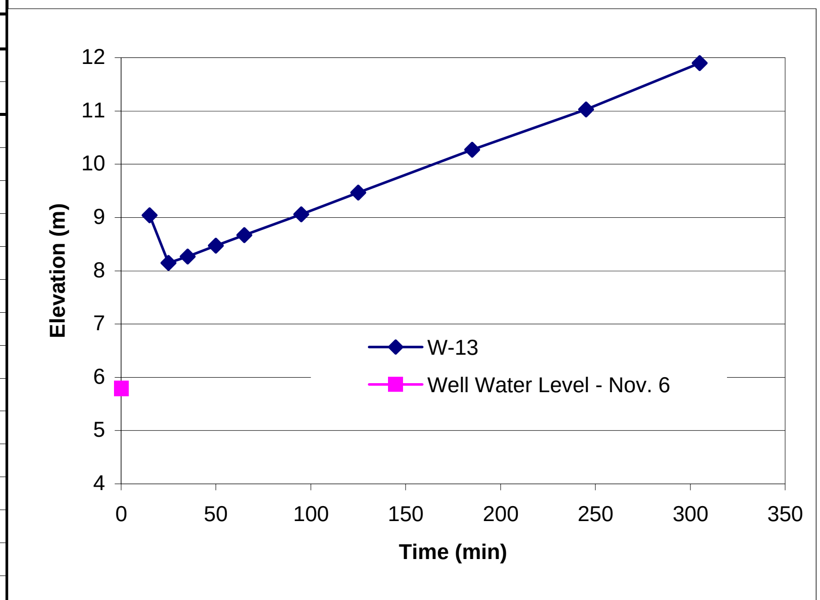
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-13 | **Date:** | Nov. 8th 2007 | **Case El.:** | 57.27 |
| **Read By:** | L. Rich | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

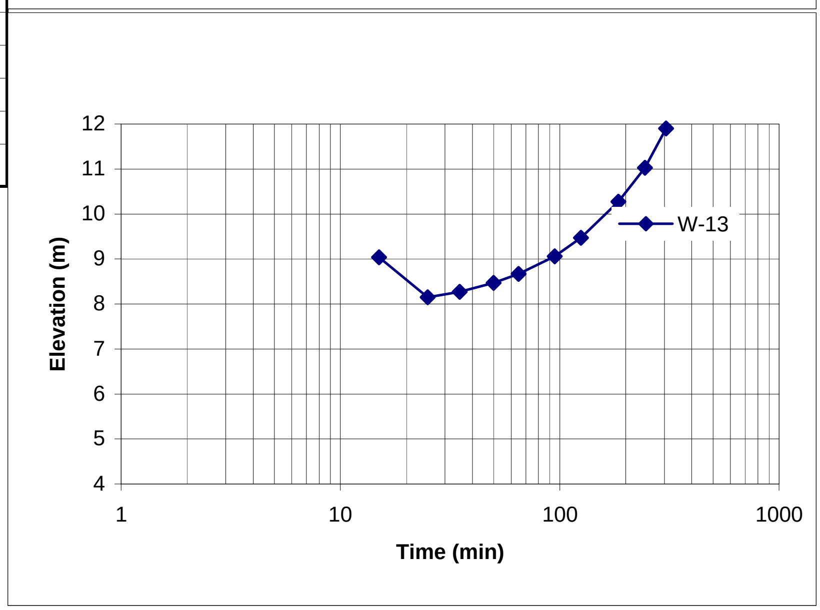
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-13 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 51.48 | 5.79 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 5 | | |
| 15 | 48.23 | 9.04 |
| 25 | 49.12 | 8.15 |
| 35 | 49 | 8.27 |
| 50 | 48.8 | 8.47 |
| 65 | 48.6 | 8.67 |
| 95 | 48.21 | 9.06 |
| 125 | 47.8 | 9.47 |
| 185 | 47 | 10.27 |
| 245 | 46.24 | 11.03 |
| 305 | 45.37 | 11.9 |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

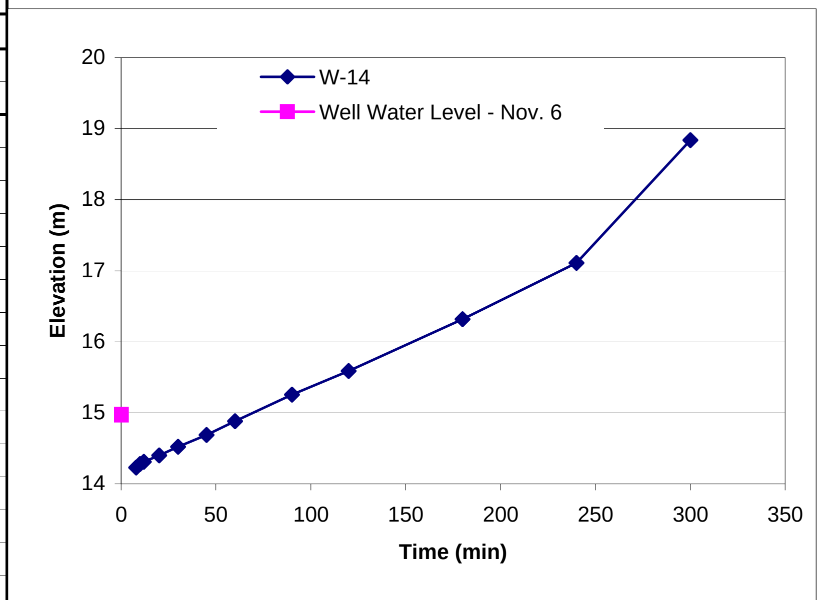
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-14 | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.01 |
| **Read By:** | J. Mitchell | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

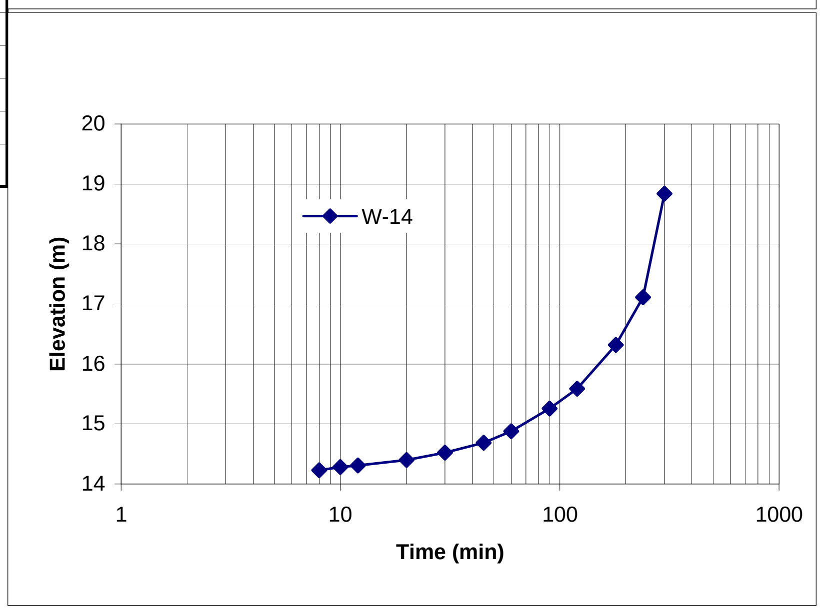
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-14 Reading (m)* | W-14 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | 44.04 | 14.97 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 8 | 44.78 | 14.23 |
| 10 | 44.73 | 14.28 |
| 12 | 44.7 | 14.31 |
| 20 | 44.61 | 14.4 |
| 30 | 44.49 | 14.52 |
| 45 | 44.32 | 14.69 |
| 60 | 44.13 | 14.88 |
| 90 | 43.755 | 15.255 |
| 120 | 43.42 | 15.59 |
| 180 | 42.69 | 16.32 |
| 240 | 41.9 | 17.11 |
| 300 | 40.17 | 18.84 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

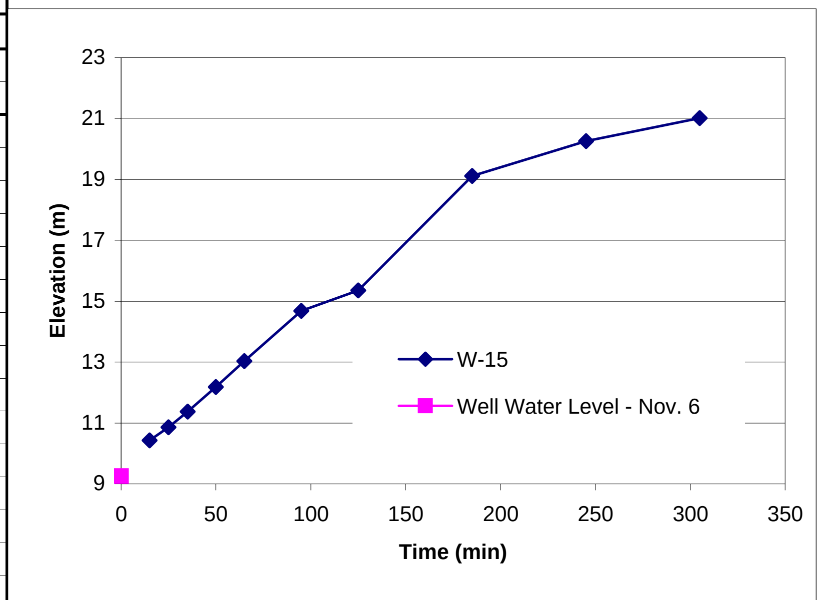
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-15 | **Date:** | Nov. 8th 2007 | **Case El.:** | 58.91 |
| **Read By:** | J. Mitchell | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

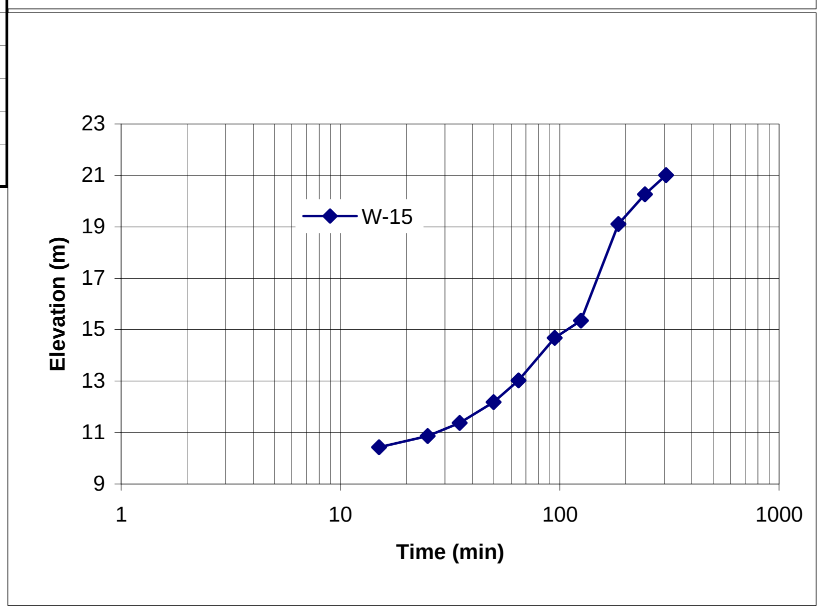
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-15 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 49.66 | 9.25 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 8 | | |
| 10 | | |
| 15 | 48.48 | 10.43 |
| 25 | 48.05 | 10.86 |
| 35 | 47.54 | 11.37 |
| 50 | 46.73 | 12.18 |
| 65 | 45.88 | 13.03 |
| 95 | 44.23 | 14.68 |
| 125 | 43.56 | 15.35 |
| 185 | 39.8 | 19.11 |
| 245 | 38.65 | 20.26 |
| 305 | 37.9 | 21.01 |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

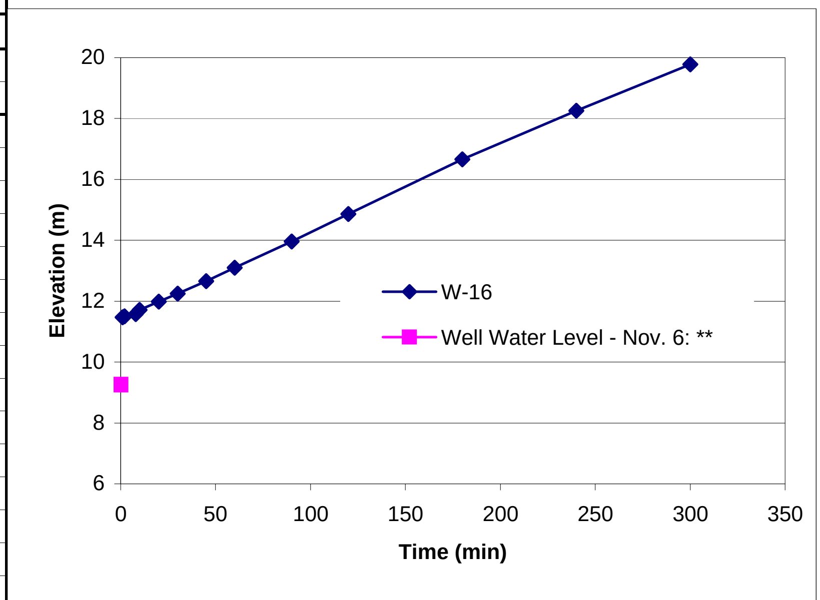
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-16 | **Date:** | Nov. 8th 2007 | **Case El.:** | 58.76 |
| **Read By:** | B. Crowe | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

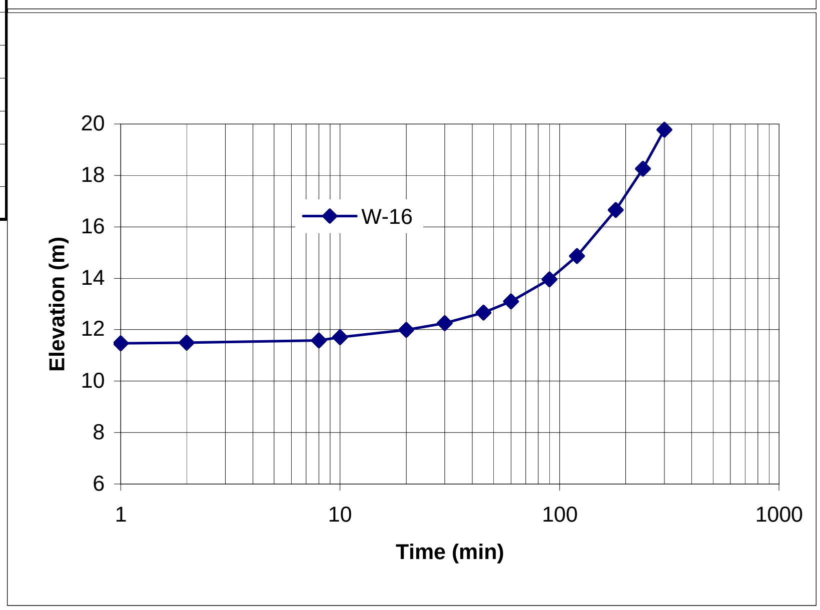
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-16 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6: ** | | |
| 0 | 49.5 | 9.26 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | 47.29 | 11.47 |
| 2 | 47.26 | 11.5 |
| 8 | 47.18 | 11.58 |
| 10 | 47.05 | 11.71 |
| 20 | 46.77 | 11.99 |
| 30 | 46.51 | 12.25 |
| 45 | 46.1 | 12.66 |
| 60 | 45.66 | 13.1 |
| 90 | 44.8 | 13.96 |
| 120 | 43.9 | 14.86 |
| 180 | 42.1 | 16.66 |
| 240 | 40.5 | 18.26 |
| 300 | 38.98 | 19.78 |
| | | |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing
** Variation in elevations is due to high variations in well water level.



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-17 | **Date:** | Nov. 8th 2007 | **Case El.:** | 58.76 |
| **Read By:** | B. Crowe | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-17 Reading (m)* | W-17 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6: ** | | |
| 0 | 48.46 | 10.3 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 1 | | |
| 2 | | |
| 8 | | |
| 15 | 47.82 | 10.94 |
| 25 | 47.72 | 11.04 |
| 35 | 47.63 | 11.13 |
| 50 | 47.51 | 11.25 |
| 65 | 47.38 | 11.38 |
| 95 | 47.13 | 11.63 |
| 125 | 46.9 | 11.86 |
| 185 | 46.42 | 12.34 |
| 245 | 46.01 | 12.75 |
| 305 | 45.64 | 13.12 |
| | | |
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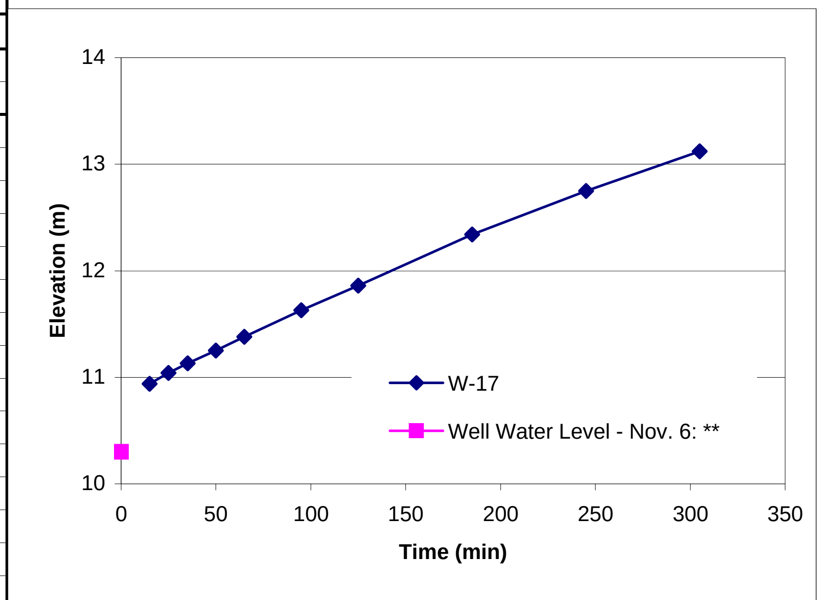
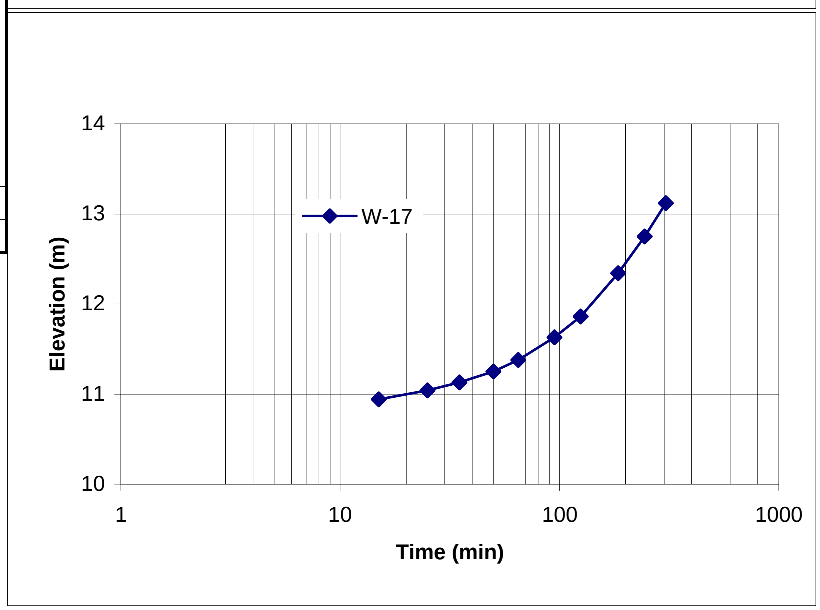
| | | |

* Relative to the top of casing
** Variation in elevations is due to high variations in well water level.



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

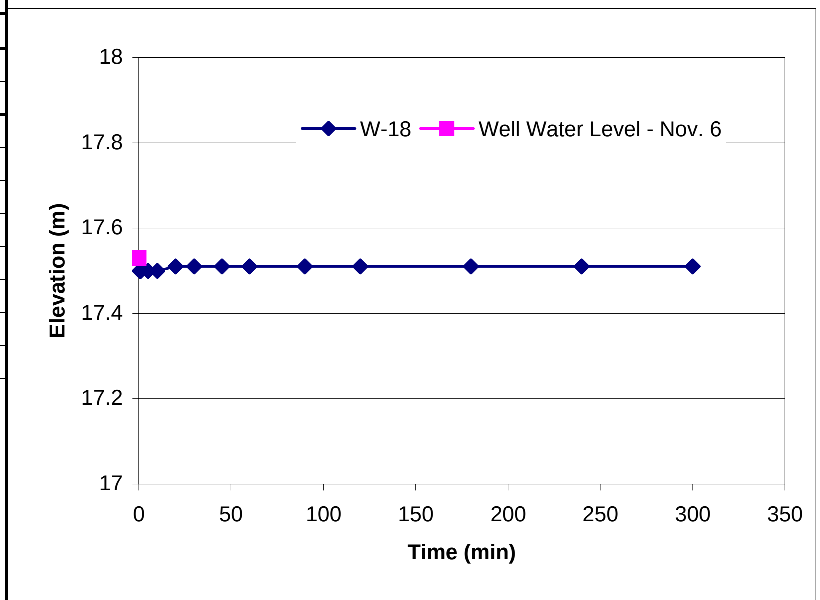
| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-18 | **Date:** | Nov. 8th 2007 | **Case El.:** | 57.87 |
| **Read By:** | P. Ashayer | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

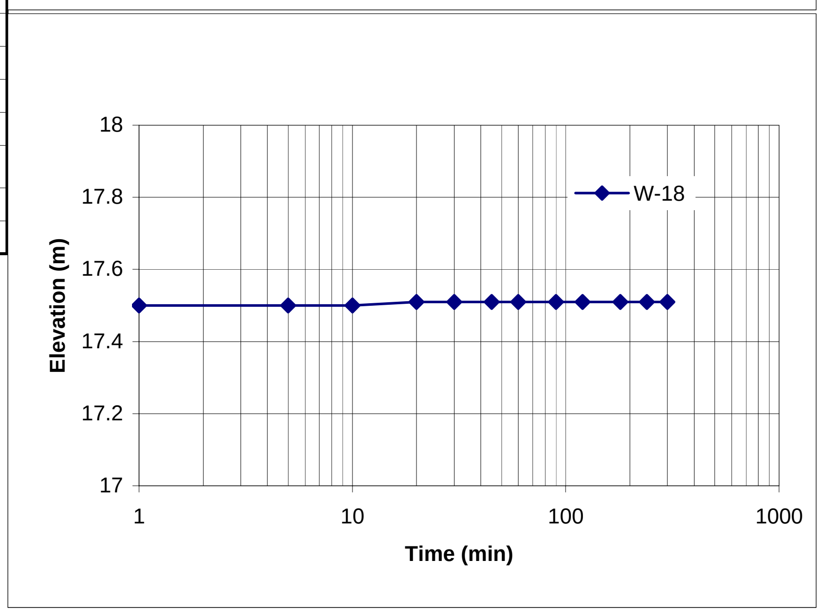
**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-18 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 40.34 | 17.53 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | 40.37 | 17.5 |
| 1 | 40.37 | 17.5 |
| 5 | 40.37 | 17.5 |
| 10 | 40.37 | 17.5 |
| 20 | 40.36 | 17.51 |
| 30 | 40.36 | 17.51 |
| 45 | 40.36 | 17.51 |
| 60 | 40.36 | 17.51 |
| 90 | 40.36 | 17.51 |
| 120 | 40.36 | 17.51 |
| 180 | 40.36 | 17.51 |
| 240 | 40.36 | 17.51 |
| 300 | 40.36 | 17.51 |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-19 | **Date:** | Nov. 8th 2007 | **Case El.:** | 57.01 |
| **Read By:** | D. O'Driscoll | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-19 Reading (m)* | W-19 Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6 | | |
| 0 | 48.2 | 8.81 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | 47.95 | 9.06 |
| 1 | 47.94 | 9.07 |
| 2 | 47.86 | 9.15 |
| 5 | 47.73 | 9.28 |
| 10 | 47.54 | 9.47 |
| 20 | 47.12 | 9.89 |
| 30 | 46.75 | 10.26 |
| 45 | 46.12 | 10.89 |
| 60 | 45.5 | 11.51 |
| 90 | 44.25 | 12.76 |
| 120 | 43.04 | 13.97 |
| 180 | 41.48 | 15.53 |
| 240 | 40.33 | 16.68 |
| 300 | | |
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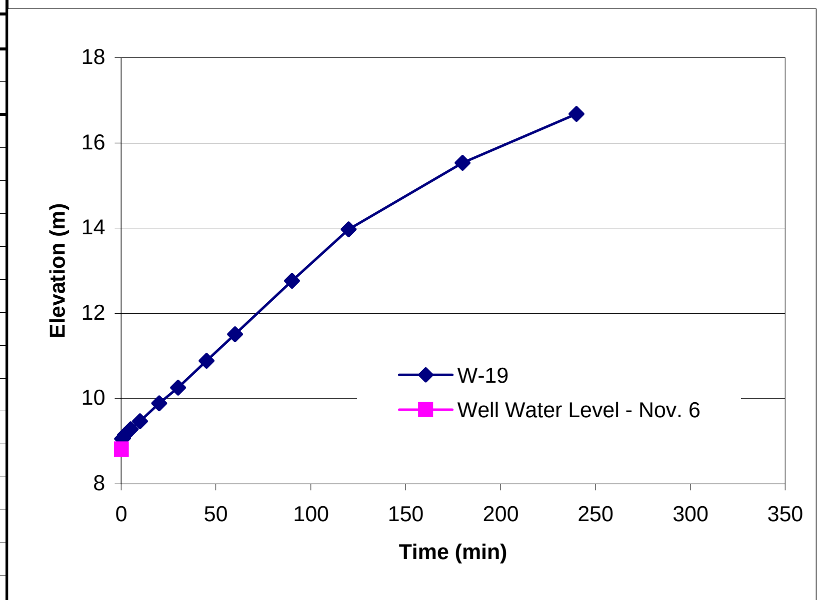
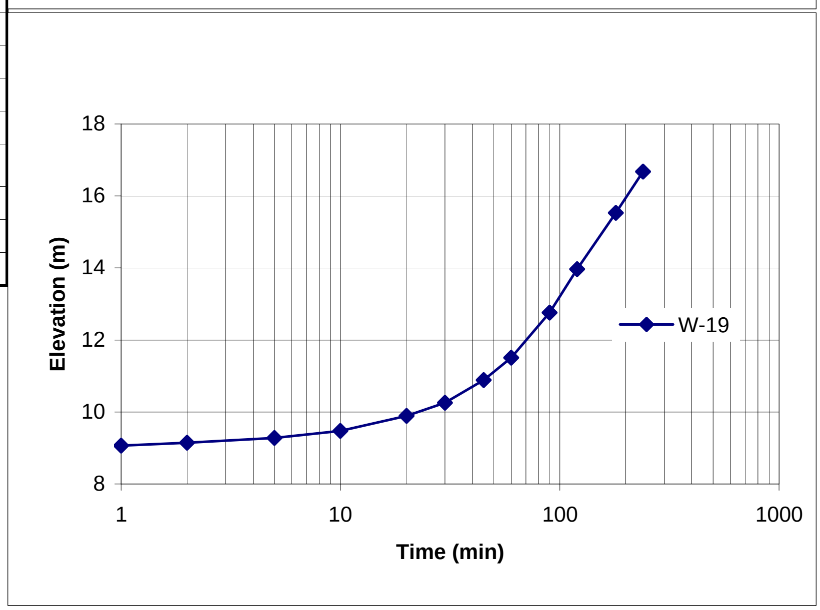
* Relative to the top of casing



## Newfoundland and Labrador Hydro - Muskrat Falls

### MF 1260 - Condition Assessment of Existing Equipment
### Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-20 | **Date:** | Nov. 8th 2007 | **Case El.:** | 56.01 |
| **Read By:** | P. BroomField | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-20 Reading (m)* | Elevation (m) |
|---|---|---|
| Well Water Level - Nov. 6: ** | | |
| 0 | 43.75 | 12.26 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | 44.06 | 11.95 |
| 1 | 44.06 | 11.95 |
| 5 | 44.06 | 11.95 |
| 10 | 44.055 | 11.955 |
| 20 | 44.05 | 11.96 |
| 30 | 44.04 | 11.97 |
| 45 | 44.025 | 11.985 |
| 60 | 44.015 | 11.995 |
| 90 | 43.99 | 12.02 |
| 120 | 43.96 | 12.05 |
| 180 | 43.905 | 12.105 |
| 240 | 43.85 | 12.16 |
| 300 | 43.79 | 12.22 |
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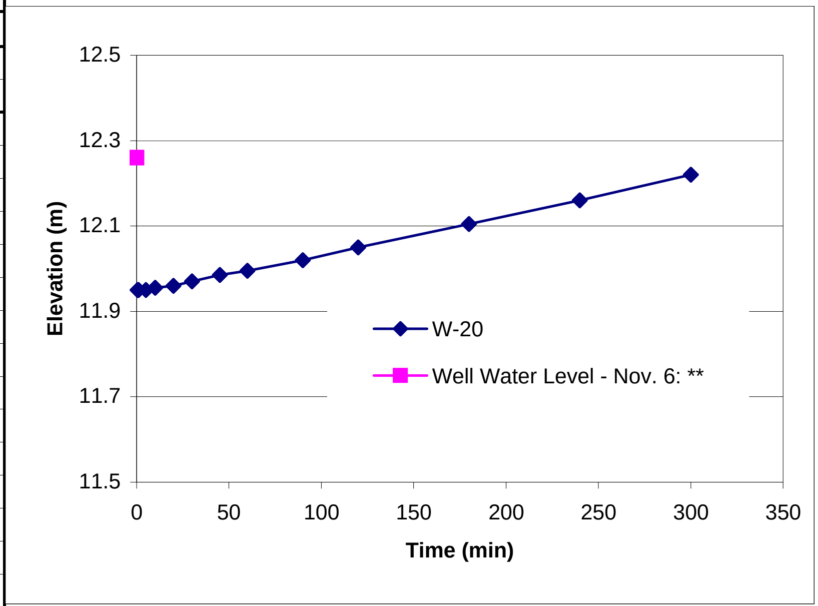


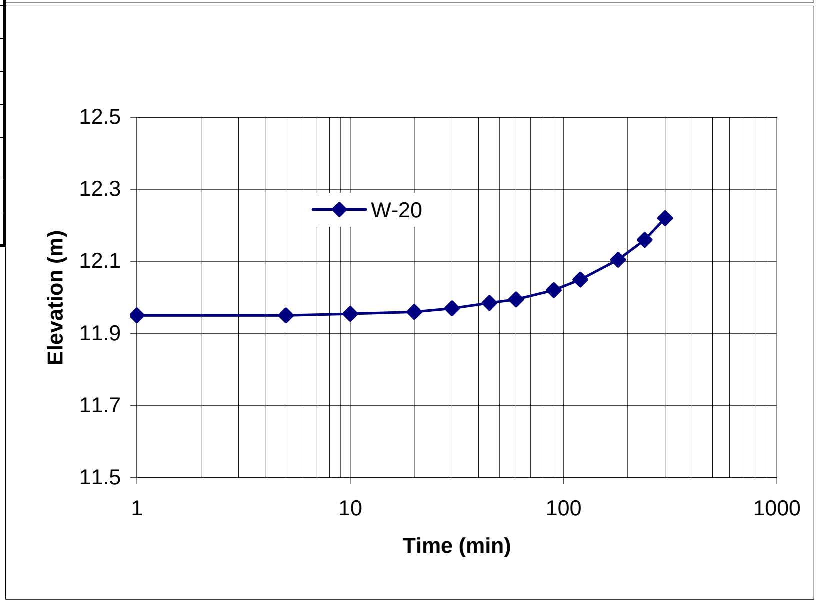


* Relative to the top of casing
** Variation in elevations is due to high variations in well water level.

# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-21 | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.99 |
| **Read By:** | L. Evans | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-21 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | | |
| Nov 8, Recovery test: | | |
| 0 | - | |
| 0.5 | | |
| 2 | 45.66 | 14.33 |
| 5 | 45.67 | 14.32 |
| 10 | 45.66 | 14.33 |
| 20 | 45.6 | 14.39 |
| 30 | 45.55 | 14.44 |
| 45 | 45.47 | 14.52 |
| 60 | 45.39 | 14.6 |
| 90.5 | 45.22 | 14.77 |
| 120 | 45.06 | 14.93 |
| 180 | 44.72 | 15.27 |
| 240 | 44.41 | 15.58 |
| 300 | 44.08 | 15.91 |
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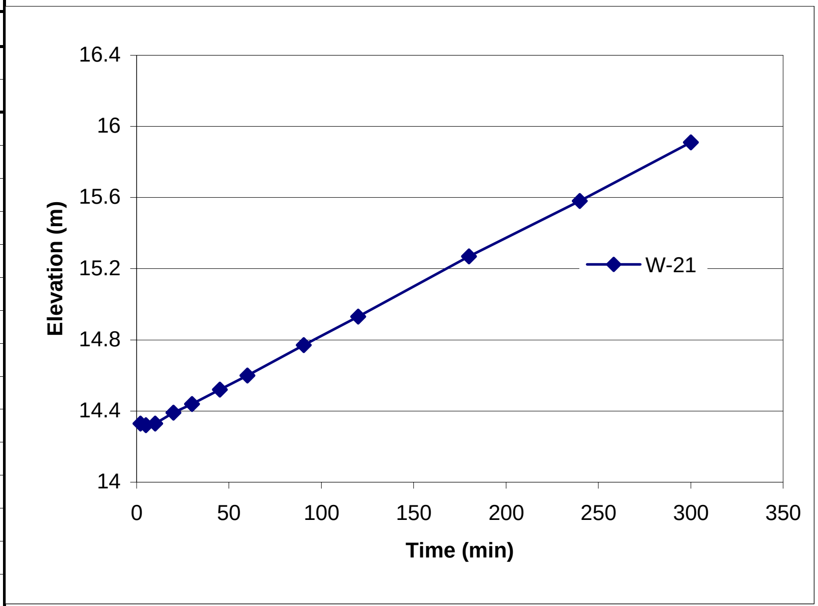
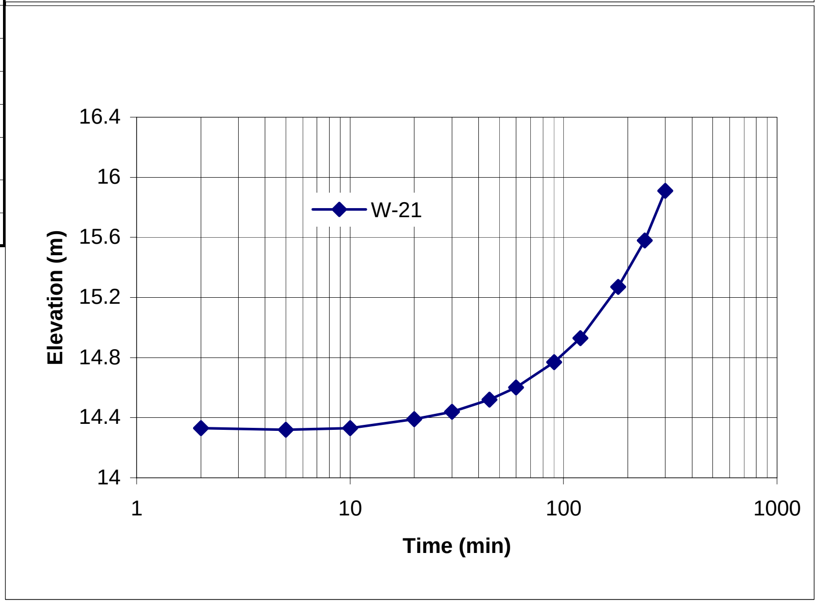
| | | |

* Relative to the top of casing



# Newfoundland and Labrador Hydro - Muskrat Falls

## MF 1260 - Condition Assessment of Existing Equipment
## Block Recovery Test

| | | | | | |
|---|---|---|---|---|---|
| **Well or Piez. #** | W-22 | **Date:** | Nov. 8th 2007 | **Case El.:** | 59.99 |
| **Read By:** | L. Evans | **Temperature:** | -3 to +1 | | |
| **Block No:** | 2 | **Weather Condition:** | Cloudy | | |

**Shutdown Phase**

Start Time:

| Elapsed Time (Min) | W-22 | |
|---|---|---|
| | Reading (m)* | Elevation (m) |
| Well Water Level - Nov. 6 | | |
| 0 | 30.41 | 29.58 |
| Nov 8, Recovery test: | | |
| 0 | | |
| 0.5 | | |
| 2 | | |
| 5 | | |
| 15 | 30.33 | 29.66 |
| 25 | 30.33 | 29.66 |
| 35 | 30.33 | 29.66 |
| 50 | 30.33 | 29.66 |
| 65 | 30.34 | 29.65 |
| 95 | 30.34 | 29.65 |
| 125 | 30.34 | 29.65 |
| 185 | 30.35 | 29.64 |
| 245 | 30.35 | 29.64 |
| 305 | 30.35 | 29.64 |
| | | |
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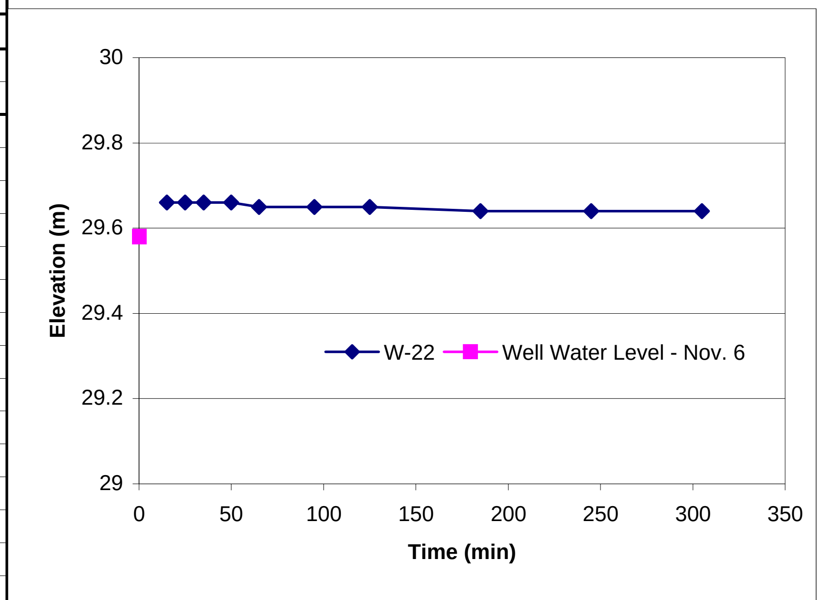
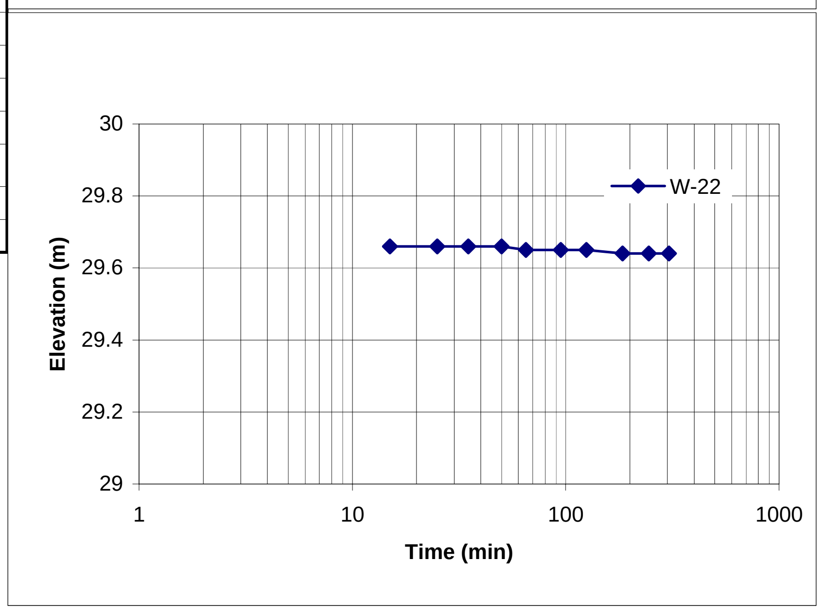
* Relative to the top of casing



# Appendix D

## Cost Estimate for Data Acquisition System

**Price Estimate for Data Acquisition System**

Two budgetary estimates are provided for the Data Acquisition System as follows:

Option A: all sensors to be wired to data logger in the control room. The total cost for this option is $28,295.

Option B: sensors in the NE and Southern regions to communicate remotely using a transceiver with the central data logger in the control room. The cost for this option would be $29,320.

The catalogue of each item used in the above options is attached and also they are listed in Table D1 for both the options A and B. It should be mentioned that in both cases a miniature vibrating wire piezometer should be installed in each piezometer's pvc pipe. This piezometer acts as a sensor and reads and transfers the water head. In both cases the data logger is to be interfaced through cell modem to the internet. Also power is available in the control room only.

It is recommended for option B an additional allowance of $7,200 may be added for professional services.

**Table D1**
**Descriptions for the suggested Items for Options A and B of Data Acquisition System**

| Part Specifications | Part # | Items Quantity for Option A | Items Quantity for Option B |
|---|---|---|---|
| MINIATOR VIBRATING WIRE PIEZOMETER 0.35 MPa, 17.5 mm DIA | VW2100-0.35-M | 13 ea | 13 ea |
| CABLE 4 CONDUCTOR x 22 AWG | EL380004 | 4000 m | 375 m |
| LIGHTNING PROTECTOR 4 WIRES w/GND WIRE | ELLP | 13 ea | 10 ea |
| FLEXDAQ LOGGER 800 TO MONITOR 13 VW PIEZOMETERS C/W MODEM INTERFACE TO INTERNET | ELGL1300 | 1 | 0 |
| FLEXDAQ LOGGER 800 TO MONITOR 13 VW PIEZOMETERS C/W MODEM INTERFACE TO INTERNET | ELGL 1300 CONTROL RM | 0 | 1 ea |
| FLEXDAQ LOGGER 800 & FLEXI-MUX - FOR 6 PIEZOMETERS (NE zone)C/W MODEM INTERFACE TO INTERNET | ELGL 1300 NE ZONE | 0 | 1 ea |
| FLEXDAQ LOGGER 800 & FLEXI-MUX - FOR 4 PIEZOMETERS (NE zone)C/W MODEM INTERFACE TO INTERNET | ELGL 1300 S ZONE | 0 | 1 ea |

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200 - 2050 Hartley Avenue
Coquitlam BC V3K 6W5
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www.rstinstruments.com

ISO 9001:2000

# QUOTE

**Q010162**

**CUSTOMER NO.** HATE02

**BILL TO:**
HATCH ENERGY
43342 QUEEN STREET
P. O. BOX 1001
NIAGRA FALLS ON L2E 6W1
(905) 374-0701 Ext. 5252

**SHIP TO:**
HATCH ENERGY
43342 QUEEN STREET
P. O. BOX 1001
NIAGRA FALLS ON L2E 6W1
(905) 374-0701 Ext. 5252
VICTOR CHAN

| EST. SHIP DATE | SHIP VIA | F.O.B. | TERMS | ORDER NUMBER |
|---|---|---|---|---|
| | TBA | Our Dock | Advance pmt. | Q010162 |

| ORDER DATE | P.O. NUMBER | SALESPERSON |
|---|---|---|
| 20-Dec-07 | | Al Hunter |

| L# | PART NUMBER / DESCRIPTION | QTY. | U/M | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| | *CHURCHILL FALLS DAM PROJECT*<br>*BUDGETARY ESTIMATE FOR A SYSTEM*<br>*TO MONITOR 11 BOREHOLES CONTAINING 13 PIEZOMETERS (4x DAILY)*<br>*OPTION A: ALL SENSORS TO BE WIRED TO DATA LOGGER IN THE CONTROL ROOM.*<br>*OPTION B: SENSORS IN THE NE AND SOUTHERN REGIONS TO COMMUNICATE REMOTELY USING A TRANSCEIVER WITH THE CENTRAL DATA LOGGER IN THE CONTROL ROOM.*<br>*IN BOTH CASES THE DATA LOGGER IS TO BE INTERFACED THROUGH CELL MODEM TO THE INTERNET. ALSO POWER IS AVAILABLE IN THE CONTROL ROOM ONLY.*<br>.<br>*OPTION A* | | | | |
| | **VW2100-0.35**<br>VIBRATING WIRE PIEZOMETER 0.35 MPa, 19 mm DIA | 0.00 | ea | 472.00 | |
| | **VW2100-0.35-MM**<br>MICRO MINIATURE VIBRATING WIRE PIEZOMETER, 11mm DIA., 0.35 MPa | 0.00 | ea | 795.00 | |
| | **VW2100-0.35-M**<br>MINIATURE VIBRATING WIRE PIEZOMETER, 17.5mm DIA., 0.35 MPa<br>*Cable lengths: TO BE CONFIRMED, 19MM ID PVC MUST BE CLEAN* | 13.00 | ea | 550.00 | 7,150.00 |
| | **EL380004**<br>CABLE, 4 CONDUCTOR x 22 AWG, OSD, RED POLYURETHANE JACKET 0.250" DIA.<br>*ESTIMATED QUANTITY OF CABLE FOR WIRING ALL PIEZOMETERS TO THE CONTROL ROOM DATA LOGGER* | 4,000.00 | m | 2.60 | 10,400.00 |
| | **ELLP4500**<br>LIGHTNING PROTECTION 4 WIRES w/GND WIRE | 13.00 | ea | 290.00 | 3,770.00 |
| | **ELGL1300**<br>FLEXDAQ LOGGER 800 TO MONITOR 13 VW PIEZOMETERS C/W MODEM INTERFACE TO INTERNET<br>*Includes: AVW1 VW interface, PS100 Battery unit, AC Power DIN mount, RST Flexi-Mux 2042, LoggerNet Software, SC32B Interface RS-232, Surge for antenna, Raven Antenna, Raven CDMA IP Cell, Raven Mounting Bracket, Cable glands, and Enclosure .*<br><br>*Note: All FLEXDAQ loggers are pre-programmed and ready to run.*<br>.<br>*OPTION B* | 1.00 | ea | 6,975.00 | 6,975.00 |
| | **VW2100-0.35-M**<br>MINIATURE VIBRATING WIRE PIEZOMETER, 17.5mm DIA., 0.35 MPa<br>*Cable Lengths: TO BE CONFIRMED, 19MM ID PVC MUST BE CLEAN* | 13.00 | ea | 630.00 | 8,190.00 |
| | **EL380004**<br>CABLE, 4 CONDUCTOR x 22 AWG, OSD, RED POLYURETHANE JACKET 0.250" DIA.<br>*ESTIMATED QUANTITY OF CABLE FOR WIRING THE PIEZOMETERS IN THREE SEPERATE ZONES: NORTHEAST, SOUTH , and CONTROL ROOM* | 375.00 | m | 2.60 | 975.00 |
| | **ELLP4500** | 10.00 | ea | 290.00 | 2,900.00 |

**CONTINUED**

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VICTOR CHAN

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|---|---|---|---|---|
| | TBA | Our Dock | Advance pmt. | Q010162 |

| ORDER DATE | P.O. NUMBER | SALESPERSON |
|---|---|---|
| 20-Dec-07 | | Al Hunter |

| L# | PART NUMBER / DESCRIPTION | QTY. | U/M | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|
| | LIGHTNING PROTECTION 4 WIRES w/GND WIRE | | | | |
| | **ELGL1300 CONTROL RM**<br>FLEXDAQ LOGGER 800 TO MONITOR 13 VW PIEZOMETERS C/W MODEM INTERFACE TO INTERNET<br>*AND TRANSCEIVER SYSTEM TO REMOTELY INTERFACE WITH FLEXIMUXES IN NORTHEAST AND SOUTH ZONES*<br>*Includes: AVW1 VW interface, PS100 Battery unit, AC Power DIN mount, RST Flexi-Mux 2042, LoggerNet Software, SC32B Interface RS-232, Surge for antenna, Raven Antenna, Raven CDMA IP Cell, Raven Mounting Bracket, RF401 spread spectrum, 14162 RF401 mounting kit, Antenna whip Omni-directional, Cable glands, and Enclosure .* | 1.00 | ea | 6,615.00 | 6,615.00 |
| | **ELGL1300 NE ZONE**<br>FLEXDAQ LOGGER 800 & FLEXI-MUX - FOR 6 PIEZOMETERS (NE zone) C/W<br>*LOCAL TRANSCEIVER SYSTEM TO COMMUNICATE WITH THE CONTROL ROOM DATA LOGGER*<br>*Includes: AVW1 VW interface, PS100 Battery unit, RST Flexi-Mux 2042, SC32B Interface RS-232, RF401 spread spectrum, 14162 RF401 mounting kit, Antenna whip Omni-directional, 22 Watt Solar Panel, 22 Watt Pole mounting bracket, Cable glands, and Enclosure.* | 1.00 | ea | 5,500.00 | 5,500.00 |
| | **ELGL1300 S ZONE**<br>FLEXDAQ LOGGER 800 & FLEXI-MUX - FOR 4 PIEZOMETERS (S zone) C/W<br>*LOCAL TRANSCEIVER SYSTEM TO COMMUNICATE WITH THE CONTROL ROOM DATA LOGGER*<br>*Includes: AVW1 VW interface, PS100 Battery unit, RST Flexi-Mux 2042, SC32B Interface RS-232, RF401 spread spectrum, 14162 RF401 mounting kit, Antenna whip Omni-directional, 22 Watt Solar Panel, 22 Watt Pole mounting bracket, Cable glands, and Enclosure .* | 1.00 | ea | 5,140.00 | 5,140.00 |
| | *Note: All FLEXDAQ loggers are pre-programmed and ready to run.*<br>.<br>*ON SITE SYSTEM COMISSIONING- Optional* | | | | |
| | **PSDLABOUR**<br>PROFESSIONAL SERVICES LABOUR - DAY RATE 10 HR - estimate 2 to 3 days on site<br>*SITE VISIT LABOUR IS CHARGED PORTAL TO PORTAL. ALL OTHER ASSOCIATED EXPENSES ARE CHARGED WITH RECEIPTS AND A 10% PROCESSING CHARGE.*<br>. | 6.00 | dy | 1,200.00 | 7,200.00 |
| | **VW2106**<br>VIBRATING WIRE PORTABLE READOUT- Optional<br>*w/ USB CABLE AND SOFTWARE/MANUAL CD*<br>.<br>*GEOVIEWER- Optional* | 1.00 | ea | 1,985.00 | 1,985.00 |
| | **ELGL5000**<br>GEOVIEWER STANDARD LOGGER SOFTWARE w/ USB KEY | 1.00 | ea | 1,380.00 | 1,380.00 |
| | **PSLABOUR**<br>PROFESSIONAL SERVICES LABOUR<br>*ESTIMATED COST TO COMMISSION GEOVIEWER* | 6.00 | hr | 105.00 | 630.00 |

**CONTINUED**

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# QUOTE

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**CUSTOMER NO.** **HATE02**

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NIAGRA FALLS ON L2E 6W1
(905) 374-0701 Ext. 5252

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(905) 374-0701 Ext. 5252
VICTOR CHAN

| EST. SHIP DATE | SHIP VIA | F.O.B. | TERMS | ORDER NUMBER |
|---|---|---|---|---|
| | TBA | Our Dock | Advance pmt. | Q010162 |

| ORDER DATE | P.O. NUMBER | SALESPERSON |
|---|---|---|
| 20-Dec-07 | | Al Hunter |

| L# | PART NUMBER | DESCRIPTION | QTY. | U/M | UNIT PRICE | TOTAL |
|---|---|---|---|---|---|---|

*INITIAL ESTIMATE FOR BUDGETARY PURPOSES*
*Validity of quote: 60 DAYS*
*Estimated delivery: to be confirmed.*
*Subject to RST Instruments Sales Terms and Conditions*
*(http://www.rstinstruments.com/standard_terms.html).*

| | |
|---|---|
| **NET AMOUNT** | 68,810.00 |
| **G.S.T.** | 4,128.60 |
| **TOTAL DUE** | 72,938.60 |

CDN DOLLARS

# Vibrating Wire Piezometers

The RST Vibrating Wire Piezometer provides excellent long-term accuracy, stability of readings and reliability under demanding geotechnical conditions. Vibrating Wire Piezometers are the electrical piezometers of choice as the frequency output of VW devices is immune to external electrical noise, and able to tolerate wet wiring common in geotechnical applications.

The vibrating wire piezometer senses pressure by means of a metal diaphragm attached to a vibrating wire element. When pressure is applied to the diaphragm, its deflection is sensed by the vibrating wire element – i.e. the tension in the wire is reduced, and the resonant frequency of the vibrating wire is changed as a result. The vibrating wire is induced to vibrate, and then the resonant frequency is measured via an electromagnetic coil circuit. The resulting frequency is precisely related to the pressure.

The frequency signal is exceptionally immune from cable effects, including length (to several kilometers), splicing, resistance, noise pickup, and moisture. The vibrating wire coil circuit contains no semiconductor devices and has built-in ionized gas discharge device protection against transient damage. As a result, the vibrating wire piezometer provides excellent reliability in typical geotechnical situations – i.e. long outdoor cables buried in saturated soil.

The piezometer is equipped with a standard sintered stainless steel porous filter to prevent soil particles from contacting the diaphragm. A thermistor is built into the piezometer body to permit temperature measurement and temperature compensation of the piezometer. Standard construction is all stainless steel. RST vibrating wire piezometers are shipped with extremely tough polyurethane-jacketed foil-shielded cable for maximum endurance in field conditions.

## FEATURES

- Field proven reliability and accuracy.
- Will tolerate wet wiring common in geotechncial applications.
- Immune from external electrical noise.
- Signal transmission of several kilometers.
- Cable lengths may be changed without affecting the calibration.
- High accuracy, IE a low pressure vented model will measure water level changes as small as 0.05 mm (0.02 in.).
- Thermistor for temperature measurement is standard.
- Negligible displacement of pore water during the measurement process.
- Hermetically sealed, stainless steel construction.
- Heavy case to minimize reading errors caused by overburden pressure.
- Data logger compatible.
- Integral lightning protection.

## FUNCTIONS

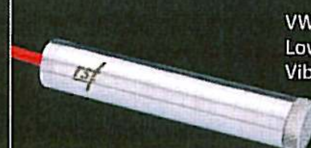
- Assessing performance and investigating stability of earth fill dams and embankments.
- Slope stability investigations.
- Monitoring water levels in wells & standpipes.
- Monitoring pressures behind retaining walls and diaphragm walls.
- Monitoring pore pressures during fill or excavation.
- Monitoring pore pressure in land reclamation applications.

VW2100 Standard Vibrating Wire Piezometer

VW2100-HD: Heavy Duty Vibrating Wire Piezometer

VW2100-DP: Drive Point Vibrating Wire Piezometer

VW2100-L:
Low Pressure Unvented
Vibrating Wire Piezometer



VW2100-MM:
Micro-Miniature
Vibrating Wire Piezometer

Specifications may change without notice. ELB0003D

**RST Instruments Ltd.**
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Toll Free (USA & Canada): 1-800-665-5599
Email: info@rstinstruments.com
www.rstinstruments.com

The RST Instruments Management System is certified to ISO 9001:2000

## OPERATING PRINCIPLE

Vibrating Wire Piezometers contain a high tensile steel wire with a fixed anchor at one end and are attached to a diaphragm at the other end. The wire is electrically plucked, with the resonant frequency of vibration proportional to the tension in the wire. This frequency induces an alternating current in a coil, which is detected by the readout unit and can then be converted to a pressure.

## ELECTRICAL CABLE

| PART | DESCRIPTION |
|---|---|
| EL380004 | Two twisted pairs cable with polyurethane jacket. |

Other types of cables, depending on site conditions and atmospheric reference requirements, are available upon request. These include Vented, FEP, PVC, Polyurethane, and Armored varieties.

## VIBRATING WIRE PIEZO SPECIFICATIONS

| DESCRIPTION | SPECIFICATIONS |
|---|---|
| Over range | 2 X F.S. |
| Resolution | 0.025% F.S. minimum |
| Accuracy | 0.1% F.S. |
| Operating Temperature | -20 to 80°C (-4 to 176°F) |
| Diaphragm Displacement | <0.001 cc at F.S. |
| Thermal Zero Shift | <0.05% F.S./°C |
| Materials | Hermetically sealed stainless steel housing |
| Thermistor Matching | ±0.5°C |
| Thermistor Resolution | 0.1°C |
| Thermistor Accuracy | 0.5°C |
| Filter | 50 micron sintered filter.<br>(High air entry alumina filter 1, 3, 5 Bar available) |

## VIBRATING WIRE PIEZO OPTIONS (Specify when ordering)

- Heavy-duty bodies for embankment use.
- Push-in drive points for soft soils
- High air entry ceramic filters to exclude air
- Low range and vented piezometers
- Titanium construction for use with corrosive fluids
- Multi-point/mixed type sensor strings
- Kevlar™* reinforced cable

## ANCILLARY EQUIPMENT (Specify when ordering)

- VW2106 Vibrating Wire Readout
- Dataloggers
- Terminal stations
- Electrical cable
- Cable splice kits
- Installation geotextile and socks
- Increased lightning protection

## ORDERING INFORMATION

| PART | DESCRIPTION | PRESSURE RANGE | DIMENSION |
|---|---|---|---|
| VW2100 | Standard model for general applications. | 0.35, 0.7, 1.0, 2.0, 3.0, 5.0, 7.5 MPa | 19 mm Ø X 133 mm<br>0.75 in. Ø X 5.23 in. |
| VW2100-HD | Heavy duty piezometer for direct burial in fills and large dam embankments. | 0.07, 0.175, 0.35, 0.7, 1.0, 2.0 3.0, 5.0, 7.5 MPa | 38.1 mm Ø X 203 mm<br>1.5 in. Ø X 8.0 in. |
| VW2100-HHP | High pressure transducer with NPT port. | 5.0, 7.5, 10, 25, 50, 75, 100 MPa | 25.4 x 143 mm<br>1 in. Ø X 5.63 in. |
| VW2100-DP | Drive point model with CPT adapter. | 0.07, 0.175, 0.35, 0.7, 1.0, 2.0, 3.0, 5.0, 7.5 MPa | 33 mm Ø X 432 mm<br>1.31 in. Ø X 17 in. |
| VW2100-L | Low Pressure, unvented. | 70, 175 kPa | 25 mm Ø X 133 mm<br>1 in. Ø X 5.23 in. |
| VW2100-LV | Low Pressure vented. | 70, 175 kPa | 25 mm Ø X 133 mm<br>1 in. Ø X 5.23 in. |
| VW2100-M | Miniature version – 17.5 mm diameter. | 0.35, 0.7, 1.0, 2.0, 3.0, 5.0, 7.5 MPa | 17.5 mm Ø X 133 mm<br>0.68 in. Ø X 5.23 in. |
| VW2100-MM | Micro-miniature version – 11.1 mm diameter. | 0.35, 0.7 MPa | 11.1 mm Ø X 165 mm<br>0.43 in. Ø X 6.5 in. |



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# VW2106 Vibrating Wire Readout

The portable VW2106 Vibrating Wire Readout reads, displays, and logs both vibrating wire sensors and thermistors. Vibrating wire load cells can be read without any additional accessories.

Unprecedented accuracy, flexible memory options and ease of use make the VW2106 invaluable for projects requiring vibrating wire sensor monitoring. Maximum download time is only 15 seconds.

Complementing its high level of accuracy, the VW2106 is also designed for maximum efficiency with the user in mind. In addition to the simple power requirements of only 3 "AA" batteries, the VW2106 comes well-equipped with standard features such as a large graphics display with backlight, a built-in multiplexer, "no-tools" vibrating wire transducer inputs (eliminating the need for alligator clips), and a convenient on-board speaker for sensor diagnostics.


## FEATURES

- Durable, compact design for excellent portability and field use.
- Large graphics display with a convenient backlight.
- Readings in raw or engineering units.
- Built-in multiplexer for load cells up to 6 vibrating wire gauges.
- "No-tools" vibrating wire transducer inputs eliminates the need for alligator clips.
- Field-replaceable "AA" alkaline batteries eliminate the need for a large, bulky 12 V battery and a charger.
- On-board speaker for sensor diagnostics.
- Stores up to 254 instrument locations per route, each with a text label, calibration constants, previous data, and up to 11,400 time/date stamped data points.
- Data transfer to a host computer via USB in a compatible file format for Microsoft Excel® and other spreadsheets. User friendly host software for Microsoft Windows® included.

## FUNCTIONS

Reads, displays, and logs both vibrating wire sensors and thermistors.

## SPECIFICATIONS

| | |
|---|---|
| **Vibrating Wire Readout Excitation Range** | 400 Hz to 6000 Hz, 5 V Square Wave |
| **Vibrating Wire Readout Resolution** | 0.01 µs |
| **Vibrating Wire Readout Timebase Accuracy** | ±50 ppm |
| **Supported Temperature Readout Sensors** | NTC3000 (standard), NTC2252, NTC10K, RTD |
| **Temperature Readout Accuracy** | ±0.1°C |
| **Temperature Readout Range** | -50°C to 80°C |
| **Display** | Graphic 128 x 64 pixels large character display |
| **Display Backlight** | High efficiency LCD with auto off |
| **Max Instrument Locations** | 254 |
| **Memory Capacity** | 11,400 custom labelled points |
| **Location Identification String** | Up to 20 characters |
| **Download Speed** | 15 seconds (full memory) |
| **Battery** | 3 "AA" alkaline |
| **Battery Indicator** | On-screen, low battery indicator |
| **Operating Temperature** | -20°C to 60°C |
| **Dimensions** | W 22 cm x D 19 cm x H 9.5 cm (8.75 x 7.5 x 3.75in.) |
| **Weight** | 1.1 kg (2.4 lbs) |

## ORDERING INFORMATION

| | |
|---|---|
| **Part Number** | VW2106 |


Specifications may change without notice. MIB0033H

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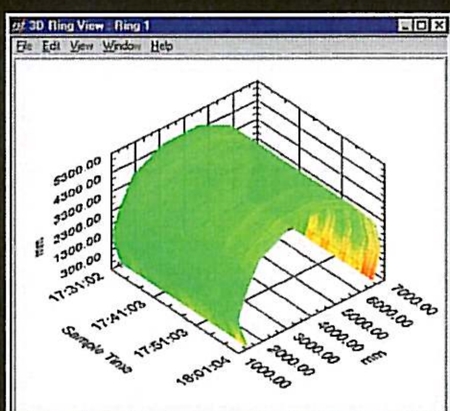
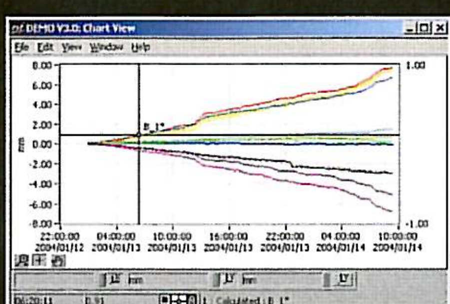
# GeoViewer Software

Designed to simplify data interpretation, the GeoViewer Software allows the user to retrieve data from loggers in near-real time and graphically process the information.

The XY coordinates and displacement data for each reference pin is calculated and displayed in a variety of different charts and graphs, displayed graphically, or presented as a 3D image. Deformation may be animated, time sliced, or rotated as required. An original image may be superimposed with post deformation data to show displacement with time. GeoViewer will automatically collect and process the data to update the screen in near-real time. Alarm functions with user programmable rate/magnitude thresholds are provided. The program format allows data to be imported into outside software programs for further analysis, or will export JPEG images to the internet. Windows™ 95, 98, 2000, NT™ and XP™ operating systems are supported.

The RST GeoViewer program is custom written in both English and the user's language for each site-specific application. Free demonstration software is available on CD. Please contact RST for details.



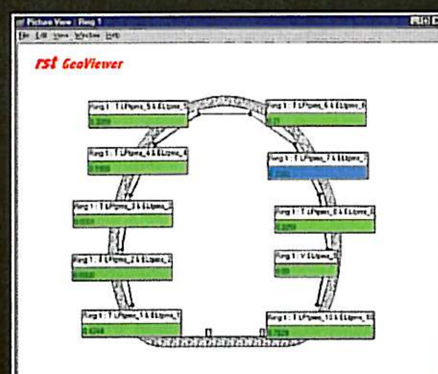



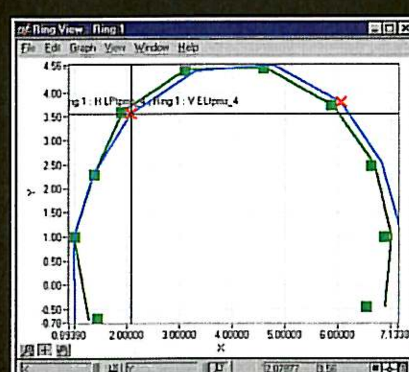

## FEATURES

- Near-real time data logger retrieval.
- Graphical representation of data in a variety of forms.
- Software written in both English and customized to the user's specified language.
- Superimposition of original images over post deformation data.
- Automated collection and processing of data updating in near-real time.
- Multiple alarm functions with user programmable rate/magnitude thresholds provisions.
- Cross platform data export abilities to Windows™ 95, 98, 2000, NT™ and XP™ operating systems.
- Export on-screen data representation as JPEG image for internet and e-mail use.

## FUNCTIONS

- Assess settlement effects on various civil structures.
- Correlate data obtained from various monitoring instrumentation used on the same specific project.

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flexDAQ DATALOGGERS

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pre-wired
pre-tested
pre-programmed

# CR1000 Data Logger

The CR1000 Datalogger is part of the flexDAQ Datalogger Series. It is a multi-channel data logger designed for reliable, remote monitoring under demanding geotechnical conditions. It provides sensor measurement, timekeeping, data reduction, data/program storage and control functions. Data values are are stored in tables with a time stamp and record number. The CR1000 is capable of monitoring all types of sensors including vibrating wire, servo-accelerometer, linear potentiometer, strain gauge, thermistor, electrolevel, etc.

The standard CR1000 datalogger includes 2 Mbytes of memory for data and program storage. Data and programs are stored either in a nonvolatile Flash memory or RAM. A lithium battery backs up the RAM and real-time clock. The CR1000 also suspends execution when primary power (BPALK, PS100) drops below 9.6 V, reducing the possibility of inaccurate measurements. The CR1000 can be augmented with peripherals to form a data acquisition system; many CR1000 systems can be networked to form a local or regional monitoring network.

Battery-backed SRAM memory, and clock, ensure that data, programs, and accurate time is maintained while the CR1000 is disconnected from its main power source.

Multiplexers, such as the RST Flexi-Mux, can increase the number of sensors that can be measured by the CR1000 by sequentially connecting each sensor to the datalogger. Several multiplexers can be controlled by a single CR1000.

## FEATURES

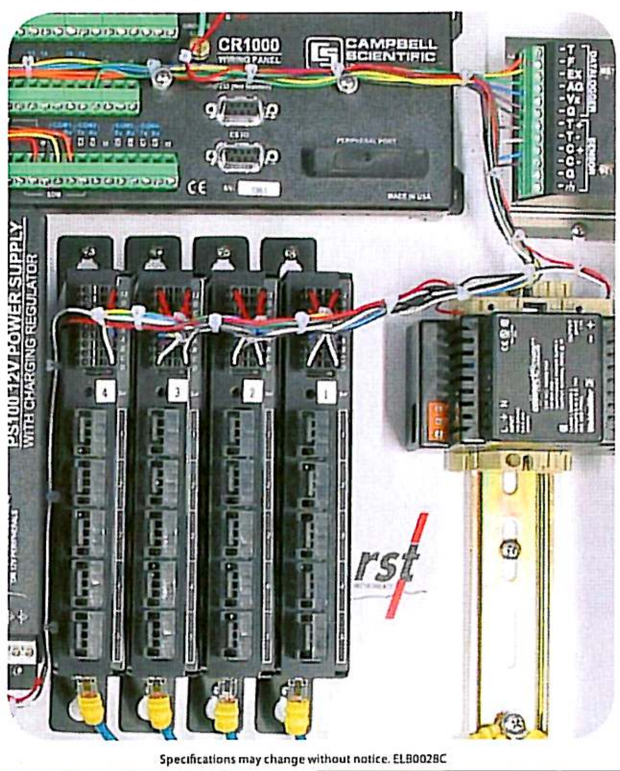
- 2 Mbytes standard memory; 4 Mbytes optional memory.
- Program execution rate of up to 100Hz.
- CS I/O and RS-232 serial ports.
- 13-bit analog to digital conversions.
- 16-bit H8S Hitachi Microcontroller with 32-bit internal CPU architecture.
- Temperature compensated real-time clock.
- Background system calibration for accurate measurements over time and temperature changes.
- Data values stored in tables with a time stamp and record number.
- Battery-backed SRAM memory, and clock, ensure that data, programs, and accurate time is maintained while the CR1000 is disconnected from its main power source.

## FUNCTIONS

- Remote datalogging of various types of geotechnical instrumentation used in dams, tunnels, bridges, mines, and natural slopes.
- Alarm triggering when movement reaches a preset critical rate or levels reach a present value.
- Real time data logging and analysis.

## ORDERING INFORMATION

| Part Number | CR1000 |
|---|---|

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## COMMUNICATION PROTOCOLS

The CR1000 supports three comunication protocols: traditional, PAKBUS®, and Modbus. The traditional communication protocol is connection-based.

The PAKBUS® communication protocol improves upon traditional communications for datalogger networks. PAKBUS® networks have the distributed routing intelligence to continually evaluate links. Continually evaluating links optimizes delivery times and, in case of delivery failure, allows automatic switch over to a configured backup route.

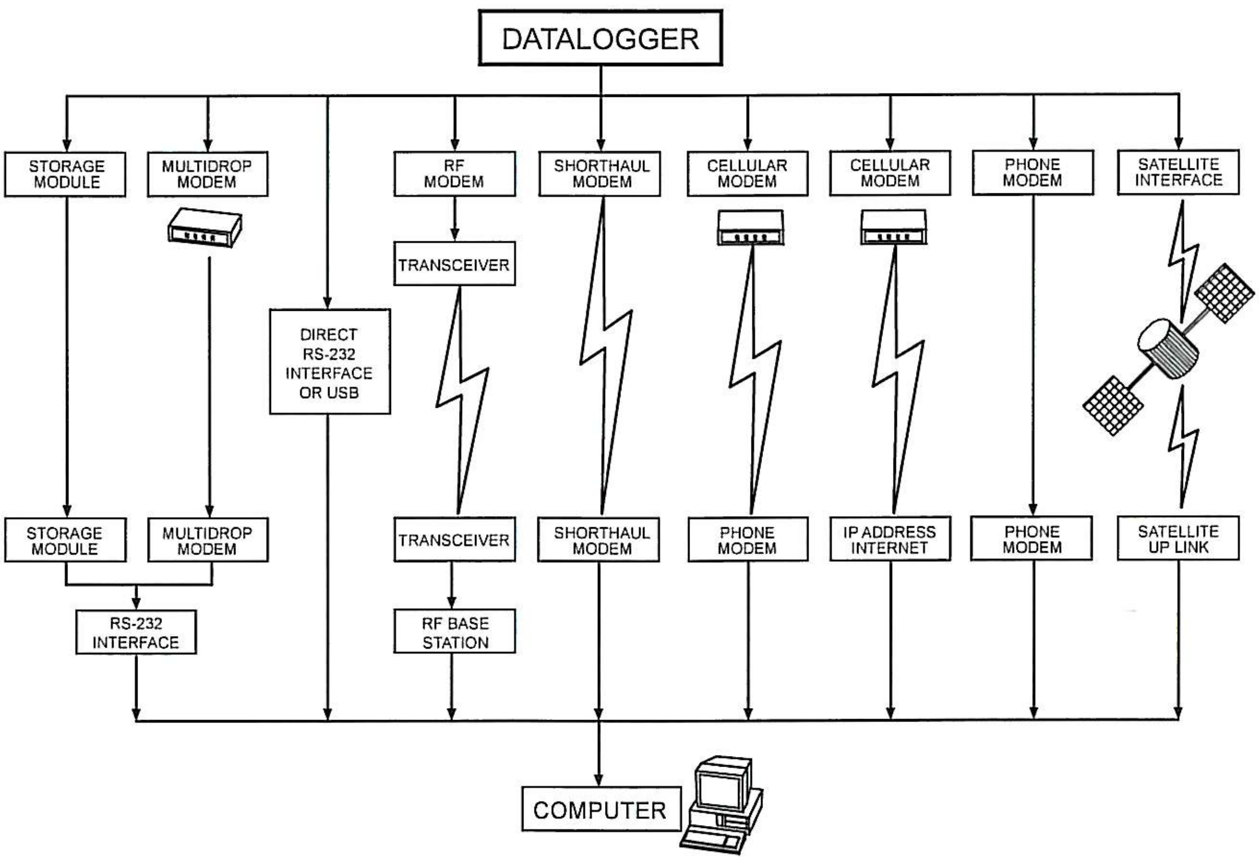
The Modbus protocol allows the CR1000 to work with "off the shelf" Modbus software packages.

## COMMUNICATIONS

Compatible telecommunication options include ethernet, phone modems (land-line and cellular), radios, short haul modems, GOES satellite transmitters, and multidrop modems. Real-time and historical data can be displayed on-site using a PDA (requires PConnect 3.1), the CR1000KD keboard/display, or a PC.

The PC connects to the CR1000 via an RS-232 cable, or if optional isolation is required, via the CS I/O port and SC32B interface. Users can transport programs/data to a PC via CompactFlash® cards. The CFM100 module is used to store the programs/data on the card; a SanDisk® ImageMate® card reader is used to download the programs/data to the PC.

## DIAGRAM OF POSSIBLE COMMUNICATION METHODS



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# Appendix E

## Cost Estimate for Construction of the Proposed Wells and Piezometers

**Price Estimate for the Construction of the Proposed Wells and Piezometers**

In this appendix, a budgetary estimate is provided for the installation of the proposed wells and piezometers. This estimate is based on the following three activities:

- Mobilization
- Construction of seven wells with 12″ in diameter and 200′ in depth
- Construction of eight new piezometers, four to the depth of 200′ and four to the depth of 115′

It should be mentioned that almost half of this estimate is related to the drilling and casing of the wells. This is mainly due to the size of drilling and the installation of filter sand pack.

The approximate estimate for the above activities is as follows:

- Mobilization: $90,750
- Well construction: $931,770
- Piezometer Construction: $116,741

The details of the estimate and the proposed designs are in the next two pages.

Davidson

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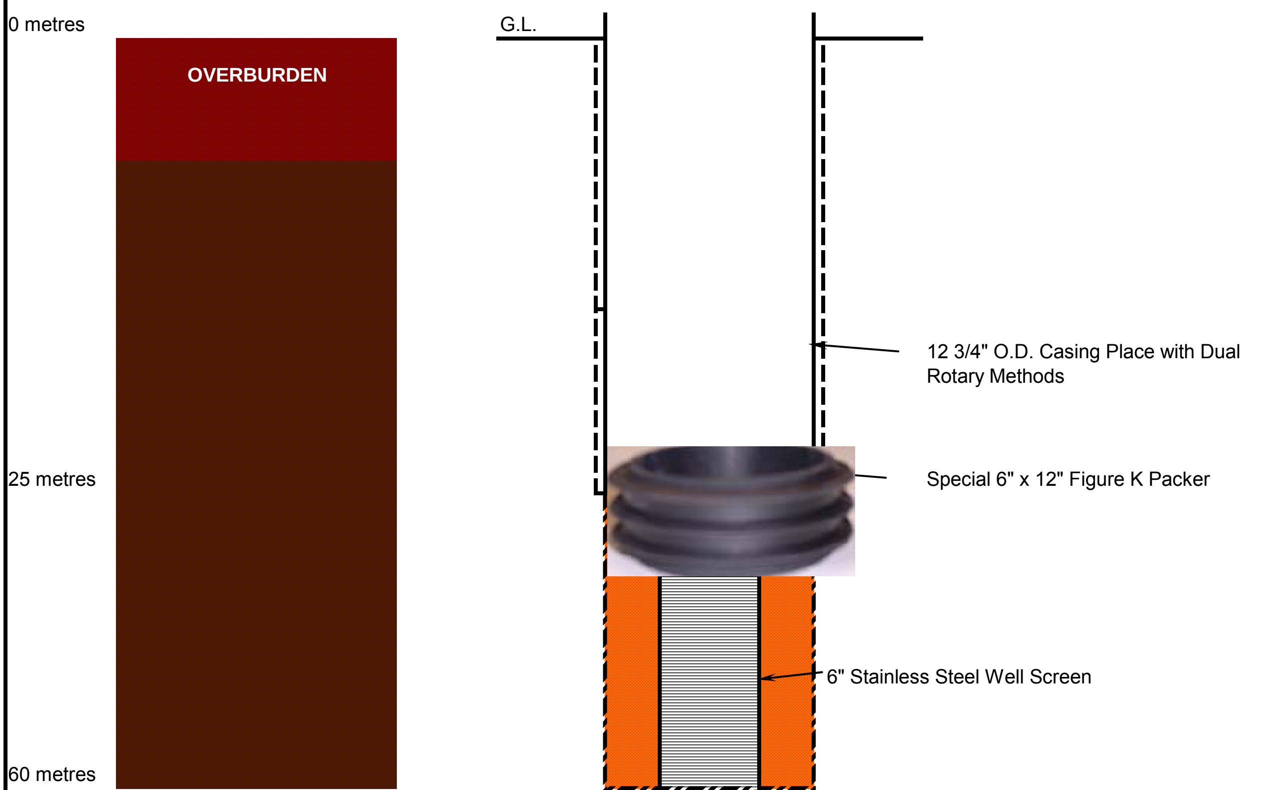
ESTIMATED SCHEDULE OF QUANTITIES AND PRICES
MUSKRAT FALLS POWER FACILITY
MUSKRAT FALLS, LABRADOR, NEWFOUNDLAND

FOR: HATCH
Attention: Mr. Warren Hoyle

| ITEM NO. | DESCRIPTION | UNIT | EST. QUANTITY | UNIT COST | ITEM COST |
|---|---|---|---|---|---|
| A1 | Mobilization and demobilization of drilling equipment, tooling and supplies, room & board | L.S. | 1 | $90,750.00 | **$90,750.00** |
| | **CONSTRUCTION OF SEVEN (7) - 12 INCH PRODUCTION WELLS TO 200 FEET EACH** | | | | |
| B1 | Drill in 12 3/4" O.D. casing to approximately 200 feet per well | Foot | 1400 | $375.00 | $525,000.00 |
| B2 | Supply 12 3/4" Casing | Foot | 700 | $75.00 | $52,500.00 |
| B3 | Supply 6" Pipe Size Stainless steel well screens - based on 115 feet per well | Foot | 805 | $245.00 | $197,225.00 |
| B4 | Supply 6" screen lead pipe - based on 10 feet per well | Foot | 70 | $15.00 | $1,050.00 |
| B5 | Supply 6" x 12" centralizers for well screen | Each | 21 | $145.00 | $3,045.00 |
| B6 | Supply filter pack sand - 2000 lb bags | Bag | 62 | $700.00 | $43,400.00 |
| B7 | Supply special figure K packer | Each | 7 | $1,900.00 | $13,300.00 |
| B8 | Other work for drill rig and crew and well development, etc. | Hour | 175 | $550.00 | $96,250.00 |
| | | | | **TOTAL** | **$931,770.00** |
| | **CONSTRUCTION OF EIGHT NEW PIEZOMETERS - FOUR TO 200 FEET AND FOUR TO 115 FEET** | | | | |
| C1 | Drilling of 6" borehole utilizing Dual Rotary drilling and sampling methods | Foot | 1260 | $65.00 | $81,900.00 |
| C2 | Supply 2" PVC Sch. 40 Riser Pipe - 10 ft lengths | Foot | 900 | $4.25 | $3,825.00 |
| C3 | Supply 2" PVC Sch. 40 Slotted Screen - 10 foot lengths | Foot | 400 | $5.35 | $2,140.00 |
| C4 | Supply threaded end caps and Slip-on caps | Set | 8 | $22.00 | $176.00 |
| C5 | Supply Graded Sand filter pack material - 50 lb bags | Bag | 240 | $14.00 | $3,360.00 |
| C6 | Supply Holeplug grout - 50 lb bags | Bag | 16 | $25.00 | $400.00 |
| C7 | Supply Quik Grout Bentonite - 50 lb bags | Bag | 50 | $30.00 | $1,500.00 |
| C8 | Supply 4" x 5' Casing Protectors | Foot | 8 | $180.00 | $1,440.00 |
| C9 | Other work for drill rig and crew and well development, etc. | Hour | 40 | $550.00 | $22,000.00 |
| | | | | **TOTAL** | **$116,741.00** |
| | | | | **TTOTAL** | **$1,139,261.00** |

***Conceptual Design of 12 3/4" O.D. Dewatering Well***

***Dewatering Well Replacement***
***Muskrat Falls Power Facility***
***Labrador, Newfoundland***




Drawn by: Bill Davidson

Date February 12, 2008

Note Not To Scale