GEOLOGICAL SURVEY OF CANADA

OPEN FILE 4942

Hydrogeological data from the South-Central Area of the Maritimes Carboniferous Basin (MGWI project)

C. Rivard, Y. Michaud, V. Boisvert, T. Calvert, R.H. Morin, C. Deblonde, R. Lefebvre and D.A. Pupek

A contribution to the New Brunswick Environmental Reporting Series.

2005

Natural Resources Canada Ressources naturelles Canada

Canada

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C. Rivard[1], Y. Michaud[1], V. Boisvert[2], T. Calvert[3], R.H. Morin[4], C. Deblonde[1], R. Lefebvre[2] and D.A. Pupek[5]

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[5] New Brunswick Department of Environment and Local Government

2005

Available from:
Geological Survey of Canada
601, Booth Street
Ottawa (Ontario) K1A 0E8

C. Rivard, Y. Michaud, V. Boisvert, T. Calvert, R.H. Morin, C. Deblonde, R. Lefebvre, D.A. Pupek
2005: Hydrogeological data from the South-Central Area of the Maritimes Carboniferous Basin (MGWI project), Geological Survey of Canada, Open file 4942, 143 p.

PREAMBLE

This Open file contains information related to fieldwork and associated analysis performed within the framework of the Maritimes Groundwater Initiative (MGWI project). The information therein is complementary to the GSC Bulletin “Canadian Groundwater Inventory: Regional Hydrogeological Characterization of the South-central area of the Maritimes Carboniferous Basin”. The MGWI project was a large integrated regional hydrogeological study focusing on a representative area of the Maritimes Carboniferous Basin (Eastern Canada). The study area covered a standard 1:250 000 map sheet and encompassed parts of three provinces: New Brunswick, Nova Scotia, and Prince Edward Island (see Figure 1).

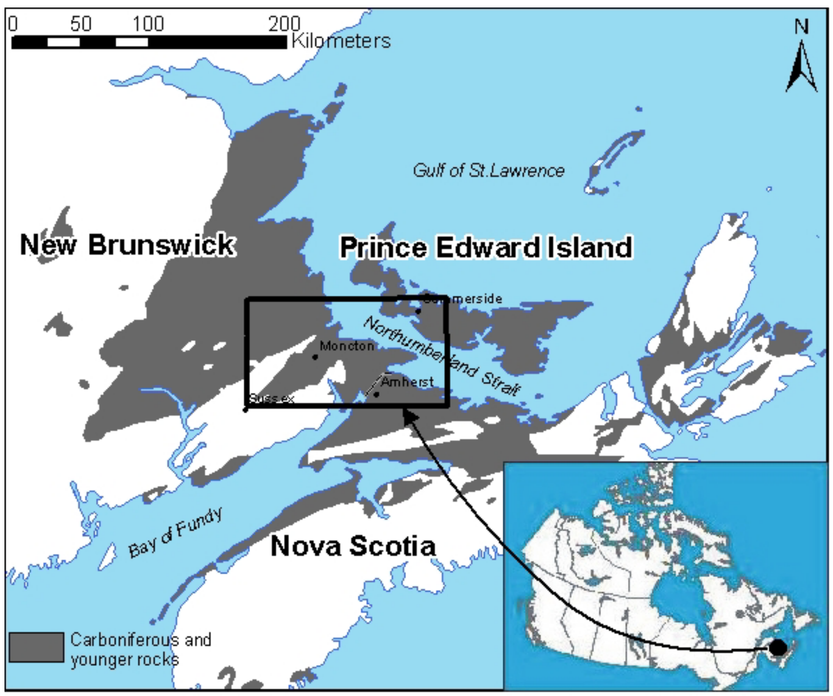

Figure 1: Location of the study area for the MGWI project

The region under study covers an area of about 14 000 km^2, of which 8 000 km^2 is underlain by Carboniferous rocks. It is located within geographical coordinates 45^o 45’ and 46^o 30’ north and 63^o 30’ and 65^o 30’ west (corresponding to 305 000 to 462 000 mE in X and 4 961 000 to 5 153 000 mN in Y UTM coordinates). The major towns within the area are Moncton, Sackville, Shediac, and Bouctouche in New Brunswick, Amherst in Nova Scotia, and Borden and Summerside in Prince Edward Island. The sedimentary bedrock is composed of a cyclic sequence of discontinuous strata of highly variable hydraulic properties (mostly sandstone, siltstone, shale, and conglomerate), and is generally overlain by a thin layer of glacial till. The main objectives of the MGWI project were to improve the general understanding of groundwater flow dynamics and to provide baseline information and tools for a regional groundwater resource assessment.

Fieldwork was carried out during the summers of 2001 and 2002 in order to gather additional data on stratigraphy, hydraulic properties, fracturing, and groundwater characteristics in specific areas in an attempt to fill the main gaps in information coverage. The activities were performed within the various geological formations representative of the Maritimes Carboniferous Basin, and have emphasized their particularities and features.

This document has been divided in three parts:

- Part A Pumping test reports
- Part B Geophysical resistivity soundings report
- Part C Borehole log description reports
- Part D Quaternary sediment hydraulic testing
- Part E Borehole geophysics logging.

The location of fieldwork performed is presented in Figure 2 (along with all other activities conducted for this project).

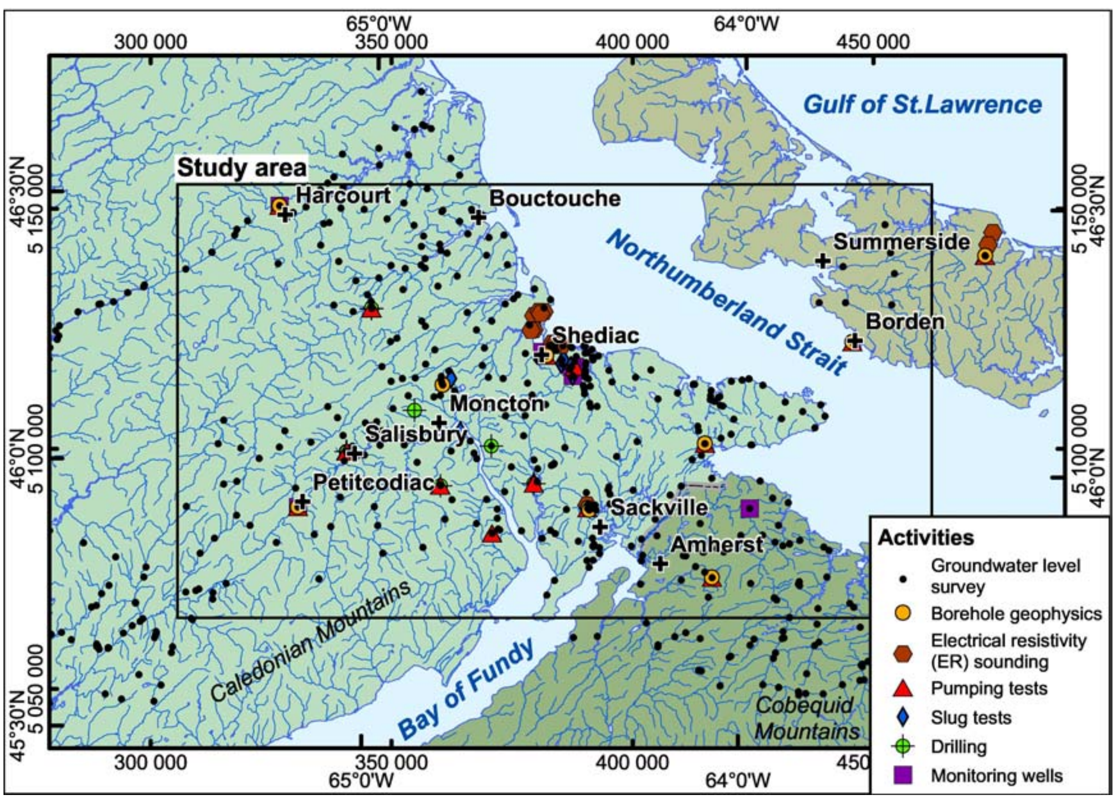

Figure 2: Location map of the study area showing investigated sites

The results obtained were added to the large database and have significantly contributed to the general understanding of this hydrogeological system, described in the Bulletin. A companion atlas (Open File 4884) to the Bulletin has also been developed, which presents 44 maps and thematic plates presenting compiled and interpreted data, and major results regarding hydrogeology, geology and hydrology. The atlas also integrates the data and results presented in this Open File.

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Part A

Pumping test reports for bedrocks units

Pumping test in the Village of Salisbury, New Brunswick

1. Introduction

As part of the fieldwork undertaken by the Geological Survey of Canada (GSC) for the characterization of the aquifers of the Maritimes Carboniferous Basin (Maritimes Groundwater Initiative project), a pumping test was conducted in the Village of Salisbury, New Brunswick, in August 2002. The pumping test used two wells that had been drilled by the GSC the week before. This site was selected since very few data were available for the Salisbury Formation. Two pumping and recovery periods at two different pumping rates were used for the interpretation.

The observation well is located 141.8 m east (10^{o} north) of the pumping well. This site is situated within the Salisbury municipal zoning, in a wooded area belonging to Mr. and Mrs. MacDonald, which can be reached by a trail from Reeder Road. Table 1 summarises the wells' characteristics. Their geological logs are presented in Appendix K. Groundwater static levels are quite different, indicating that they probably do not intercept the same strata or fracture network. Moreover, considerably more water came out during the drilling from the pumping well than from the observation well. Both wells seem to tap a confined aquifer since drilling revealed that water originated from fractures located much deeper than the measured static levels.

Table A-1: Characteristics of the Salisbury wells

Name	X*	Y*	Z*	Well depth (m)	GW static depth (m)	Casing (cm)
#1	340 460	5 099 498	40.35	68.6	5.11	0.45
#2	340 601	5 099 513	43.04	68.6	1.965	0.1

* X and Y have been measured with a GPS and the elevation Z has been calculated with a DEM (using 10m topographic isocontours from 1:50 000 maps)

2. Implementation of the pumping test

The pump was set at a depth of 24 m. Pumping rates were measured during both tests using a flowmeter. Data loggers were introduced in both wells and set to take measurements every 30 seconds.

The hydraulic test began on Saturday August 17th at 3 pm, and extended until Wednesday 21st since several technical problems occurred. According to the drillers, the pumping well should have yielded 3.8 l/s (50 Igpm). Since our pump could provide 3.3 l/s, we decided to carry out a 3-step drawdown test with the valve 1/3, 2/3 and completely open. However, the groundwater level within the pumping well dropped 9.5 m within the first 4 minutes of the first step. The test was therefore stopped, and a recovery was allowed for 3.7 h. The valve was then closed to 80%.

The first pumping test used a pumping rate of 1.9 l/s and lasted 9.1 h (including pumping and recovery periods). The second test was implemented using a pumping rate of 1.1 l/s and extended over 49 hours (for both periods).

3. Results of the pumping tests

The observation well never reacted during the pumping tests. Drilling revealed that the stratigraphy in both wells is quite different despite the fact that they are relatively close (141.8 m). This is typical of the Maritimes Carboniferous Basin aquifers, since the geological units are composed of a sequence of lenticular strata (mainly sandstone, shale, siltstone and conglomerates) of various extents. Thus, fractures encountered at both wells do not seem to be connected at all. Drilling also indicated that major water bearing fractures were found at 24.4 m for the pumping well and at 15.2 m for the observation well (but in smaller quantity). The static levels, being quite different, reflect this fact,.

For the first test, the well was pumped for 73 minutes at 1.9 l/s and the maximum drawdown was 9.53 m. This test was stopped since we wanted to pump for several more hours and did not want to influence the neighbouring wells. Indeed, the observation well did not react, but it is not located in the direction of the major fractures (N45^{o}E), but some residential wells were. During the second test, the well was pumped at 1.1 l/s for 611 min. (10.2 h) and the drawdown reached 5.65 m, then the rate dropped to 0.64 l/s during the night. The pumping went on at this second rate for 13 additional hours. Figures 1, 2, 3 and 4 present semi-log and log-log plots of these two tests. The transmissivity values found using the Theis and the Cooper-Jacob methods (developed for confined homogenous isotropic media) for both tests range between T= 1.2 x 10^{-4} and 1.4 x 10^{-4} m^2/s if we eliminate the very first data (0-5 minutes), which are generally not representative. Both pumping period curves are very close to Theis theoretical curves, as shown by the good agreement calculated using a least square method in the Aqtesolv software. The interpretation of the second pumping test was done using the first part (pumping rate Q_1) only with the Cooper-Jacob method and using the complete period (Q_1 and Q_2) with the Theis method in Aqtesolv.

The recovery periods reflect the behaviour of the wells during the pumping periods. The plots use the time ratio t/t', where t corresponds to time since the beginning of the pumping and t' the time since the beginning of the recovery. The first recovery shows the two short tests performed at the end of the first pumping test to reach the pumping rate we wanted to use for the following one. The second recovery curve shows two slopes, illustrating the change in flow rate that occurred after 10 h. To obtain a representative value of transmissivity for this case, we used the geometrical mean of both T values calculated using the weighted average of the pumping rates (611 min. at 1.1 l/s and 786 min. at 0.64 l/s, giving 0.83 l/s). We found T= 1.1 x 10^{-4} and 1.8 x 10^{-4} m^2/s, which are very close to the ones obtained with the pumping periods. The overall geometrical mean gives T=1.4 x 10^{-4} m^2/s. No storage coefficient could be estimated as there was no reaction at the observation well.

A boundary was not encountered during the hydraulic testing of the well. Indeed, the pumping period curves do not show any abrupt change in slopes. This is probably due to the fact that the well was pumped for short periods (less than 24 hours) at a relatively low rate according to aquifer properties and also to the fact that the aquifer limits are probably quite distant (more than 1-2 km).

The results of the geochemical analyses are also presented at the end of the report. The groundwater sample shows that all parameters are below the health advisory limit for drinking water, except for turbidity. However, the groundwater sample was taken at the end of a third test, which was abruptly stopped because of a problem with one of the generators. The groundwater was very clear during the second and third pumping tests, before problems with the generator occurred. As we had to stop the pumping test, we took a sample, but the stopping/starting of the generator led to brownish turbid water, as shown by the high value of the analyse. However, this problem would likely go away after a few hours of pumping.

4. Conclusions

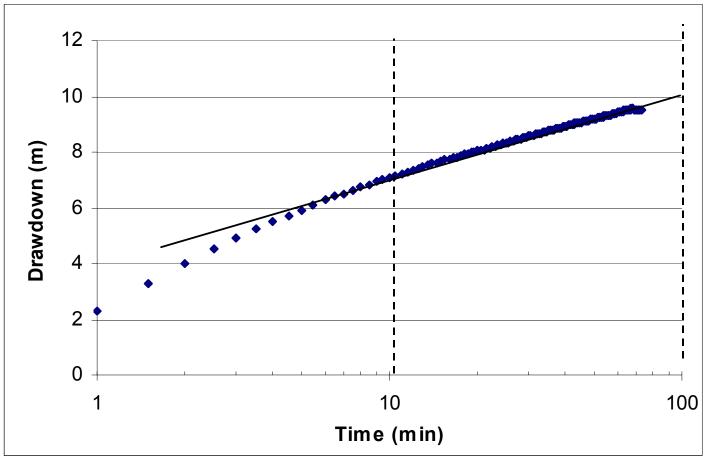
A pumping test was carried out in one of the wells constructed by the Geological Survey of Canada during August 2002 in the Village of Salisbury, New Brunswick. The objective was to acquire data for the Salisbury Formation, since very few are available. The average transmissivity value, calculated using two methods and both the pumping and the recovery periods, provided $T = 1.4 \times 10^{-4}\ m^2/s$, which corresponds to a relatively good aquifer.

The observation well never reacted throughout the hydraulic testing of this well. Consequently, no storage coefficient could be calculated. This well is located 141.8 m due east from the pumping well, while major fractures of the Maritimes Carboniferous Basin are generally oriented in a north-eastern (N45^{o}E) direction. In addition, both wells are showing major differences in their stratigraphy and static water-level. We therefore believe that these wells are not tapping the same strata. This cannot be considered an unexpected finding, since this Basin is known to be composed of a sequence of small extent lenticular strata of variable permeabilities. As pumping period curves are typical of those of a confined isotropic porous media, and because the static level is way above the water bearing fracture depth, we can say that this well is likely located within a confined aquifer.

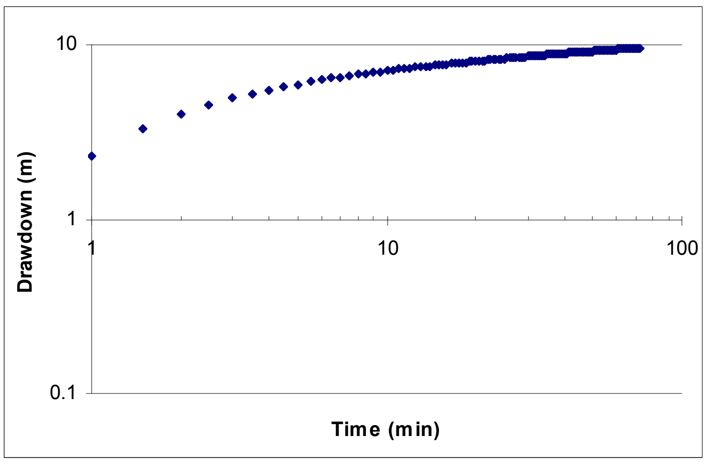
Results from the geochemical analyses showed that the groundwater sample exceed limits for drinking water standards only in the case of turbidity. However, several hours of pumping should probably solve the problem.

As such, there should not be any problems in terms of water quantity nor quality with domestic use of this aquifer, assuming the upcoming septic tank is appropriately located and installed. This well should not be pumped at a rate leading to a drawdown larger than

20 m, since a shale strata is present below this level. This could result in turbid water. No bacteriological analyses were performed. We highly recommend to do those tests before using this well as a residential water supply.



a)



b)

Figure A-1: Drawdown versus time for the pumping well, test #1 a) semi-log and b) log-log plot, Salisbury, NB

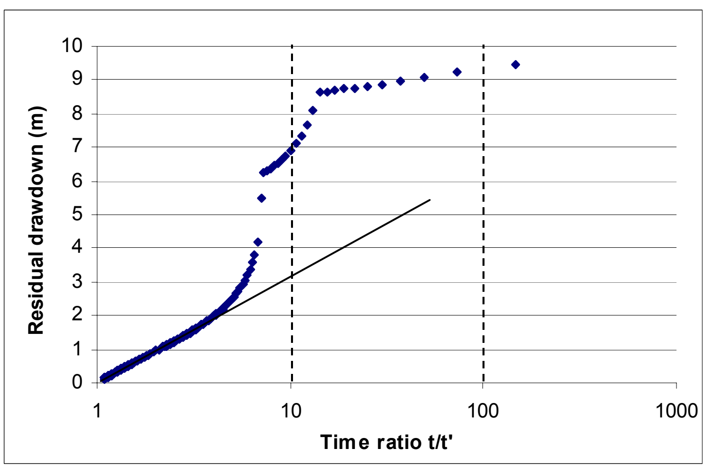
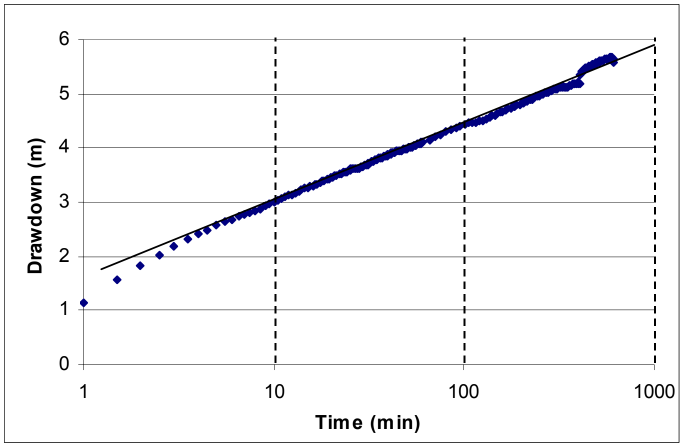
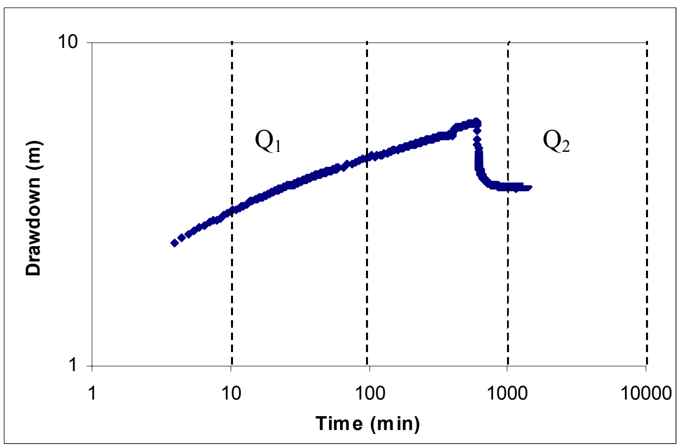


Figure A-2: Residual drawdown versus time for the pumping well, test #1, Salisbury, NB



a)



b)

Figure A-3: Drawdown versus time for the pumping well, test #2 a) semi-log and b) log-log plot, Salisbury, NB

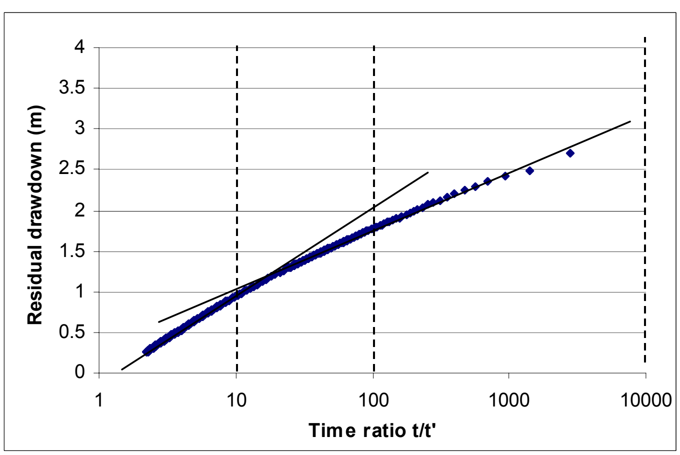


Figure A-4: Residual drawdown versus time for the pumping well, test #2, Salisbury, NB

WATER WELL DRILLER'S REPORT
21-1093 (5/97)

New Brunswick

DEPARTMENT OF THE ENVIRONMENT
ENVIRONMENTAL QUALITY BRANCH

Well ID Number: 1 2 5 7 8 7   PID Number:

For NBDOE Office Use Only
Payment received ☐ Yes ☐ No
☐ Cheque ☐ Money Order ☐ Cash

Name of Well Owner: A D I Limited
Address of Well Owner: 40 Henri Dunant St
Moncton   Postal Code: E1E 1E5

Well Location Address as above ☐ on Reserve ☐
OR ____________ Postal Code ______

Well paid for by Provincial Dept. of ______

Was the well already tagged Yes ☐ No ☐
If yes, the Old Well ID Number was ______

Well / Water Use: ☐ Domestic ☐ Municipal ☐ Abandoned ☐ Exploratory ☐ Heat Pump ☐ Industrial ☒ Observation ☐ Other ______

Type of work completed: ☒ New Well ☐ Deepened ☐ Other ______

Drilling Method: ☐ Cable Tool ☒ Rotary ☐ Other ______

Drillers Log * (Salisbury OW)

From (ft.)	To (ft.)	Colour	~~Rock Type~~
Ground Level	14	red	clay
14	40	red	sandstone
40	85	red	shale
85	200	red	sandstone

* If insufficient space please use additonal sheets

Casing Installed: ☐ Steel ☐ Slotted ☒ PVC
6 in. diam. from 0 ft. to 20 ft.
______ in. diam. from ______ ft. to ______ ft.
Drive Shoe: ☐ Yes ☒ No
Length of Casing Above Ground: 1 ft. ______ in.

Total Well Depth: 200 ft. **Depth to Bedrock:** 14 ft.

Water Bearing Fracture Zones: 10 igpm at 35 ft. 40 igpm at 170 ft.
______ igpm at ______ ft. ______ igpm at ______ ft.

Screens: Type: ______ Slot Size: ______
______ in. diam. from ______ ft. to ______ ft.

Well Grouted? ☐ Yes ☐ No Type: ______
from ______ ft. to ______ ft.

Pumping Test: Method: ☒ Air ☐ Bailer ☐ Pump
Initial Water Level: 40 ft. below top of casing
Pumping Rate: 50 igpm. Duration: ______ hrs. ______ min.
Final Pumping Water Level: 40 ft. below top of casing

Drilling Fluids Used: Type: ______
Well Disinfected? ☐ Yes ☐ No Type: ______ Amt: ______ gal.

Pump Installation: ☐ Installed ☒ Not Installed
Pump Type: ☐ Submersible ☐ Jet ☐ Turbine ☐ Other ______

Flowing Well? ☐ Yes ☒ No If yes, Rate: ______ igpm (approx)

Estimated Safe Yield: 50 igpm

(Recommended) Pump Intake Setting: ______ ft. below top of casing

Drillers Comments: Well drilled on Reeder Rd Salisbury

Name of Drilling Company: Walter Chappell Well Drilling
Company Licence Number: 62
Completion Date (D M Y): 14 8 02

I Certify that the well herein described has been constructed in accordance with the Water Well Regulation under the New Brunswick Clean Water Act.

Walter Chappell — Signature of Driller
Jerry Freeman — Signature of Helper

White - NB DoE
Yellow - Homeowner
Pink - Drilling Company

WELL WATER TESTING VOUCHER PAYMENT MUST BE INCLUDED WHEN SUBMITTING WATER WELL DRILLER'S REPORT

Figure A-5: Water well drillers's report, Salisbury, NB

Geochemical analyses, Salisbury, August 2002

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques

12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Client information du Client:

Report Date / Date du rapport: **2002/08/30**

Organization/Organisation:	N.B. Environment & Loc. Govt.
Attention:	Darryl Pupek
Prop. No./No. de Projet:	1502
Lab No./No. de Lab. :	**28482 - 200206728**
Authorization/Authorité:	Leslie Carr
Matrix/Matrice:	Groundwater / Eau Souterraine
Matrix/Matrice:	Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client:	SALISBURY 6H 02 MGCR 0005`
Date Collected/Date de prelevement:	2002/02/20

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Alkalinity / Alcalinité		130	mg/l		
Aluminum / Aluminium		0.106	mg/l	0.025	
Antimony / Antimoine	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	6.0
Arsenic	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	25.0
Barium / Baryum		0.245	mg/l	0.010	1.0
Boron / Bore		0.016	mg/l	0.010	5.0
Bromide / Bromure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	
Cadmium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	5.0
Calcium		37.0	mg/l	0.10	200
Chloride / Chlorure		0.228	mg/l	0.050	250
Chromium / Chrome	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.050
Conductivity / Conductivité		260	µS/cm		
Copper / Cuivre	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	1.0
Fluoride / Florure		0.128	mg/l	0.100	1.5
Iron / Fer		0.089	mg/l	0.010	0.300
Lead / Plomb	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	10
Magnesium / Magnésium		2.81	mg/l	0.10	150
Manganese / Manganèse		0.057	mg/l	0.005	
Nitrate	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrate / Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	1.0
pH		7.81			
Potassium		1.42	mg/l	0.10	
Selenium / Sélénium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	10

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.842	Sum of Anions	2.624	% Difference	-3.99
Saturation Index @ 5ºC	0.029	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	130.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date
Date du rapport: **2002/08/30**

Client information du Client:

Organization/Organisation: N.B. Environment & Loc. Govt.
Attention: Darryl Pupek

Prop. No./No. de Projet: 1502
Lab No./No. de Lab. : **28482 - 200206728**
Authorization/Authorité: Leslie Carr
Matrix/Matrice: Groundwater / Eau Souterraine
Matrix/Matrice: Drinking Water/Eau Potable

Client Sample Identifier/
No. d'Echantillon du client: SALISBURY 6H 02 MGCR 0005`

Date Collected/Date de prelevement: 2002/02/20

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Sodium		16.3	mg/l	0.10	270
Sulfate		0.359	mg/l	0.050	
Thallium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	
Tot. Diss. Solids / Matières tot. dissoutes		150	mg/l	10.0	500
Total Hardness / Dureté totale		104	mg/l	0.65	200
Turbidity / Turbidité	*** Exceeds H.A.L. / Plus que L.A.S. ***	41.4	NTU	0.01	1.0
Uranium		2.5	µg/l	0.5	20
Zinc		0.025	mg/l	0.005	5.0

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.842	Sum of Anions	2.624	% Difference	-3.99
Saturation Index @ 5ºC	0.029	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	130.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification
[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Page 2 of/de 2.

Figure A-6: Water quality report, Salisbury, NB

Pumping test in the Town of Sackville, New Brunswick

1. Introduction

As part of the fieldwork undertaken by the Geological Survey of Canada for the characterization of the aquifers of the Maritimes Carboniferous Basin (Maritimes Groundwater Initiative project), a pumping test was done in the Town of Sackville, New Brunswick, in one of the municipal wells in July 2002. The municipality owns seven wells, of which two are alternately pumped to supply the municipality. Consequently, six wells could serve as observation wells and there were no constraints regarding the length of the pumping period. However, the permitted recovery period (shut down of the pump) did not allow the groundwater levels to recover their static state. As a result, the recovery period is of limited help.

Figure 1 shows the geographical location of the seven municipal wells in UTM coordinates. This site is located approximately 3 km north-west from the municipality, close to Walker Road. Table 1 summarises the well characteristics. Four wells are artesian and their flow rates are quite large. It is thus evident that this aquifer can yield a large quantity of water and is confined, and as such, well protected from potential surface contamination.

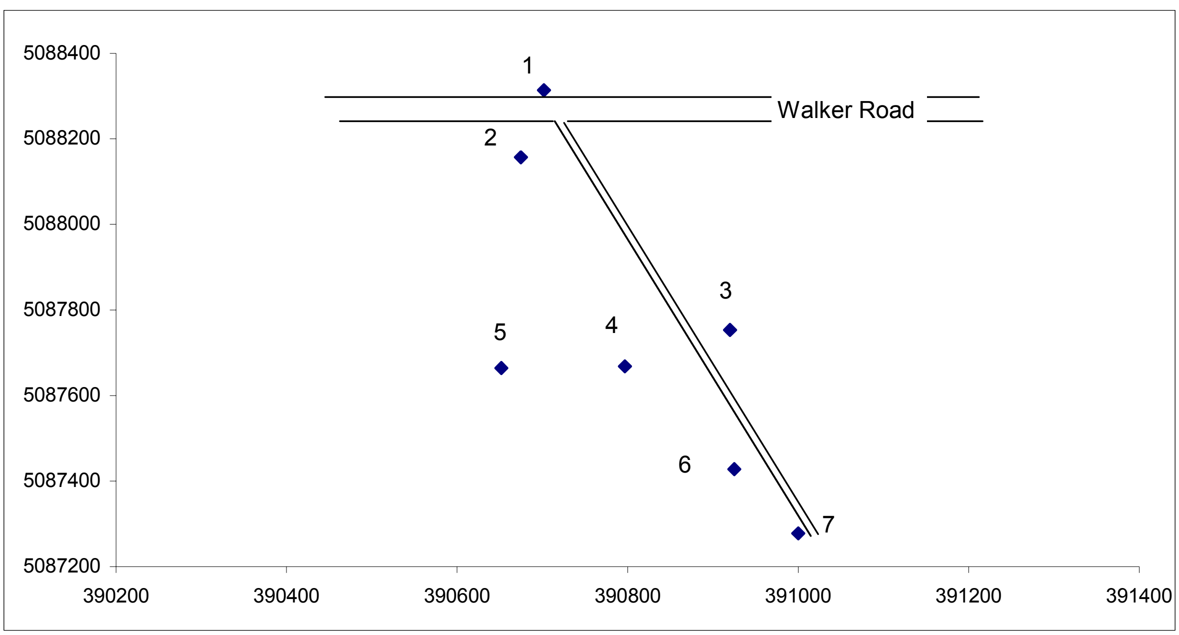


Figure A-7: Geographical location of the Sackville municipal wells

Table A-2: Characteristics of the Sackville wells

Name	X*	Y*	Z*	Artesian?	Well depth (m)
#1	390 702	5 088 314	98	N	-
#2	390 675	5 088 157	93	Y	-
#3	390 920	5 087 753	86	N	123.5
#4	390 797	5 087 668	83	Y	-
#5	390 652	5 087 664	85	N	155.8
#6	390 925	5 087 428	78	Y	-
#7	391 000	5 087 278	74	Y	-

* X and Y have been measured with a GPS and the elevation Z has been calculated with a DEM (using 10m topographic isocontours from 1:50 000 maps)

Very high concentrations of iron (Fe) and manganese (Mn) are present in the groundwater in this region. The wells contain a large quantity of Fe and Mn oxides (rust-coloured paste) which accumulates at the bottom of the well, on pipes and walls. Since the groundwater is directly sent to the pumping station, where iron and manganese are removed, “raw” groundwater could not be sampled and analysed during the pump test.

The pumping rate was measured using the filling of one of the reservoirs at the pumping station. We calculated a yield for well #5 of 35.98 l/s (475 Igpm). The groundwater static level could be measured only in well #1 because the other wells are either artesian or affected by pumping, and the allowed recovery time did not permit the groundwater to go back to its static level. The groundwater level measured in well #1 was 2.24 m from the top of the casing (located 0.35 m above the ground). This well was subsequently re-sealed to avoid surficial contamination since it is very close to a road.

2. Implementation of the pumping test

All municipal wells were shut down for under 7 hours (6.9 h) prior to the pumping test. Pumping of well #5 began on Wednesday July 10th at 7h00 am, and was stopped on Saturday the 13th at 23h22. The municipality had to start the pump on Sunday morning at 7h22, since the water in the reservoir was low. Well #5 was thus pumped for 88 hours, but the recovery period lasted only 6 hours. The pumping rate seemed to remain constant throughout the pumping test.

Data loggers were introduced in five wells (#1, 3, 4, 5 and 6) and groundwater levels were recorded every 30 seconds during the whole test. Flow rates were measured using a 20 L bucket in two artesian wells (#2 and 7). The only well that has been pumped for the municipality besides wells #3 and 5 is well #1, many years ago.

Two ponds are located between the two active municipal wells. Their level was measured using a total station during the pump test.

3. Results of the pumping test

There was no reaction at the artificial ponds during the pumping test. Since five out of seven wells are generally overflowing (depending on the season), it is likely that wells #3 and #5 are tapping a very well-confined aquifer.

Well #3:

Well #3 is located 282.4 m away from pumping well (#5) in a north-eastern direction. This well is pumped on a regular basis by the municipality and should therefore respond well. Semi-log and log-log plots for the pumping period are shown on Figure 2, at the end of the report. The semi-log plot is showing a typical confined isotropic porous media until approximately 700 min. After that, the drawdown begins to accelerate significantly. The slope of the second (later) linear segment is four times larger. This cannot be attributable to bad development of the well, since it has been regularly pumped for several years. We believe this is due to the interception of an impermeable boundary (or a region with a significantly lower permeability). The maximum drawdown recorded was 3.66 m.

The transmissivity (T) and the storage coefficient (S) were calculated using both the Theis and the Cooper-Jacob methods, the latter being an approximation of the former method. Those two methods assume confined conditions and a fully penetrating well. For the Theis curve match, the software Aqtesolv was used. Very similar values were found using both methods. For the first segment, the Theis method provided $T=7.2 \times 10^{-3}$ m^2/s and $S=1.3 \times 10^{-4}$, and the Cooper-Jacob method $T=7.4 \times 10^{-3}$ m^2/s and $S=1.3 \times 10^{-4}$. These values correspond to highly favourable aquifer conditions, the aquifer being very transmissive and confined, in agreement with site observation.
To check if the behaviour of the second part of the curve is due to an impermeable boundary, the theoretical Theis curve was subtracted from the second part of the measured curve. These data also behaved according to the Theis curve, modified with a factor 1/t for the time shift, which confirms our hypothesis. The presence of an impermeable boundary doubles the slope (rate of drawdown). As the slope has more than doubled, it probably indicates that the well is bounded by more than one single linear impermeable boundary. In other words, it reflects the typical Maritimes Carboniferous Basin stratigraphy, in which the various layers are lenticular. As their lateral extent is generally small (in the order of 3 km or less), it is not surprising to sometimes reach the limits of a permeable strata during a pumping test, depending on the location of the well within the discontinuous layer.

The recovery period is shown on a semi-log plot in Figure 3. The plot of the recovery uses the time ratio t/t', where t corresponds to time since the beginning of the pumping and t' the time since the beginning of the recovery. Since the pumping period showed a linear segment starting close to 30 min., we believe the most representative value of T should be obtained at the corresponding t/t', i.e. 175 or less. However, the recovery data does not present a linear segment for t/t'=175 or less, it is rather a curve until t/t'=60. We thus decided to use a mean value obtained from both segments shown on Figure 3. With the Cooper-Jacob approximation, we have: T= 3.9 x 10^{-3} m^2/s for the first segment and T= 4.7 x 10^{-3} m^2/s for the second one, leading to a mean value of T= 4.3 x 10^{-3} m^2/s. Usually, values obtained with the recovery period are very "robust" since the "pumping rate" is constant. However in this case, the recovery didn't last long enough. Nevertheless, the values obtained during both periods are reasonably close.

Well #4:

Well #4 is located approximately between #3 and #5 (the pumping well), 145.1 m away from #5, in an eastern direction. This well has not been pumped by the municipality. It behaved somewhat strangely, reacting very little (6 cm) for the first 540 min. (9 h). This almost-no-reaction behaviour cannot be attributed to clogging since the same behaviour is shown at the end of the recovery curve (Figure 5). Using the first part of the curve would provide values of T=3 x 10^{-1} m^2/s and S=4 x 10^{-3}, which is unlikely, knowing other surrounding values.

The second part of the curve has a slope 75 times the first one, which cannot realistically reflect the presence of impermeable boundaries. It is thus possible that this well, since it is not aligned with the direction of major fracture networks (east and not north-east) has been little affected by the pumping at first, the larger fractures being able to yield the sufficient amount of water required. But as the larger fractures empty (and aquifer boundaries are reached?), smaller fractures, which are "less directly" connected to the main fractured network, have to contribute to provide the same yield. Indeed, simultaneously to the gradual change in slope of well #3, the slope increases rapidly. The third slope of well #4 is two times the second one, likely indicating that an impermeable boundary has been reached. The Cooper-Jacob values for the second and third slopes are: T=4.5 x 10^{-3} ; S=1.9 x 10^{-2} and T=2.1 x 10^{-3} m^2/s ; S=3.3 x 10^{-2}. The storage coefficient values are incorrect since the first 11 hours cannot be used. The Theis match using the second part of the curve yields T=1.8 x 10^{-3} m^2/s and S=2.3 x 10^{-2}, which is again unlikely since the aquifer is confined.

At the end of the pumping period, the drawdown is still about half of the one measured in well #3 (s=1.93 m compare to 3.66 m), despite the fact that it is approximately half the distance away. The plot of the drawdown as a function of t/r^2, t being the time since the beginning of the pumping and r the distance to the pumping well, for both observation wells, should yield similar curves in the case of homogeneous isotropic media, but this is not the case here. Figure 6 presents this graph. We therefore decided to put aside data of well #4, since it does not behave according to an isotropic homogeneous media.

Well #5 (pumping well):

Well #5 was pumped for 88 hours at a steady rate of 35.98 l/s. The maximum drawdown recorded was 13.53 m. Figures 7 and 8 present pumping and recovery periods for this well. Except for the few first data, the semi-log plot shows a linear segment until the 2000 min. mark (33.3 h), which is surprising, since wells #3 and 4 have an earlier change in behaviour (prior to 1000 min.). Afterwards, the slope almost quintuples and the curve seems again linear until the end of the test, indicating again limits of the aquifer. The log-log plot of the pumping period is very flat, and thus, does not much resemble a Theis curve. Nevertheless, values of transmissivity were calculated using both the Theis and the Cooper-Jacob methods yielding two close values: T=6.4 x 10^{-3} m^2/s and T=6.1 x 10^{-3} m^2/s, which are in agreement with the values obtained at well #3. The least square method in Aqtesolv for the match of the Theis curve revealed a poor agreement. The first part of the recovery curve (with the exception of the few very first data) provides a value of T=5.2 x 10^{-3} m^2/s, close to the ones found with the pumping period.

An additional verification using the complete data (incorporating data previous to pumping) in the Aqtesolv software could not be done, as well #3 was pumped prior to the pump test in well #5.

<u>Wells #1, 2, 6 and 7</u>

Wells #1, 2, 6 and 7 are located to the north and south-east of the pumping well. None of them reacted to the pumping/recovery. Measurements of the yields were taken in artesian wells (#2, 6 and 7) using a bucket and the water-levels in well #1 were recorded using a data logger. The groundwater level in the latter well increased 4 cm prior to the start of the pumping test and decreased 8 cm until the end of the test. However, we believe this is not related to the pump test, but rather to the barometric pressure, since the recovery period does not appear on the graph. Measured yields of wells #2 and 7 during the pumping test remained at 6.0 and 2.1 l/s (79.2 and 27.7 Igpm).

This implies that this fractured aquifer is very heterogeneous and anisotropic, with major fractures being oriented in a north-eastern direction, similar to Carboniferous Basin regional structures. This results in strong channelling: groundwater first comes from 45^o fractures, then, when major fractures are emptied or aquifer limits are reached, smaller fractures oriented in a direction gradually diverging from N45^{o}E begin to contribute. These four wells are likely in the same aquifer as the other ones since they are close (within 300 m), their depths are similar and they all seem to have large yields. However, wells located to the north or south do not seem to be connected to the fracture network tapped by well #5.

4. Conclusions

A pumping test was carried out in well #5, and six wells were used as observation wells. However, only two wells besides the pumping well reacted to this stress. These are wells #3 and 4, respectively oriented in a north-eastern and eastern direction from the pumping well.

The values obtained at the observation well #3 are probably the most reliable, but the pumping well values are close to them. The transmissivity values found range from 4.3 x 10^{-3} < T < 7.4 x 10^{-3} m^2/s (with a geometrical mean of 6.0 x 10^{-3} m^2/s), confirming that the aquifer is very transmissive. However, all graphs indicated that lower transmissivity layers can be found nearby (shown by the significant increase in drawdown slopes), limiting the capacity of the aquifer to yield large quantities of water over a long period. Indeed, the Maritimes Carboniferous Basin is known to be highly stratified, each strata being lenticular with a lateral extent of 3 km or less. The Sackville municipal wells might then be located quite close to one of its sides. It is therefore good practice to pump alternately wells #3 and #5, as the municipality is presently doing.

Both values for the storage coefficient found with well #3 equalled 1.3 x 10^{-4}; the site was indeed assumed to be well confined, based on the number of artesian wells and lack of reaction of the ponds to the pumping. The wells can likely be considered well-protected against surface contamination.

The behaviour recorded at well #4 appears surprising. This is probably the result of poor connectivity between the fractures tapped by this well and well #5 and, later, to the reach of the aquifer limits. The sandstone strata supplying the Sackville municipal wells are probably highly fractured, since yields are large, but they might not be sufficiently connected to allow handling of the fracture network as an equivalent porous media at the local scale. A strong anisotropy would also have to be taken into account.

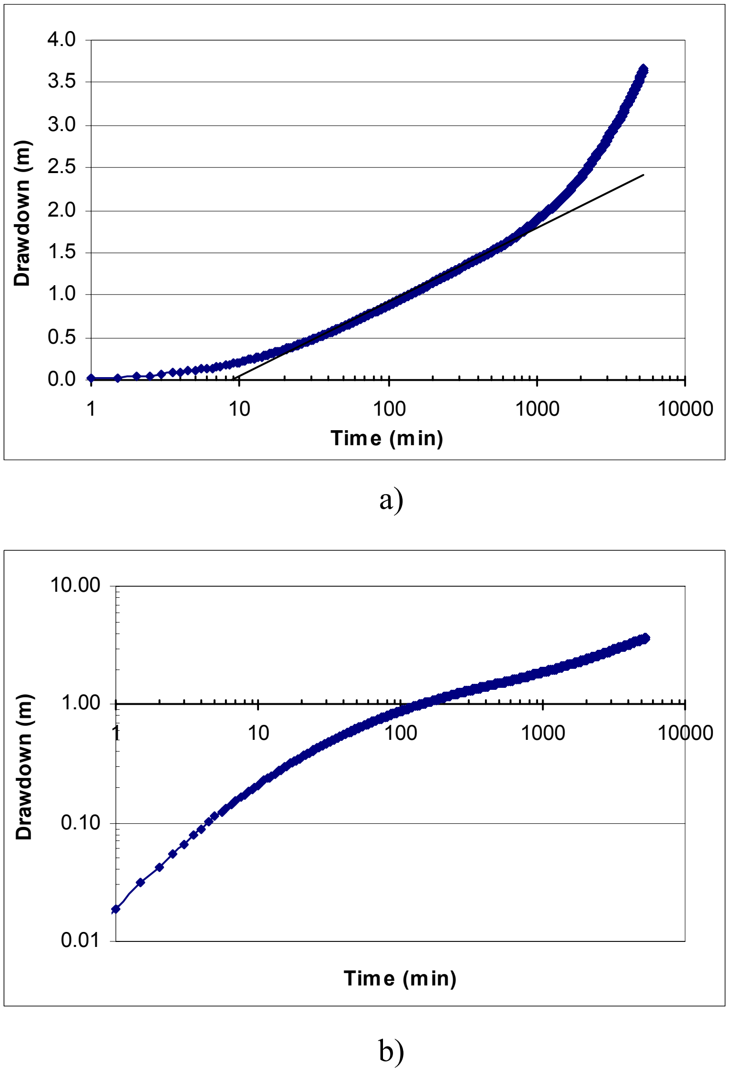


Figure A-8: Drawdown versus time for well #3 a) semi-log and b) log-log plot, Sackville, NB

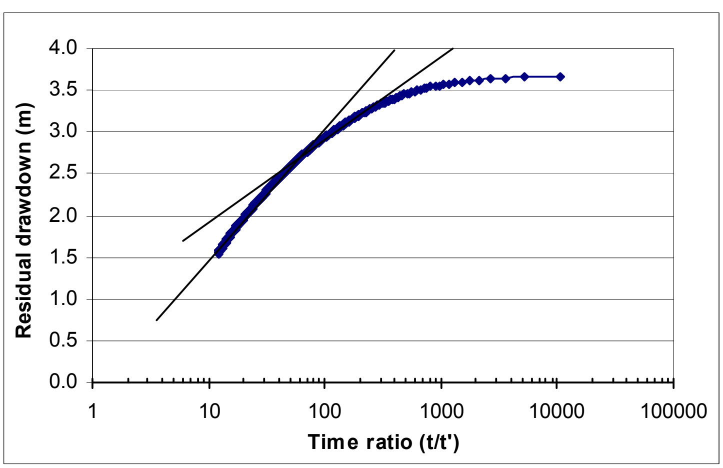
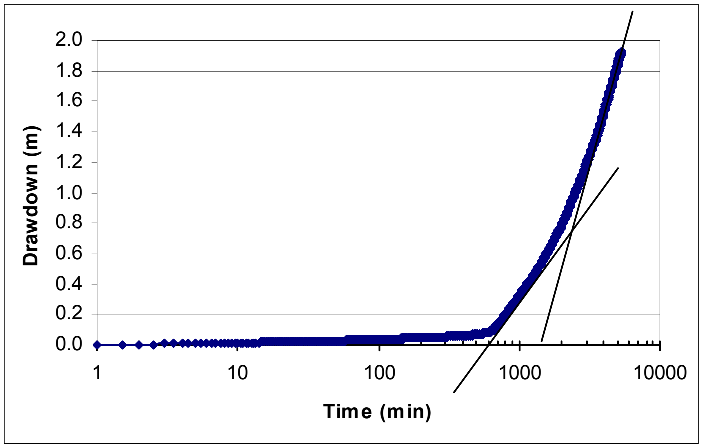


Figure A-9: Semi-log plot of the residual drawdown versus time for well #3, Sackville, NB



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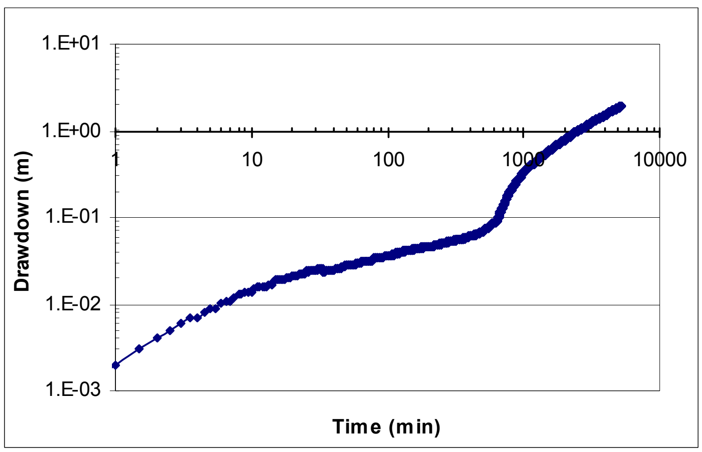


b)

Figure A-10: Drawdown versus time for well #4 a) semi-log and b) log-log plot, Sackville, NB

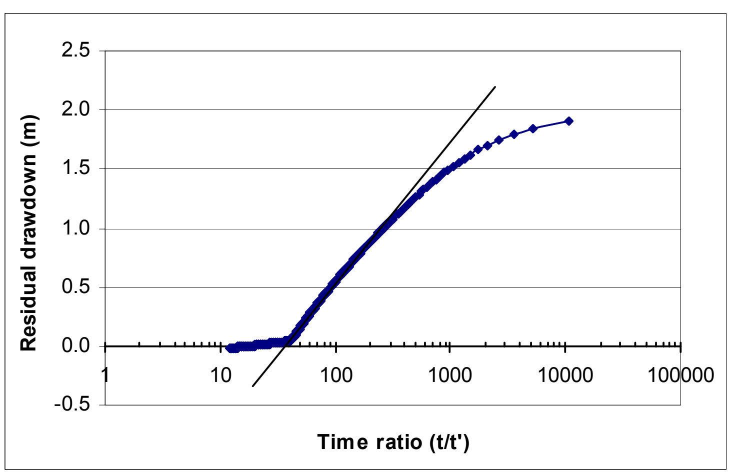


Figure A-11: Semi-log plot of the residual drawdown versus time for well #4, Sackville, NB

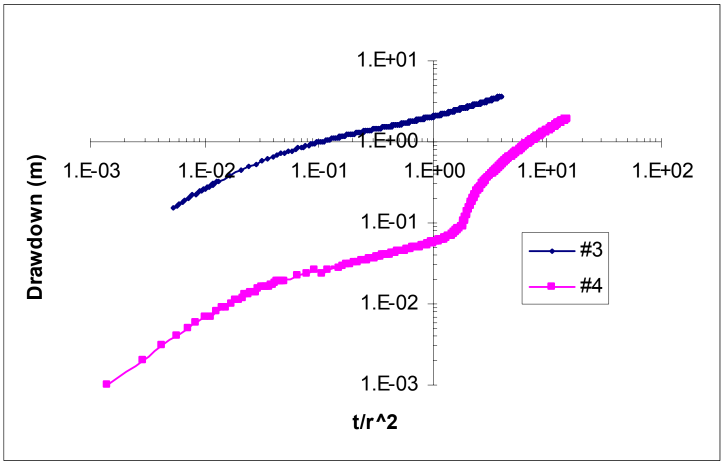
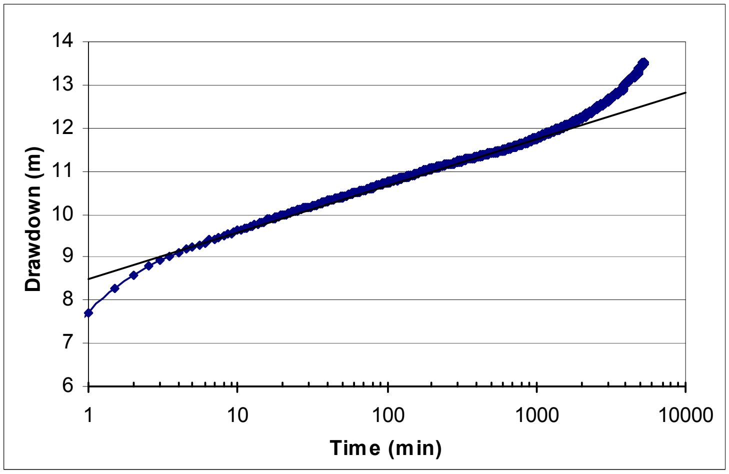


Figure A-12: Drawdown versus t/r^2 plot for observation wells #3 and 4, Sackville, NB



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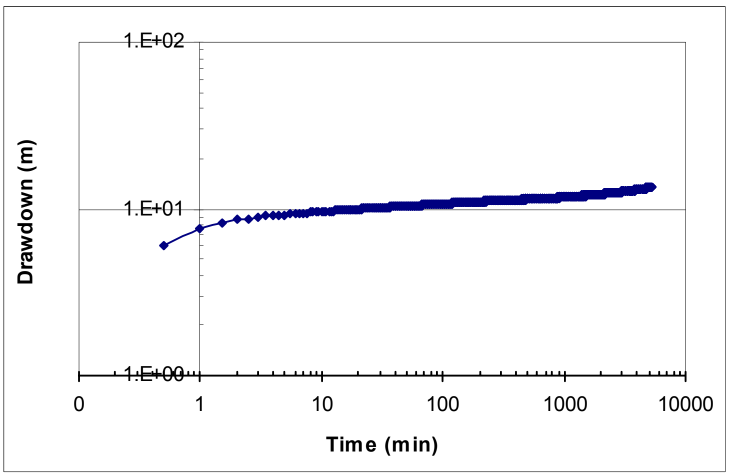


b)

Figure A-13: Drawdown versus time for well #5 (pumping well) a) semi-log and b) log-log plot, Sackville, NB

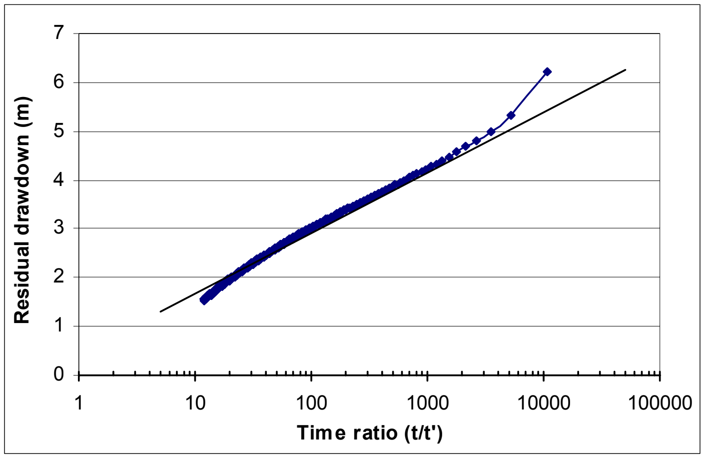


Figure A-14: Semi-log plot of the residual drawdown versus time for well #5 (pumping well), Sackville, NB

Pumping test in the Town of Riverview, New Brunswick

1. Introduction

As part of the fieldwork undertaken by the Geological Survey of Canada for the characterization of the aquifers of the Maritimes Carboniferous Basin (Maritimes Groundwater Initiative project), a pumping test was conducted in the town of Riverview, New Brunswick, in one of the municipal wells in August 2002. The municipality has two wells, constructed in the 1970s, which have never been exploited. The GSC also constructed an additional well at the beginning of August 2002. Consequently, two wells oriented in different directions as regards to the pumping well were used as observation wells. This site has been selected since very few data were available for the Boss Point Formation.

Figure 1 shows the geographical location of the three municipal wells in UTM coordinates. This site is approximately located 10 km due south of the Town, along Pine Glen Road. The road shown on the figure is a trail constructed by Irving, almost perpendicular to the Pine Glen Road. The wells are located about 1.5 km from the latter. Table 1 summarises the known well characteristics. The geological log of the observation well #2 is presented at the end of the report. These wells seem to tap a semi-confined to confined aquifer as the groundwater is very close to the ground surface. The construction of the second observation well confirmed that this area is very transmissive: the drilling had to be stopped at 68.6 m (225') as the well could not be drilled deeper with a 150 mm (6") diameter.

A 1990 geochemical analyse of a groundwater sample showed that very high concentrations of iron and manganese were present within the groundwater.

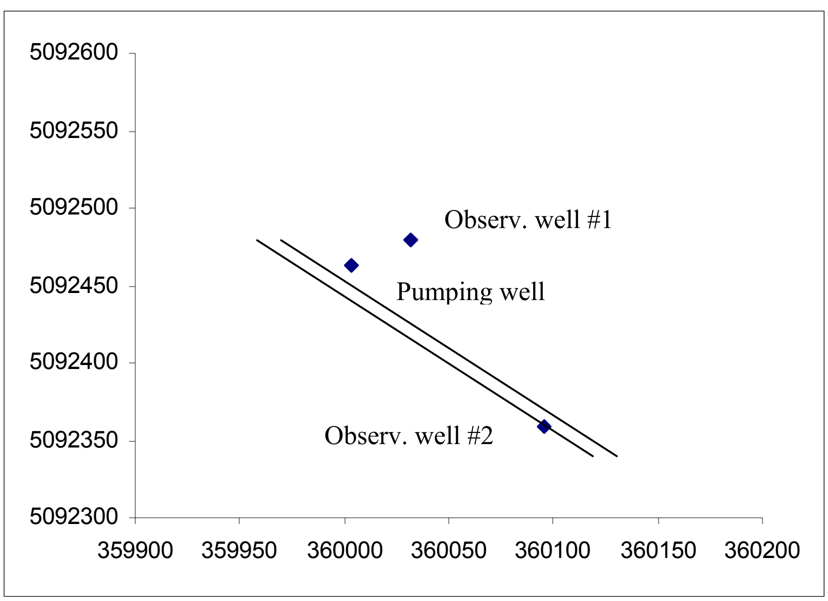


Figure A-15: Geographical location of the Riverview municipal wells

Table A-3: Characteristics of the Riverview wells

Name	X*	Y*	Z*	Well depth (m)	GW Static level (m)	Casing (cm)
Pumping well	360 003	5 092 463	106.1	91	0.96	40
Observ. #1	360 032	5 092 480	107	-	0	50
Observ. #2	360 096	5 092 359	106.9	68.6	1.65	45

* X and Y have been measured with a GPS and the elevation Z has been calculated with a DEM (using 10m topographic isocontours from 1:50 000 maps)

2. Implementation of the pumping test

Knowing that the yield was large, we decided to use two pumps within the pumping well, one on top of the other (both with a 200 mm (8') diameter). A generator was provided by the Town of Riverview. The pumping test started August the 13th at 11h30. The pumps were stopped on Thursday the 15th at 4h30 pm. The well was thus pumped for 53 h. The recovery was allowed for a little more than 18 h, since the equipment was required on other sites. The groundwater level did not recover its static level.

The pumping rate remained constant throughout the pumping test. It was measured using a 100 L bucket for one pump and with a flowmeter for the other pump. The combination of the pumping rates yielded 7.58 l/s (100 Igpm). Data loggers were introduced in all three wells. Groundwater levels were recorded every 30 seconds.

3. Results of the pumping test

A pond was located next to the pumping well, in a depression 1 m lower than the surrounding land. This pond gradually emptied as the pumping test carried on, but it went dry only after approximately 30 hours. Two other ponds located approximately 35 m away, from each side of the Irving trail, showed no reaction. This information is a good indication that the aquifer studied is semi-confined, but close to confined conditions.

Pumping well and observation well #1

The observation well #1 reacted exactly like the pumping well. Not only that, but it had the same drawdown (within 1 cm) versus time curve, indicating that those two wells could be located in a same vertical fracture. To verify this hypothesis, the Gringarten and Ramey method (Kruseman and de Ridder, 2000) was used. The particular behaviour of the first part of the log-log curve (2:1 slope) is attributable to the linear flow system (perpendicular to the fracture) at the beginning of the pumping. Then, afterwards, the flow becomes pseudo-radial and the curve resembles a Theis curve. The conditions for which Gringarten-Witherspoon method has been developed are: single, plane, vertical fracture in an otherwise homogeneous, isotropic, confined aquifer.

Semi-log and log-log plots of the pumping periods for the pumping well and its closest observation well for the 53h pumping period are shown on Figure 2 and 4. The plots for the recovery periods, shown on Figure 3 and 5, use the time ratio t/t', where t corresponds to time since the beginning of the pumping and t' the time that lasted the recovery. The F(u) versus u type curve of Gringarten, where $u=T*t/(S*x^2_f)$, T is the transmissivity, t is time, S is the storage coefficient and x_f is the half-length of the vertical fracture is presented in Figure 6. This method has enabled us to confirm that these wells are likely in a vertical fracture, as measured drawdown data fitted indeed very well on the type curve. Using this method, a value of $T=9.95 \times 10^{-4}$ m^2/s was found, very close to the values obtained using the first part of the curves with the Theis method ($T=1.1 \times 10^{-3}$ m^2/s), which has been developed for confined, isotropic and homogeneous media. This probably implies that the linear flow regime did not last long. Only the first part of the curves was used since, around 200 min., the slope doubles, indicating the presence of an impermeable boundary (or a significantly less transmissive region). Indeed, the presence of an impermeable boundary doubles the slope (rate of drawdown). The maximum drawdown recorded was 6.45 m. The recovery period data yielded a similar value of $T=1.4 \times 10^{-3}$ m^2/s. The observation well provided a storage coefficient value of 7.5×10^{-5}. This value confirms the confined to semi-confined conditions. A similar value of S was obtained using a plausible value of 100 m for the vertical fracture half-length.

<u>Observation well #2</u>

The observation well #2 is located at 140 m from the pumping well, in a direction perpendicular to the direction of the major fractures. However, this well reacted very well to the pumping, implying that the connectivity between water-bearing fractures encountered by this well and the pumping well is very good. The maximum drawdown in this well was 4.33 m. The T value has been estimated using the Theis method only, since this well is located quite far from the pumping well and a sufficient period had been recorded. The semi-log and log-log plots are shown on Figures 7 and 8. Again, the first part of the curve provided a value of 1.7×10^{-3} m^2/s. The boundary(ies?) is(are?) probably very close since the change in slope occurred very quickly (within 2 hours). The second slope is approximately 20 times the first one. To check if the behaviour of the second part of the curve is due to an impermeable boundary (or rather to insufficient development), the theoretical Theis curve was subtracted from the second part of the measured curve. These data also behaved according to the Theis curve, modified with a factor 1/t for the time shift, which confirmed our hypothesis. As the slope has more than doubled, it probably indicates that the well is bounded by more than one single linear impermeable boundary. In other words, it reflects the typical Maritimes Carboniferous Basin stratigraphy, which is composed of a sequence of lenticular layers. As their lateral extent is generally small (in the order of 3 km or less), it is thus normal to occasionally reach the limits of a permeable strata during a pumping test. A storage coefficient value of 2.1×10^{-4} was found. These values, again, correspond to a confined to semi-confined aquifer. No value was calculated for the recovery period, as it does not show any linear segments.

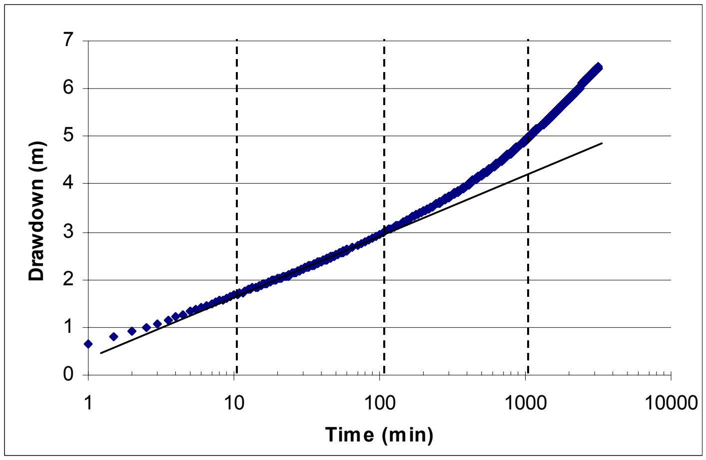
Two samples were taken during the pumping test, one after 24 hours of pumping, the other at the end, after 53 hours. The results of the geochemical analyses for both samples are also presented at the end of this report. The groundwater samples show that all parameters are below the health advisory limit for drinking water, except for turbidity. It is however very close to the limit (1.56 and 1.31 NTU) and the second sample showed a lower value for this parameter, suggesting an improvement with increased pumping duration. This parameter should therefore not pose a problem. Manganese exceeded the aesthetic criteria of 0.1 mg/l in both cases (0.51 and 0.44 mg/l). The occurrence of this element is very common throughout the Maritimes Carboniferous Basin, but is relatively easy to remove and has no harmful health effect.

4. Conclusion

A long term pumping test was carried out in one of the municipal wells of the Town of Riverview in August 2002, with two wells being used as observation wells. The furthest observation well was constructed by the GSC, at the beginning of the same month. The closest one appeared to be located within the same vertical fracture as the pumping well, their curves being identical. This well was thus interpreted using the Gringarten and Ramey method. This observation well is located in a north-eastern direction from the pumping well, i.e. in the major fractures' direction of the Maritimes Carboniferous Basin. The second observation well, even if located perpendicular to this direction (i.e. in a south-eastern direction), reacted very well.

This pumping test confirmed that the studied aquifer can yield a large quantity of water and that it is semi-confined to confined and thus, quite well protected against surface contamination. The pumping test allowed the quantification of the hydraulic properties associated with this behaviour. Overall mean values for all wells provided a transmissivity value of 1.2×10^{-3} m^2/s and a storage coefficient of 1.2×10^{-4}. However, all graphs indicated that lower transmissivity regions may be found nearby (shown by the significant increase in drawdown slopes), limiting the capacity of the aquifer to yield large quantities of water over a long period. This behaviour is in agreement with the known stratigraphy of the Maritimes Carboniferous Basin, which is highly stratified, each strata being of small lateral extent and of various permeability. These wells might be located somewhat close (within 1 km?) from one of its sides. However, the location of boundaries is impossible to determine, since it requires three observation wells, and, in this case, the slope of the observation well #2 has more than doubled, indicating the presence of more than one linear impermeable boundary.

Based on the transmissivity estimated and the quality of the groundwater, we believe this well has a good potential for water supply and could be integrated into a future municipal system. Bacteriological analyses should, however, be performed.



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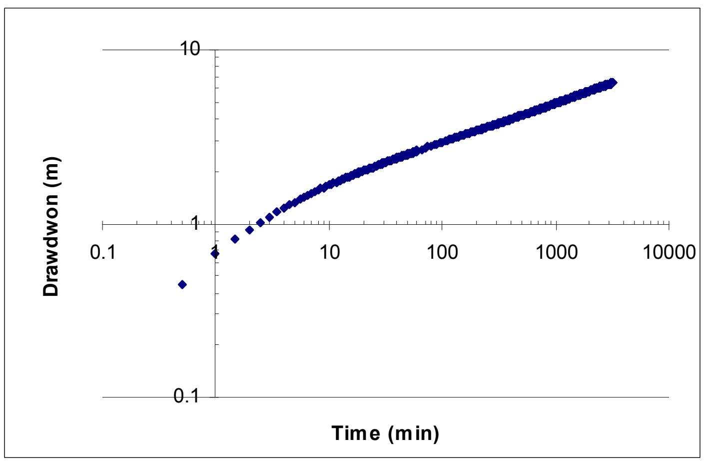


b)

Figure A-16: Drawdown versus time for the pumping well a) semi-log plot and b) log-log plot, Riverview, NB

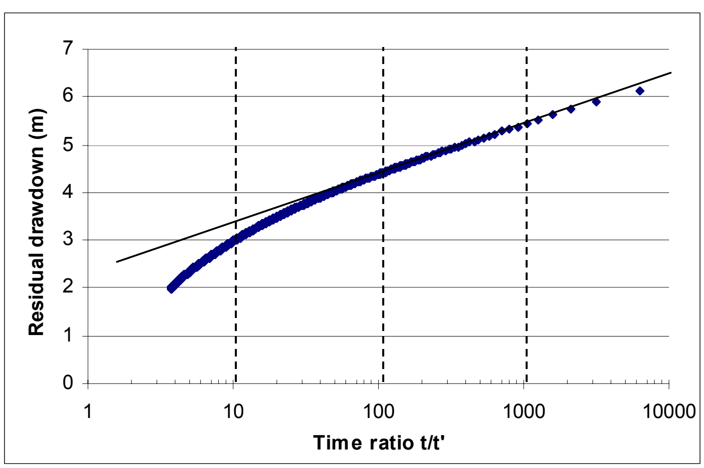
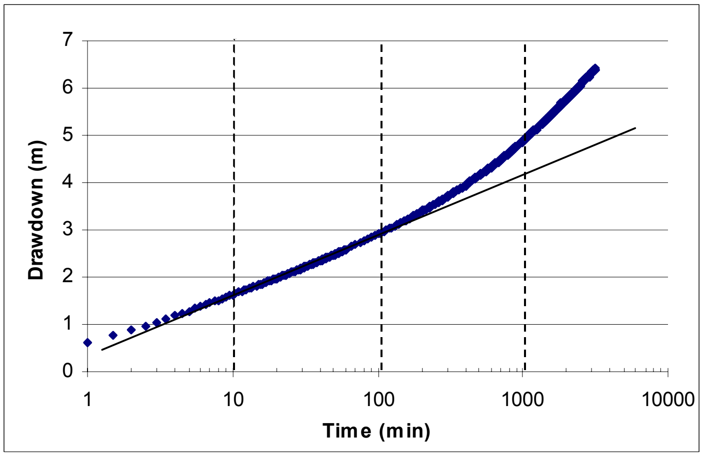


Figure A-17: Residual drawdown versus time for the pumping well, Riverview, NB



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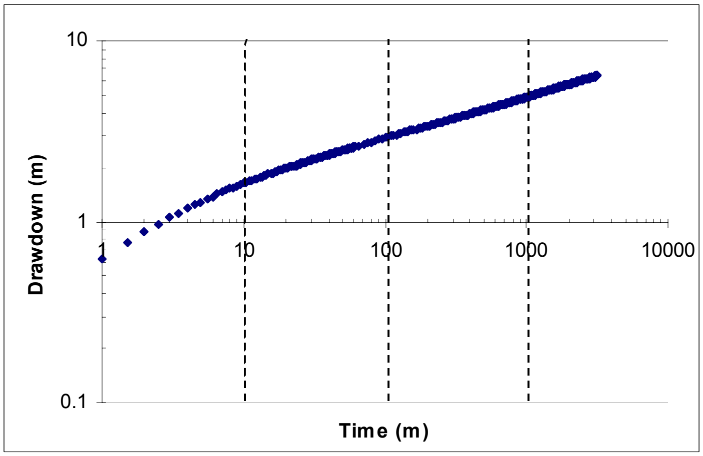


b)

Figure A-18: Drawdown versus time for observation well #1 a) semi-log plot and b) log-log plot, Riverview, NB

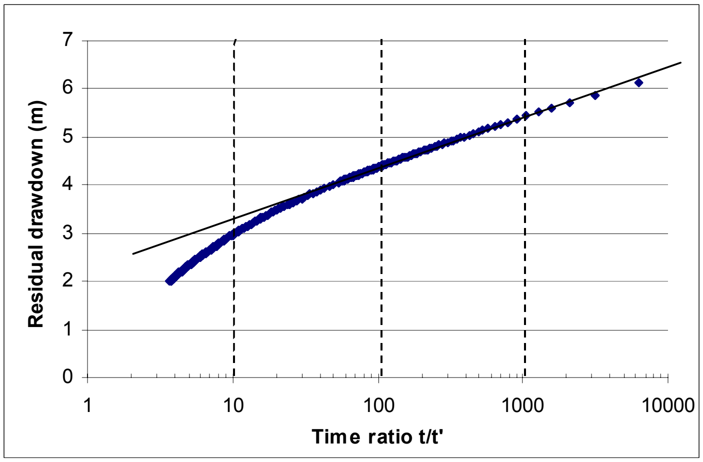


Figure A-19: Residual drawdown versus time for observation well #1, Riverview, NB

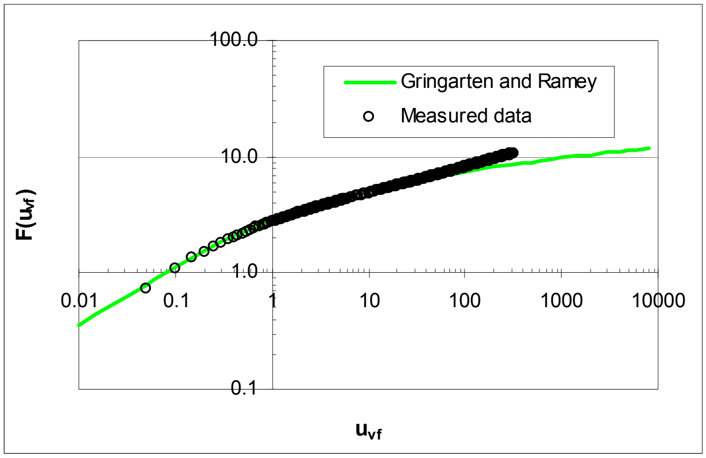
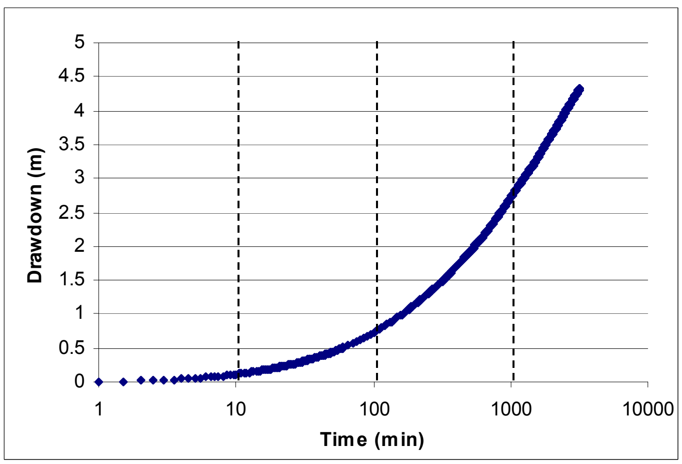


Figure A-20: Gringarten and Ramey type curve for a vertical fracture versus measured data of drawdown, Riverview, NB



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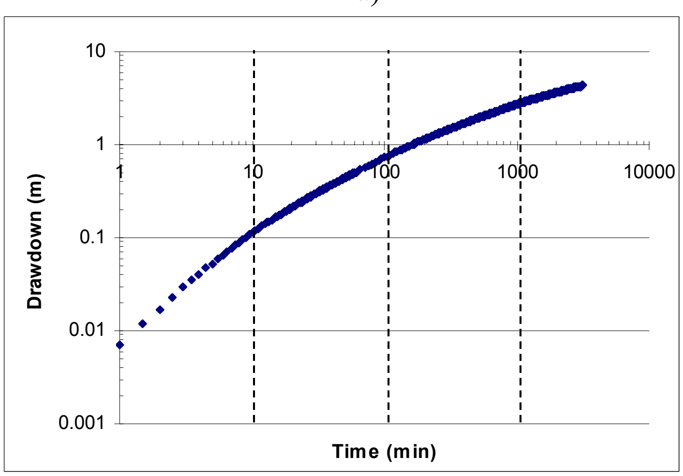

b)

Figure A-21: Drawdown versus time for observation well #2 a) semi-log plot and b) log-log plot, Riverview, NB

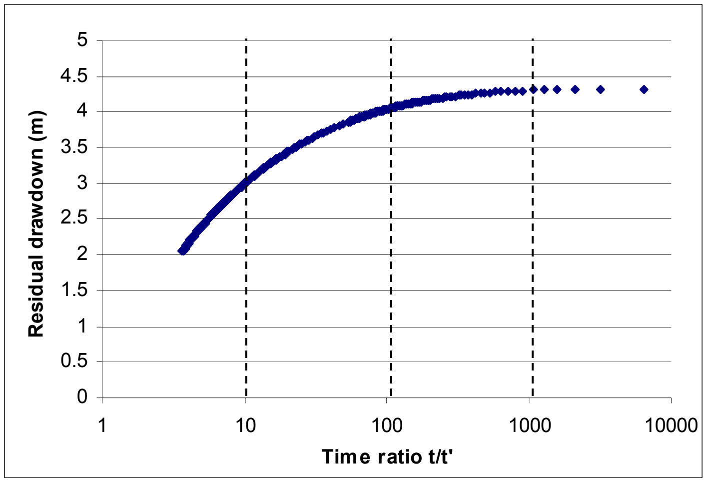

Figure A-22: Residual drawdown versus time for observation well #2, Riverview, NB

Geochemical analyses, Town of Sackville, August 2002

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Client information du Client:

Report Date / Date du rapport: 2002/08/30

Organization/Organisation:	N.B. Environment & Loc. Govt.
Attention:	Darryl Pupek
Prop. No./No. de Projet:	1502
Lab No./No. de Lab. :	28482 - 200206725
Authorization/Authorité:	Leslie Carr
Matrix/Matrice:	Groundwater / Eau Souterraine
Matrix/Matrice:	Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client:	RIVERVIEW 24H 02 MGCR 0002
Date Collected/Date de prelevement:	2002/08/14

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Alkalinity / Alcalinité		107	mg/l		
Aluminum / Aluminium	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.025	
Antimony / Antimoine	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	6.0
Arsenic	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	25.0
Barium / Baryum		0.077	mg/l	0.010	1.0
Boron / Bore		0.011	mg/l	0.010	5.0
Bromide / Bromure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	
Cadmium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	5.0
Calcium		38.2	mg/l	0.10	200
Chloride / Chlorure		1.91	mg/l	0.050	250
Chromium / Chrome	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.050
Conductivity / Conductivité		235	µS/cm		
Copper / Cuivre	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	1.0
Fluoride / Florure		0.346	mg/l	0.100	1.5
Iron / Fer		0.257	mg/l	0.010	0.300
Lead / Plomb	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	10
Magnesium / Magnésium		2.98	mg/l	0.10	150
Manganese / Manganèse		0.510	mg/l	0.005	
Nitrate	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrate / Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	1.0
pH		7.90			
Potassium		1.04	mg/l	0.10	
Selenium / Sélénium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	10

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.539	Sum of Anions	2.441	% Difference	-1.98
Saturation Index @ 5ºC	0.049	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	107.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date / Date du rapport: **2002/08/30**

Client information du Client:

Organization/Organisation: N.B. Environment & Loc. Govt.
Attention: Darryl Pupek

Prop. No./No. de Projet: 1502
Lab No./No. de Lab. : **28482 - 200206725**
Authorization/Authorité: Leslie Carr
Matrix/Matrice: Groundwater / Eau Souterraine
Matrix/Matrice: Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client: RIVERVIEW 24H 02 MGCR 0002

Date Collected/Date de prelevement: 2002/08/14

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Sodium		7.49	mg/l	0.10	270
Sulfate		10.8	mg/l	0.050	
Thallium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	
Tot. Diss. Solids / Matières tot. dissoutes		130	mg/l	10.0	500
Total Hardness / Dureté totale		108	mg/l	0.65	200
Turbidity / Turbidité	*** Exceeds H.A.L. / Plus que L.A.S. ***	1.56	NTU	0.01	1.0
Uranium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	20
Zinc		0.008	mg/l	0.005	5.0

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.539	Sum of Anions	2.441	% Difference	-1.98
Saturation Index @ 5ºC	0.049	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	107.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification
[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

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Figure A-23 : Water quality report after 24h of pumping, Riverview, NB

Environment and Local Government | New Nouveau Brunswick | Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques

12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date
Date du rapport: **2002/08/30**

Client information du Client:

Organization/Organisation: N.B. Environment & Loc. Govt.
Attention: Darryl Pupek

Prop. No./No. de Projet: 1502
Lab No./No. de Lab. : **28482 - 200206726**
Authorization/Authorité: Leslie Carr
Matrix/Matrice: Groundwater / Eau Souterraine
Matrix/Matrice: Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client: RIVERVIEW 53H 02 MGCR 0003

Date Collected/Date de prelevement: 2002/08/15

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Alkalinity / Alcalinité		107	mg/l		
Aluminum / Aluminium	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.025	
Antimony / Antimoine	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	6.0
Arsenic	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	25.0
Barium / Baryum		0.075	mg/l	0.010	1.0
Boron / Bore	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	5.0
Bromide / Bromure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	
Cadmium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	5.0
Calcium		35.9	mg/l	0.10	200
Chloride / Chlorure		1.89	mg/l	0.050	250
Chromium / Chrome	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.050
Conductivity / Conductivité		235	µS/cm		
Copper / Cuivre	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	1.0
Fluoride / Florure		0.356	mg/l	0.100	1.5
Iron / Fer		0.228	mg/l	0.010	0.300
Lead / Plomb	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	10
Magnesium / Magnésium		2.86	mg/l	0.10	150
Manganese / Manganèse		0.438	mg/l	0.005	
Nitrate	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrate / Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	1.0
pH		7.97			
Potassium		0.98	mg/l	0.10	
Selenium / Sélénium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	10

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.390	**Sum of Anions**	2.445	**% Difference**	1.14
Saturation Index @ 5ºC	0.092	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	107.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Environment and Local Government | New Nouveau Brunswick | Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8
Inorganic Report / Rapport inorganique

Report Date
Date du rapport: 2002/08/30

Client information du Client:

Organization/Organisation:	N.B. Environment & Loc. Govt.
Attention:	Darryl Pupek
Prop. No./No. de Projet:	1502
Lab No./No. de Lab. :	28482 - **200206726**
Authorization/Authorité:	Leslie Carr
Matrix/Matrice:	Groundwater / Eau Souterraine
Matrix/Matrice:	Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client:	RIVERVIEW 53H 02 MGCR 0003
Date Collected/Date de prelevement:	2002/08/15

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Sodium		7.05	mg/l	0.10	270
Sulfate		11.0	mg/l	0.050	
Thallium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	
Tot. Diss. Solids / Matières tot. dissoutes		130	mg/l	10.0	500
Total Hardness / Dureté totale		101	mg/l	0.65	200
Turbidity / Turbidité	*** Exceeds H.A.L. / Plus que L.A.S. ***	1.31	NTU	0.01	1.0
Uranium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	20
Zinc	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.005	5.0

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.390	Sum of Anions	2.445	% Difference	1.14
Saturation Index @ 5ºC	0.092	CO3(as CaCO3)	0	HCO3(as CaCO3)	107.0000

[LOQ/LDQ] Limit of quantitation/Limite de quantification
[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

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Figure A-24 : Water quality report after 53h of pumping, Riverview, NB

Pumping test in the Village of Hillsborough, New Brunswick

1. Introduction

As part of the fieldwork undertaken by the Geological Survey of Canada for the characterization of the aquifers of the Maritimes Carboniferous Basin (Maritimes Groundwater Initiative project), a pumping test was conducted in the Village of Hillsborough, New Brunswick in one of the municipal wells in August 2002. The municipality has six wells, of which only one is being pumped to supply the municipality. Two of the wells have been constructed and tested in March 1990 under the supervision of ADI Ltd. However, the pumping test was interrupted since, while pumping, the groundwater level began to rise. ADI Ltd suspected that this behaviour could be attributed to the significant spring recharge. The Village of Hillsborough thus asked us to conduct a pumping test in a dry period. The 1990 pumping test was carried out using a pumping rate of 4.55 l/s (60 Igpm) and the maximum drawdown reached in the pumping well was 30 cm. The chemical analyses had shown problems concerning turbidity and coliforms.

Table 1 summarises the characteristics for the two wells used for the pumping test; #1 corresponds to the pumping well, #2 to the observation well. The main well of the municipality is located 1.2 km away, in a north-eastern direction. As this well is located in the direction of the main fractures, a logger was installed prior to the pumping test to check if the latter was influencing the test well. The 24 h recording did not show any effect resulting from start/stop of pumping. The observation well is located only 27.9 m away from the pumping well, in a northern direction. The groundwater static levels were similar in both wells.

Table A-4: Characteristics of the studied Hillsborough wells

Name	X*	Y*	Z*	Well depth (m)	Casing (m)	GW static depth (m)
#1	370769	5082443	108.9	41	0.60	14.69
#2	370776	5082470	110.2	46	0.44	13.79

* X and Y have been measured with a GPS and the elevation Z has been calculated with a DEM (using 10m topographic isocontours from 1:50 000 maps)

2. Implementation of the pumping test

The pump was set at 35 m deep, allowing 20 m of water to cover the pump. A step-drawdown test was first implemented. Knowing that our pump could supply a maximum yield of about 4 l/s (53 Igpm) and that few centimetres of drawdown were obtained using 4.55 l/s in 1990, we decided to use a valve open at 1/3, 2/3 and complete full width for this step test. Figure 1 shows the results of this 3-step test. During the third step, we could clearly hear the flow turbulence within the well. Measured rates for the three steps were:

3.3, 3.7 and 4.1 l/s. Following this test, we decided to put the valve at two-thirds of its opening, to ensure that the pump would not be dewatered after several hours of pumping. The last measured (total) drawdown after 1h30 of pumping was 5.5 m.

The wells were tested for 4 days, starting Friday August 16th through the 21st. Data loggers were introduced in both wells and groundwater levels were recorded every 30 seconds during the whole period. Flow rates were measured using a 100 L bucket.

3. Results of the pumping test

3.1 Pumping well

The groundwater recovered its static level after 1 h; afterwards, the pump was started. The measured rate was surprisingly 4.1 l/s, but we decided to keep it at this level and watch closely. After 920 min. (15.33 h) of pumping, we decided to stop the pumping test because the pumping rate had fallen to 2.27 l/s. We let it recover for 24 h. However, someone came during the day and plugged the pump back and we realised it a little more than 3 hours later as we had left the site. The static level was not fully recovered the morning after (the groundwater depth was 15.80 m). For this second try, we decided to pump at a rate of 2.65 l/s. Again, after 17 hours, the pumping rate had fallen to 2.1 l/s. The pumping test was stopped. The groundwater levels could not be recorded within the pumping well when the drawdown reached more than 15 m since the logger had only 30 m of cable. The manual probe could not reach the water table through the tubing and cables. A third pumping test was implemented, but technical problems occurred at the beginning, so that the pumping rate fluctuated during the first 40 minutes. This one lasted 24 h and kept a relatively stable pumping rate of 1.96 l/s after stabilisation occurred.

The two recorded pumping periods for the pumping well are shown on Figures 2 and 3 using semi-log and log-log plots, in order to estimate hydraulic properties with both Theis and Cooper-Jacob methods. The "plateaus" correspond to dewatering of the logger. Note that even if the groundwater depth is located below 30 m, higher levels are recorded, due to the high turbulence within the pumping well. The middle and first parts of the pumping curves were used for tests #1 and #2 to calculate the transmissivity. We believe the first part of the test #1 curve (first 20 min.) is attributable to clogging since the well had not been pumped for 12 years. Between 140 and 200 min., the drawdown rate began to increase very quickly, likely indicating the interception of an impermeable boundary (or a region with a significantly lower permeability). Indeed, the presence of an impermeable boundary will double the slope (rate of drawdown). Since the slopes have more than doubled, we can hypothesise that the well is bounded by more than one single linear less permeable boundary. In other words, it reflects the typical Maritimes Carboniferous Basin stratigraphy, in which the various layers are lenticular. These boundaries could thus represents limits of the aquifer. The third pumping test cannot really be used because the period between stabilisation of the yield and change in slope is not long enough to be considered reliable. Nevertheless, this small interval provided a value close to the others.

The recovery periods of tests #1 and 3 are shown on a semi-log plot in Figures 4 and 5. The plot of the recovery uses the time ratio t/t', where t corresponds to time since the beginning of the pumping and t' the time that the recovery lasted. Usually, values obtained with the recovery period are very "robust" since the rate is constant. The middle parts of these curves were used, as shown on the graphs. The second recovery period could not be used as we carried out some tests with the pump to find the problem regarding changing yields.

For the pumping well, transmissivity values found using the Theis and/or Cooper-Jacob methods, both for the pumping and recovery periods, range from 7.3 x 10^{-5} to 1.0 x 10^{-4} m^2/s, with a geometrical mean of 7.7 x 10^{-5} m^2/s. For the Theis curve match, the software Aqtesolv was used. However, the least squares method used by AqteSolv revealed a rather poor agreement for test #1. All pumping curves have the same behaviour, showing abrupt changes in slopes, which comes earlier as the pumping rate is larger. The recovery curves are also very similar in shape.

3.2 <u>Observation well</u>

The observation well is located almost north (with little inclination to the East) and, as the major fracture networks within the Maritimes Carboniferous Basin are oriented N45^{o}E (i.e. in a north-eastern direction), it does not react much, even if it is just 27.9 m away from the pumping well. The maximum drawdown for each test was in the order of 1 m and the allowed recovery periods (up to 19.5 h) were never sufficient for the groundwater to recover its static level. Thus, only the third recovery (the longest) is used for the estimation of the transmissivity value. Nevertheless, the well does react in synchronicity with the pumping well. Figures 6, 7, 8 and 9 present plots of the drawdown versus time for the pumping and recovery periods for the only observation well. We can see that boundaries are also reached quite quickly (showed by the increase of the slopes). The slopes doubled during the first and second tests, and tripled in the third one.

Values calculated with the Cooper-Jacob and Theis methods are this time in the range of 1.3 x 10^{-3} to 2.0 x 10^{-3} m^2/s for the transmissivity and values between 1.7 x 10^{-3} and 5.8 x 10^{-3} were obtained for the storage coefficient. The geometrical means are: T=1.6 x 10^{-3} m^2/s and S=2.9 x 10^{-3}. This T value is more than an order of magnitude higher than the one found for the pumping well. In general, observation wells are more reliable than pumping wells for the estimation of transmissivity values because they do not experience head losses. However, the fact that this well does not respond "normally", i.e. as if it was in a homogenous isotropic media, forces us to put these values aside and not consider them as representative values of the aquifer's hydraulic properties. Indeed, the small drawdown is likely not attributable to the aquifer's very high permeability, but to the fact that this well encountered fractures that are not directly connected to those supplying the pumping well.

Despite the fact that the well was pumped for a total of 56 hours, the groundwater remained very turbid and brownish. The geochemical analyses of a sample taken at the end of the third pumping test show that the turbidity is very high, with a value of 76.3, while the limit for drinking water is 1.0 NTU . This high turbidity could likely be attributable to the presence of a shale unit and eddies within the well. The manganese concentration equals the aesthetic criteria limit (0.1 mg/l). Water was not tested for coliforms. Geochemical results are presented at the end of this report.

4. Conclusion

A pumping test was carried out in August 2002 in the Village of Hillsborough in one of the municipal wells constructed in 1990. The aquifer tapped by both wells seems to be moderately permeable, having a transmissivity in the order of 7.7×10^{-5} m^2/s. However, impermeable boundaries, likely corresponding to the aquifer limits, are reached very quickly, significantly limiting the potential of the wells. These boundaries confirm the highly stratified nature of the Maritimes Carboniferous Basin, which is known to be composed of lenticular strata of small lateral extent (in the order of 3 km). This municipal well might be located quite close (within 1 km?) to one of its sides. The slight reaction shown by the observation well implies that this fractured aquifer is heterogeneous and anisotropic. The major fractures are probably oriented in a north-eastern (45^o) direction, similarly to Maritimes Carboniferous Basin regional structures. This results in strong channelling: groundwater predominantly comes from the major network fractures (oriented at 45^o), but contributions are also made by indirectly connected fractures. The fact that the pumping rate could not stay constant throughout the pumping tests was clarified at the end, when the pump was taken out. The reinforced tube evacuating the water was bent within the well (close to the pump). The tubing was probably bending under its own weight during the pumping periods.

Even after several hours of pumping, the water was still brown and its turbidity very high. The manganese slightly exceeded the aesthetic criteria. Based on the transmissivity estimated and the quality of the groundwater (very turbid, with a possibility of coliforms), we believe that this well has poor potential for a municipal supply.

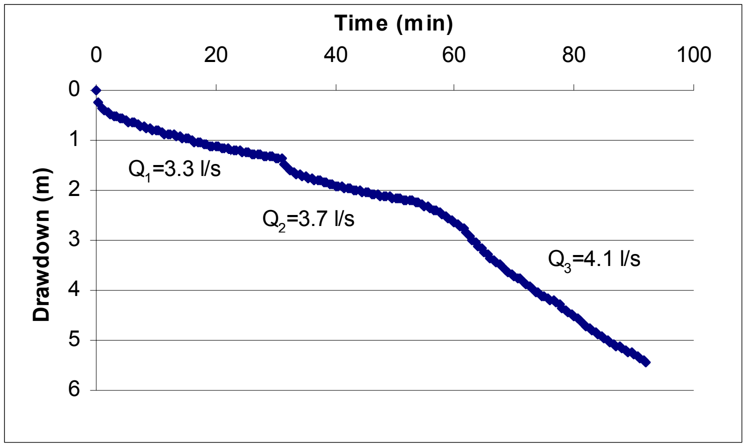
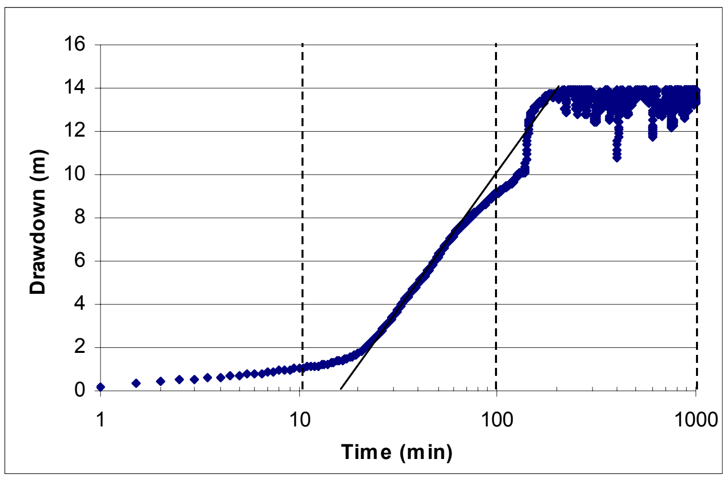
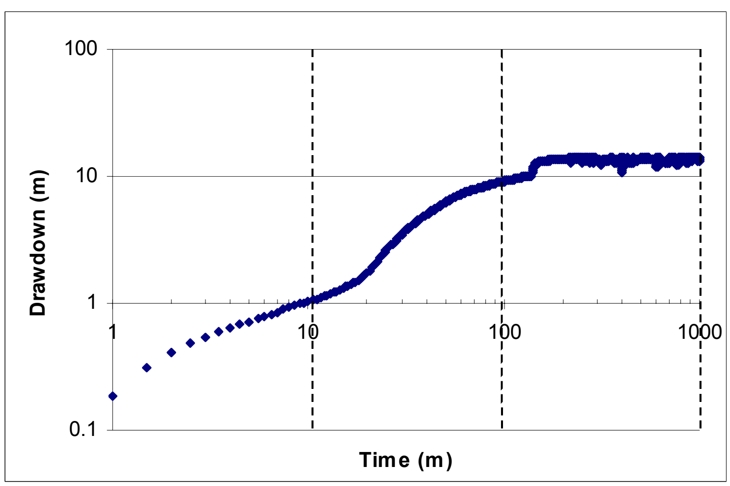


Figure A-25 : Drawdown versus time for the 3-step test, Hillsborough, NB

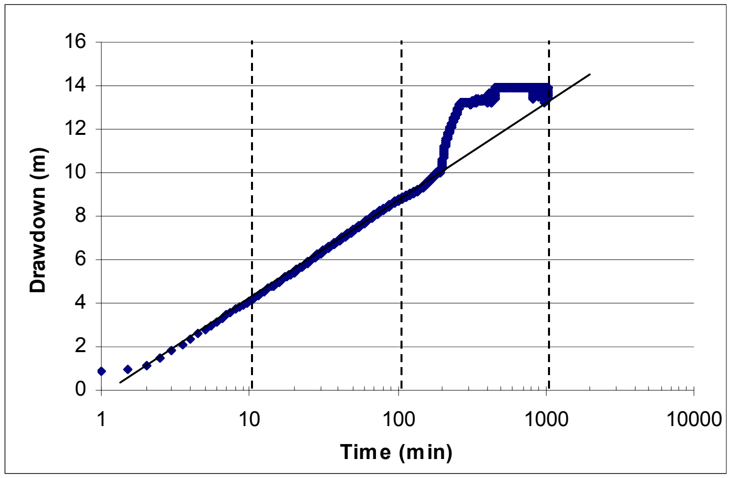


a)

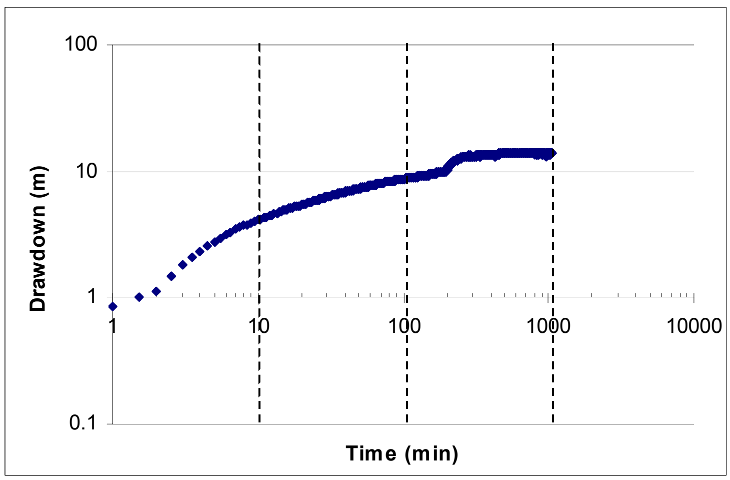


b)

Figure A-26 : Drawdown versus time for the pumping well, test #1 a) semi-log plot and b) log-log plot, Hillsborough, NB



a)



b)

Figure A-27: Drawdown versus time for the pumping well, test #2 a) semi-log plot and b) log-log plot, Hillsborough, NB

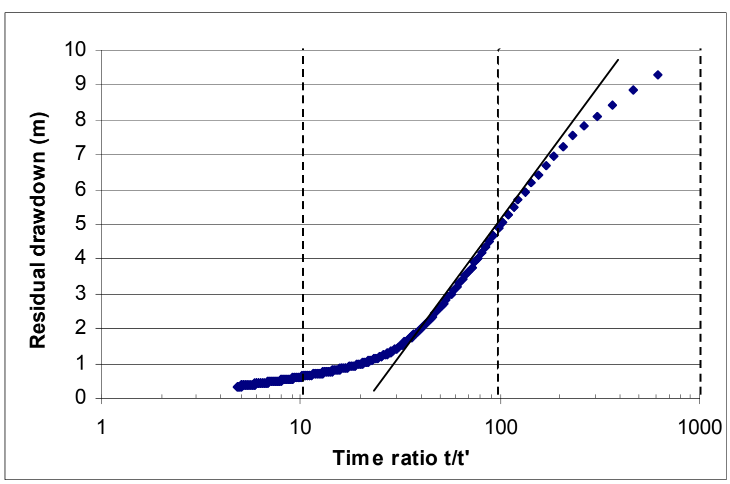


Figure A-28: Residual drawdown versus time for the pumping well, test #1, Hillsborough, NB

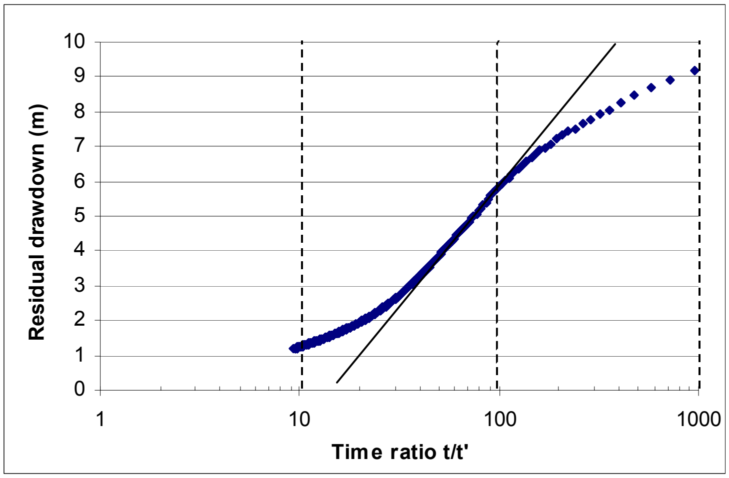
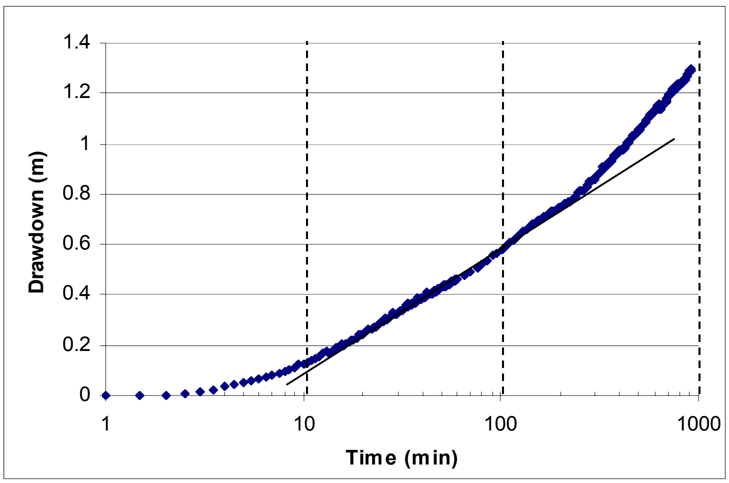
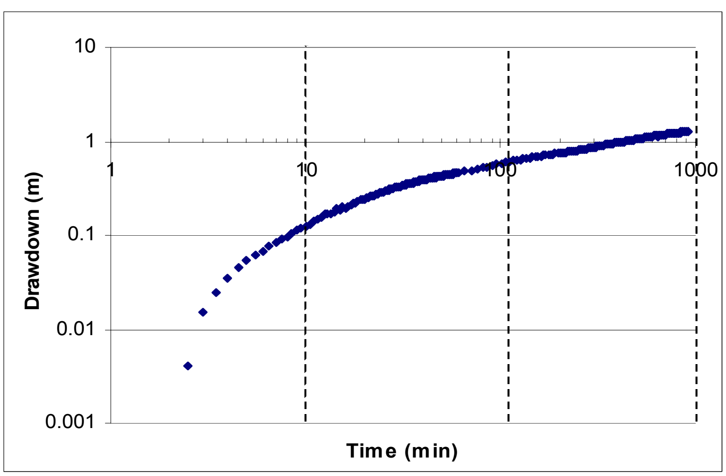


Figure A-29: Residual drawdown versus time for the pumping well, test #3, Hillsborough, NB

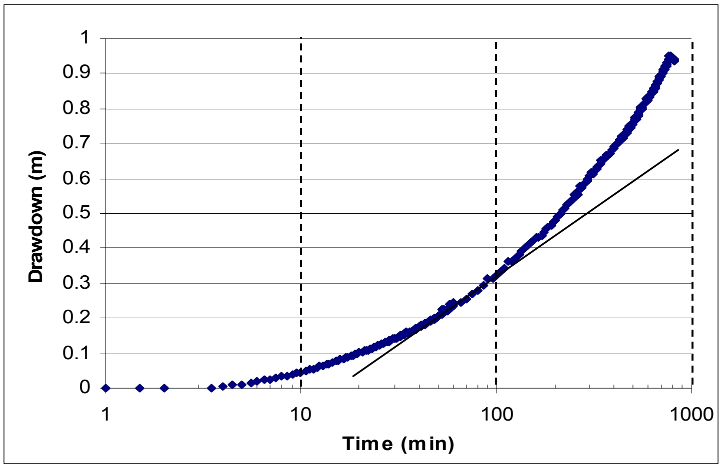


a)

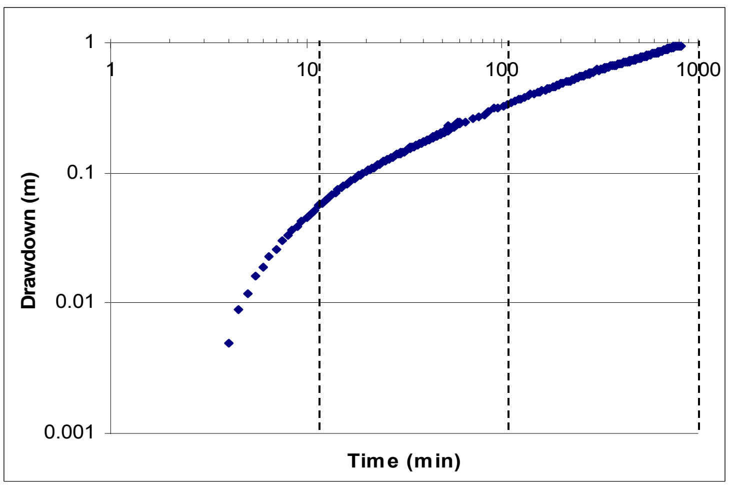


b)

Figure A-30: Drawdown versus time for the observation well, test #1 a) semi-log plot and b) log-log plot, Hillsborough, NB



a)



b)

Figure A-31: Drawdown versus time for the observation well, test #2 a) semi-log plot and b) log-log plot, Hillsborough, NB

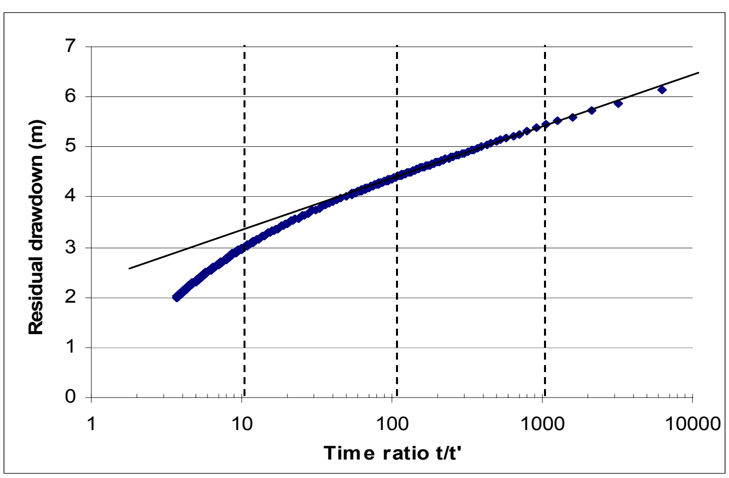


Figure A-32: Residual drawdown versus time for the observation well, test #3, Hillsborough, NB

Geochemical analyses, Village of Hillsborough, August 2002

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Client information du Client:

Report Date
Date du rapport: **2002/08/30**

Organization/Organisation:	N.B. Environment & Loc. Govt.
Attention:	Darryl Pupek
Prop. No./No. de Projet:	1502
Lab No./No. de Lab. :	**28482 - 200206727**
Authorization/Authorité:	Leslie Carr
Matrix/Matrice:	Groundwater / Eau Souterraine
Matrix/Matrice:	Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client:	HILLSBOROUGH 24H 02 MGCR 0004
Date Collected/Date de prelevement:	2002/08/20

Parameter/ Paramètre	**Flag**	**Result/ Résultats**	**Units/ Unités**	**L.O.Q./ L.D.Q.**	**H.A.L./ L.A.S.**
Alkalinity / Alcalinité		22.8	mg/l		
Aluminum / Aluminium		0.281	mg/l	0.025	
Antimony / Antimoine	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	6.0
Arsenic	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	25.0
Barium / Baryum		0.127	mg/l	0.010	1.0
Boron / Bore	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	5.0
Bromide / Bromure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	
Cadmium		0.8	µg/l	0.5	5.0
Calcium		9.61	mg/l	0.10	200
Chloride / Chlorure		2.62	mg/l	0.050	250
Chromium / Chrome	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.050
Conductivity / Conductivité		74.7	µS/cm		
Copper / Cuivre	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	1.0
Fluoride / Florure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	1.5
Iron / Fer		0.216	mg/l	0.010	0.300
Lead / Plomb	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	10
Magnesium / Magnésium		1.28	mg/l	0.10	150
Manganese / Manganèse		0.101	mg/l	0.005	
Nitrate	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	10.0
Nitrate / Nitrite		0.10	mg/l	0.05	10.0
Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	1.0
pH		7.07			
Potassium		0.72	mg/l	0.10	
Selenium / Sélénium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	10

Calculated Parameters\Paramètres calculés

Sum of Cations	0.757	Sum of Anions	0.702	% Difference	-3.77
Saturation Index @ 5ºC	-2.051	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	22.8000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques

12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date
Date du rapport: **2002/08/30**

Client information du Client:

Organization/Organisation: N.B. Environment & Loc. Govt.
Attention: Darryl Pupek

Prop. No./No. de Projet: 1502
Lab No./No. de Lab. : **28482 - 200206727**
Authorization/Authorité: Leslie Carr
Matrix/Matrice: Groundwater / Eau Souterraine
Matrix/Matrice: Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client: HILLSBOROUGH 24H 02 MGCR 0004

Date Collected/Date de prelevement: 2002/08/20

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Sodium		2.44	mg/l	0.10	270
Sulfate		7.74	mg/l	0.050	
Thallium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	
Tot. Diss. Solids / Matières tot. dissoutes		45	mg/l	10.0	500
Total Hardness / Dureté totale		29.2	mg/l	0.65	200
Turbidity / Turbidité	*** Exceeds H.A.L. / Plus que L.A.S. ***	76.3	NTU	0.01	1.0
Uranium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	20
Zinc		0.024	mg/l	0.005	5.0

Calculated Parameters\Paramètres calculés					
Sum of Cations	0.757	Sum of Anions	0.702	% Difference	-3.77
Saturation Index @ 5ºC	-2.051	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	22.8000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Page 2 of/de 2.

Figure A-33 : Water quality report, Hillsborough, NB

Essai de pompage à la plage Parlee, Shediac, Nouveau-Brunswick

1. Introduction

Dans le cadre des travaux entrepris par la Commission géologique du Canada pour caractériser les aquifères du Bassin Carbonifère des Maritimes, un essai de pompage a été réalisé à la plage Parlee, Shediac, Nouveau-Brunswick, en juillet 2002. Le puits principal étant utilisé durant tout l'été, l'essai a été réalisé sur un puits « de réserve» (backup) situé à proximité de la plage, à côté de la cantine. Le puits ayant servi à l'étude est celui appelé « back-up cantine ». Il est situé à environ 70 m de la limite de marée haute, à une altitude d'environ 2 m. Les coordonnées de l'ensemble des puits appartenant à cette plage provinciale, ainsi que leurs caractéristiques sont fournies au tableau 1.

Tableau A-5 : Caractéristiques des puits de la plage Parlee

Puits	X UTM	Y UTM	Prof. totale* (m)	Prof. pompe* (m)	Débit estimé* (l/s)
Main (artésien)	383 379	5 121 214	77.4	14.6	17.05 (225 Igpm)
Backup cantine	383 844	5 121 742	78.4	22.5	3.03 (40 Igpm)
Camping	383 978	5 120 967	40.5	-	2.65 (35 Igpm)
Backup camping	383 942	5 120 876	-	22.9	2.65 (35 Igpm)
Pique-nique	384 248	5 120 386	28	13.4	1.14 (15 Igpm)

* Données fournies par la plage Parlee d'après un rapport de Eastern Well Drillers, Octobre 2001.

2. Réalisation de l'essai de pompage

Le puits de réserve de la cantine a été pompé à un débit moyen de 3.4 l/s (44.8 Igpm) durant 16.5 h. Étant donné que cette période de l'année est très occupée pour la plage, seul un essai durant les heures creuses a pu être réalisé, soit à partir de 15h47 le mardi 16 juillet jusqu'à 8h16 le mercredi 17 juillet 2002. Une sonde à lectures automatiques (logger) a été introduite dans le puits la journée précédente de façon à enregistrer les effets de la marée et à vérifier que le puits principal n'avait aucune influence sur les fluctuations du niveau. La sonde a également enregistré la remontée du niveau d'eau suite à l'arrêt de la pompe et l'influence de la marée le jour d'après. De cette manière, l'influence de la marée durant le pompage pouvait être approximée en faisant la moyenne des jours précédent et suivant le pompage. L'enregistrement des données de niveaux d'eau a été effectué aux 30 secondes durant tout l'essai. Le débit a été mesuré à l'aide d'une chaudière de 20 L.

Ce puits n'ayant pas servi depuis plusieurs jours et les enregistrements précédents l'essai ayant montré que ce puits n'est pas influencé par un de ses voisins, le niveau enregistré au départ est bien le niveau statique. La profondeur de la nappe a été mesurée à 3.84 m.

Les enregistrements ont montré que l'influence de la marée, quoique le puits soit très proche de la mer (70 m à marée haute) se limite à au plus 15 cm (alors que le niveau de la mer peut varier jusqu'à un mètre à cet endroit). Ceci porte à croire que ce puits est, tout comme le puits principal, situé dans un aquifère confiné. En effet, le puits principal de la plage Parlee, situé à 700 m de celui testé, est artésien tout au long de l'année. Cependant, cette information ne peut être confirmée à l'aide du calcul du coefficient d'emmagasinement car aucun puits d'observation n'était disponible.

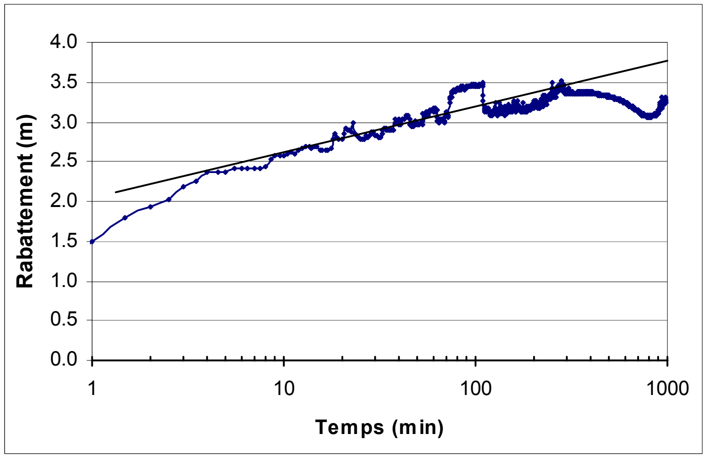
3. Résultats

Les graphiques semi-log et log-log du rabattement en fonction du temps du pompage sont présentés à la figure 1. Le débit ne s'est pas maintenu constant durant la période de pompage. Les variations se reflètent dans l'aspect peu lisse (saccadé) des courbes. Nos mesures ont indiqué que le débit aurait varié de ±13%. L'influence de la marée a été éliminée, quoiqu'elle soit très faible (d'au plus 3.5%) durant l'essai de pompage, en soustrayant la valeur moyenne des fluctuations obtenue avec les journées précédente et suivante. Les valeurs de transmissivité ont été estimées avec les méthode de Theis et de Cooper-Jacob qui supposent des aquifères confinés dans lesquels le puits pénètre complètement l'aquifère. La méthode de Cooper-Jacob est une solution approximative qui peut généralement être utilisée lorsque le rayon du puits est petit et que la durée de l'essai est grande. La remontée de la nappe est présentée à la figure 2. Étant donné qu'elle représente un « pompage inverse » au débit moyen utilisé durant l'essai, elle est nettement plus lisse. En ne prenant pas en compte les toutes premières valeurs et celles supérieures à 300 min, des valeurs de transmissivités allant de $7.3 x 10^{-4}$ à $1.4 x 10^{-3}$ m^2/s ont été trouvées en utilisant des débits de 3.2 et 3.6 l/s. En effet, le niveau semble plus ou moins se stabiliser à partir de 300 min (5h). Comme les débits mesurés durant cette période étaient similaires à ceux obtenus précédemment, nous supposons qu'un état stable a été atteint (régime permanent). Les valeurs obtenues avec les deux méthodes sont très proches. Cependant, la superposition des courbes a montré que celle des valeurs mesurées ressemblait assez peu à une courbe de Theis théorique. L'utilisation d'un puits d'observation aurait permis d'obtenir des valeurs beaucoup plus fiables. La moyenne géométrique des valeurs obtenues (pompage et remontée, pour les deux méthodes et deux débits utilisés) est de $1.0 x 10^{-3}$ m^2/s. Le rabattement maximal enregistré a été de 3.3 m.

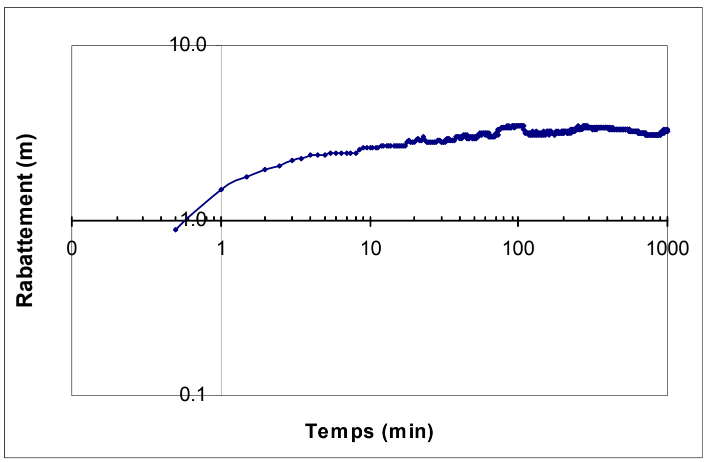
Un échantillon d'eau prélevé à la toute fin du pompage a été envoyé pour analyse au laboratoire de Frédéricton. L'eau est d'excellente qualité : tous les paramètres analysés sont en-dessous des limites pour l'eau potable. Les résultats sont présentés en annexe. La conductivité électrique (mesurée à l'aide d'un appareil portatif YSI 63), n'était que de 222 μS (salinité de 0.1 ppt) après 16.5 h de pompage malgré le fait que le puits soit très près de l'océan. Une eau est considérée « douce » lorsque celle-ci a une salinité comprise entre 0 et 1 ppt.

4. Conclusion

Un essai de pompage d'une durée de 16,5 h a été réalisé dans le puits de la cantine tout près de la plage. Ce puits est situé à 70 m de la mer (à marée haute), mais ne subit que très peu l'influence des marées. Les mesures ont montré que les fluctuations maximales attribuables à l'océan étaient de l'ordre de 15 cm. L'interprétation de l'essai a été effectuée avec les méthodes de Theis et de Cooper-Jacob. Les valeurs de transmissivités obtenues durant la descente (période de pompage) et la remontée sont en moyenne de $1.0x10^{-3}$ m^2/s, ce qui est assez élevé et permet de fournir un bon débit. Même si aucune valeur de coefficient d'emmagasinement n'a pu être calculée puisqu'aucun puits d'observation n'était disponible, il est probable que ce puits soit situé dans un aquifère confiné. La salinité du puits après 16,5 h de pompage n'était que de 0,1 ppt et tous les paramètres analysés rencontraient les normes de potabilité.



a)



b)

Figure A-34: Rabattement en fonction du temps a) graphique semi-log et b) graphique log-log, plage Parlee, NB

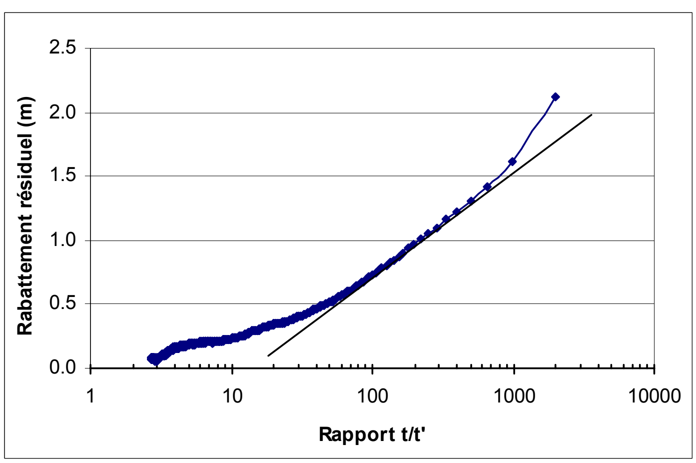


Figure A-35: Rabattement résiduel en fonction du temps, plage Parlee, NB

Résultats d'analyse de l'eau après 16,5 h de pompage (Parlee Beach, Shediac)

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date / Date du rapport: **2002/07/26**

Client information du Client:

Organization/Organisation:	N.B. Environment & Loc. Govt.
Attention:	Darryl Pupek
Prop. No./No. de Projet:	1502
Lab No./No. de Lab. :	**26982 - 200205253**
Authorization/Authorité:	Leslie Carr
Matrix/Matrice:	Groundwater / Eau Souterraine
Matrix/Matrice:	Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client:	PARLEE BEACH NB 02MGCR0001
Date Collected/Date de prelevement:	2002/07/17

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Alkalinity / Alcalinité		77.2	mg/l		
Aluminum / Aluminium	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.025	
Antimony / Antimoine	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	6.0
Arsenic		2.5	µg/l	1.5	25.0
Barium / Baryum		0.218	mg/l	0.010	1.0
Boron / Bore	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	5.0
Bromide / Bromure		0.393	mg/l	0.100	
Cadmium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	0.5	5.0
Calcium		24.9	mg/l	0.10	200
Chloride / Chlorure		28.4	mg/l	0.050	250
Chromium / Chrome	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.050
Conductivity / Conductivité		266	µS/cm		
Copper / Cuivre	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	1.0
Fluoride / Florure	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.100	1.5
Iron / Fer	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.010	0.300
Lead / Plomb	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	10
Magnesium / Magnésium		4.83	mg/l	0.10	150
Manganese / Manganèse		0.007	mg/l	0.005	
Nitrate		0.35	mg/l	0.05	10.0
Nitrate / Nitrite		0.40	mg/l	0.05	10.0
Nitrite	Less than L.O.Q. / Moins de L.D.Q.		mg/l	0.05	1.0
pH		8.08			
Potassium		1.13	mg/l	0.10	
Selenium / Sélénium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.5	10

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.460	Sum of Anions	2.570	% Difference	2.19
Saturation Index @ 5ºC	-0.099	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	77.2000

[LOQ/LDQ] Limit of quantitation/Limite de quantification

[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Environment and Local Government — New Nouveau Brunswick — Environnement et gouvernements locaux

Analytical Services Laboratory/Laboratoire des services analytiques
12, rue McGloin Street, Fredericton, NB E3A 5T8

Inorganic Report / Rapport inorganique

Report Date
Date du rapport: **2002/07/26**

Client information du Client:

Organization/Organisation: N.B. Environment & Loc. Govt.
Attention: Darryl Pupek

Prop. No./No. de Projet: 1502
Lab No./No. de Lab. : **26982 - 200205253**
Authorization/Authorité: Leslie Carr
Matrix/Matrice: Groundwater / Eau Souterraine
Matrix/Matrice: Drinking Water/Eau Potable

Client Sample Identifier/ No. d'Echantillon du client: PARLEE BEACH NB 02MGCR0001

Date Collected/Date de prelevement: 2002/07/17

Parameter/ Paramètre	Flag	Result/ Résultats	Units/ Unités	L.O.Q./ L.D.Q.	H.A.L./ L.A.S.
Sodium		18.1	mg/l	0.10	270
Sulfate		9.10	mg/l	0.050	
Thallium	Less than L.O.Q. / Moins de L.D.Q.		µg/l	1.0	
Tot. Diss. Solids / Matières tot. dissoutes		150	mg/l	10.0	500
Total Hardness / Dureté totale		82.0	mg/l	0.65	200
Turbidity / Turbidité		0.04	NTU	0.01	1.0
Uranium		1.4	µg/l	0.5	20
Zinc		0.011	mg/l	0.005	5.0

Calculated Parameters\Paramètres calculés					
Sum of Cations	2.460	Sum of Anions	2.570	% Difference	2.19
Saturation Index @ 5ºC	-0.099	**CO3(as CaCO3)**	0	**HCO3(as CaCO3)**	77.2000

[LOQ/LDQ] Limit of quantitation/Limite de quantification
[HAL/LAS] Health Advisory Level (Drinking water only)/Limites acceptables pour la santé (Eau potable seulement)

Page 2 of/de 2.

Figure A-36 : Rapport de qualité d'eau, plage Parlee, NB

Part B

Electrical resistivity soundings report

Geophysical soundings in New Brunswick and Prince Edward Island

Methodology

The electrical resistivity method was used to delineate saline intrusion and map subsurface stratigraphy at several locations in the MGWI area. In this method, an electric current is applied to the surface through two electrodes and a potential difference is measured between two other electrodes. The current flow and the distribution of electrical potential in the subsurface are affected by the differences in electrical resistivity of the geological materials encountered. Increasing the electrode separation increases the depth of investigation. Therefore, a two-dimensional electrical image can be obtained by making measurements with increasing electrode separations for each position along a survey line. The equipment used for the MGWI was an Iris Instruments Syscal R1 Switch 48 resistivity imaging system. This system has 48 electrodes spaced 5 m apart (240 m cable length) that can be selected automatically by computer control.

Two array types were used for the surveys. For detailed investigations, a Wenner array configuration was used. This array has four electrodes placed at equal separations along a line. The current is applied to the two outer electrodes and the potential difference is measured between the two inner electrodes. The depth of investigation is approximately one-half the electrode separation. For the equipment used, the maximum depth of investigations was approximately 40 m.

For deeper investigations, a pole-dipole array was used. One current electrode was fixed at a location at least 1 km away from the beginning of the survey line and current was injected through a second current electrode that was selected from the multi-electrode cable. The resulting potential difference was then measured between two adjacent electrodes on the cable. The spacing between the current and potential electrodes was augmented to increase the depth of investigation. For the equipment used, the maximum depth of investigation was approximately 80 m.

The electrical resistivity images were processed to obtain an electrical resistivity model using the inversion software RES2DINV, which uses a least-squares finite-difference method. The models were then interpreted to assess stratigraphy and potential for saline intrusion.

Results

<u>Shediac Bay, New Brunswick</u>

The primary goal of geophysical surveys in the Shediac Bay was to determine the location of the saltwater-freshwater interface. Six locations, shown in Figure B-1, were selected around Shediac Bay for electrical resistivity imaging. The results are presented below:

Cap Brûlé

Both Wenner and pole-dipole electrical resistivity images were acquired along Cap Brûlé Road. The Wenner array image, shown in Figure B-2, indicates high resistivity near the surface, due to the presence of dry sand, underlain by lower resistivity clay and/or silt and a poorly-defined lower layer of resistive material. Zones of very low resistivity were not detected, suggesting that saline water does not occur within 40 m from the surface. The corresponding pole-dipole image is shown in Figure B-3. The differences between the Wenner and pole-dipole measured apparent resistivity pseudosections are due to the differing array geometries and maximum depths of investigation. The greater depth of investigation of the pole-dipole array (80 m versus 40 m) results in better definition of a resistive lower layer that is interpreted to be bedrock. A decrease in resistivity at the north end of the image may indicate brackish water at depths greater than 60 m, suggesting that the saline / freshwater interface is located approximately 80 m inshore.

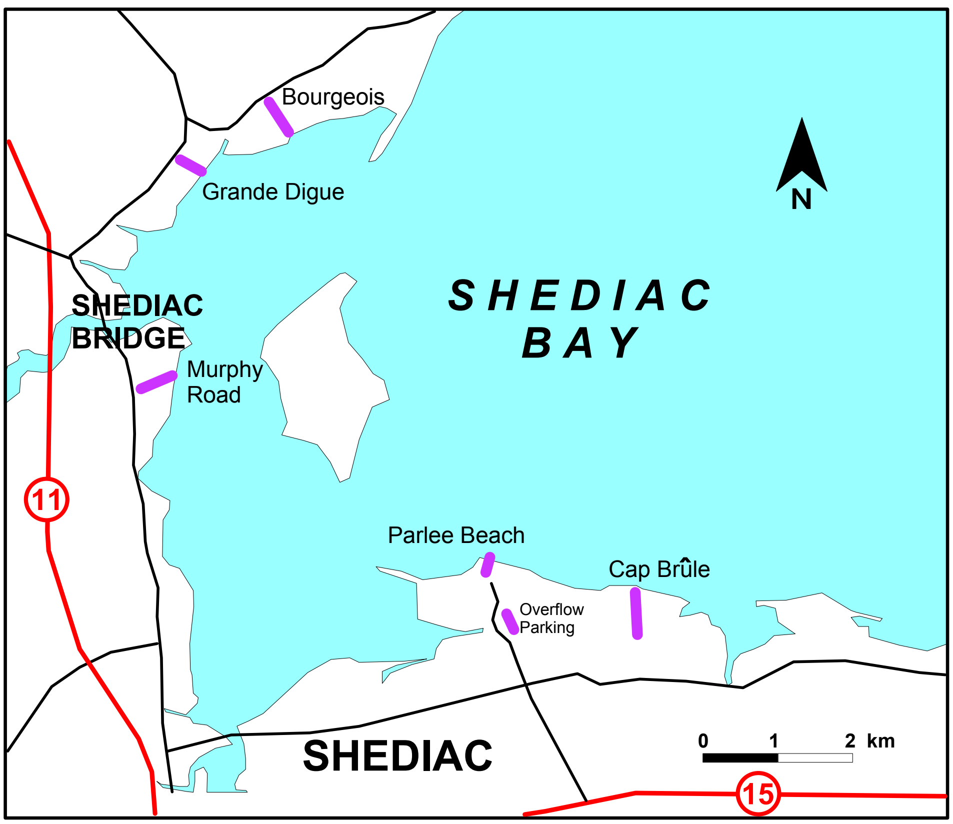


Figure B-1. Location of electrical resistivity images, Shediac Bay, New Brunswick

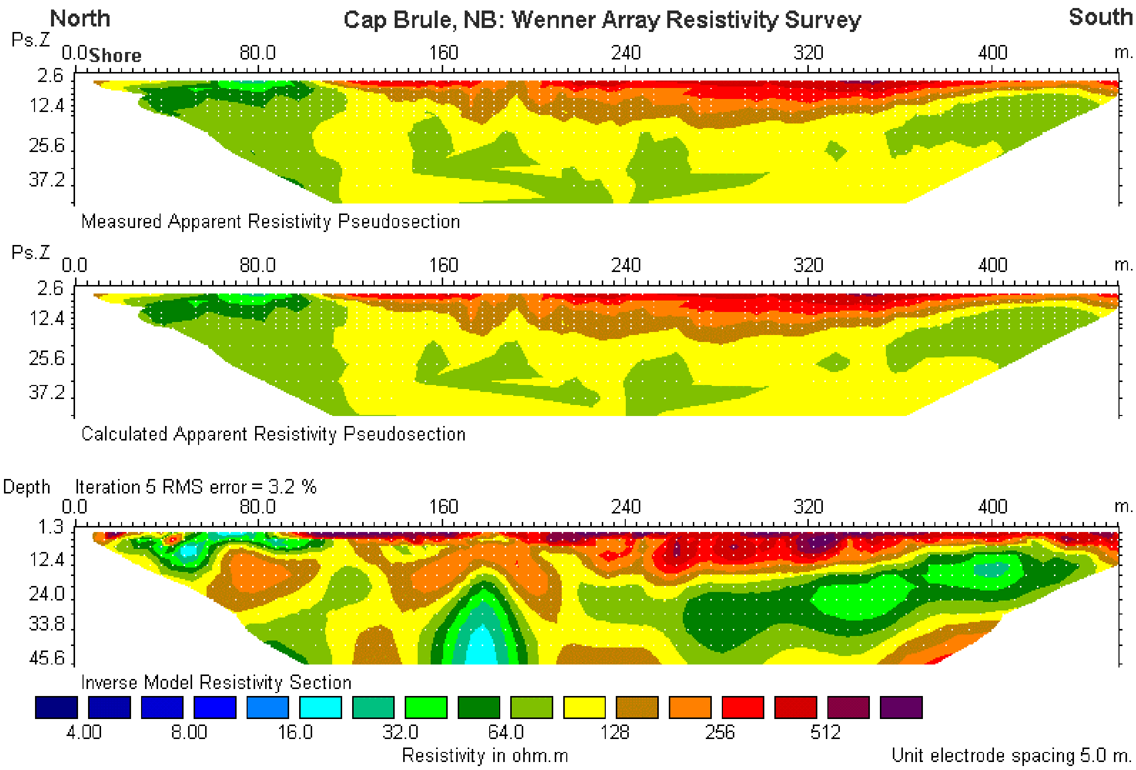


Figure B-2. Wenner array electrical resistivity image, Cap Brûlé, New Brunswick

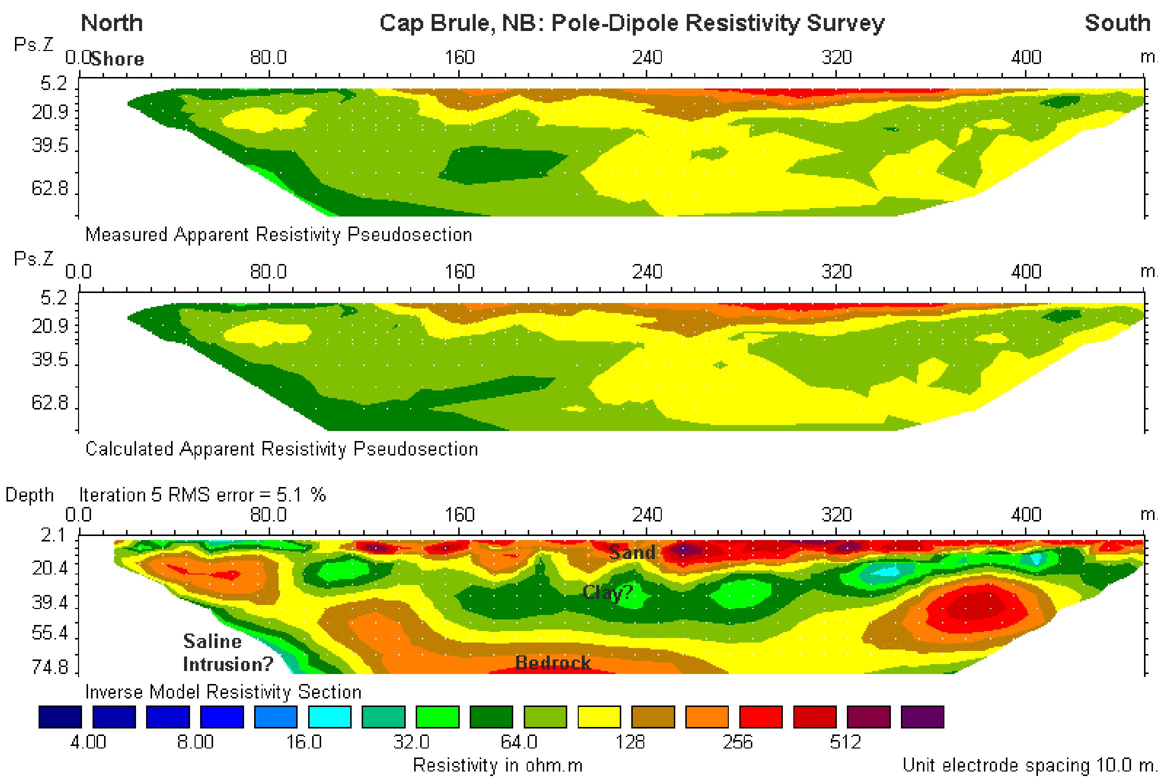


Figure B-3: Pole-dipole array electrical resistivity image, Cap Brûlé, New Brunswick

Parlee Beach

Wenner array resistivity images were acquired at the overflow parking lot and at the beach volleyball court in Parlee Beach Provincial Park. The results for the overflow parking lot survey are shown in Figure B-4. The image indicates the presence of a shallow high-resistivity layer in the north portion due to a sand layer that pinches out to the south. The upper layer in the central portion of the image has lower resistivity which is indicative of clay or silt. This layer dips gently to the south and is overlain by a higher resistivity sand layer to the south. A northward-dipping high-resistivity zone occurs at the base of the image and is interpreted as bedrock. There do not appear to be any zones with very low resistivity, indicating that the saltwater-freshwater interface is located much further seaward.

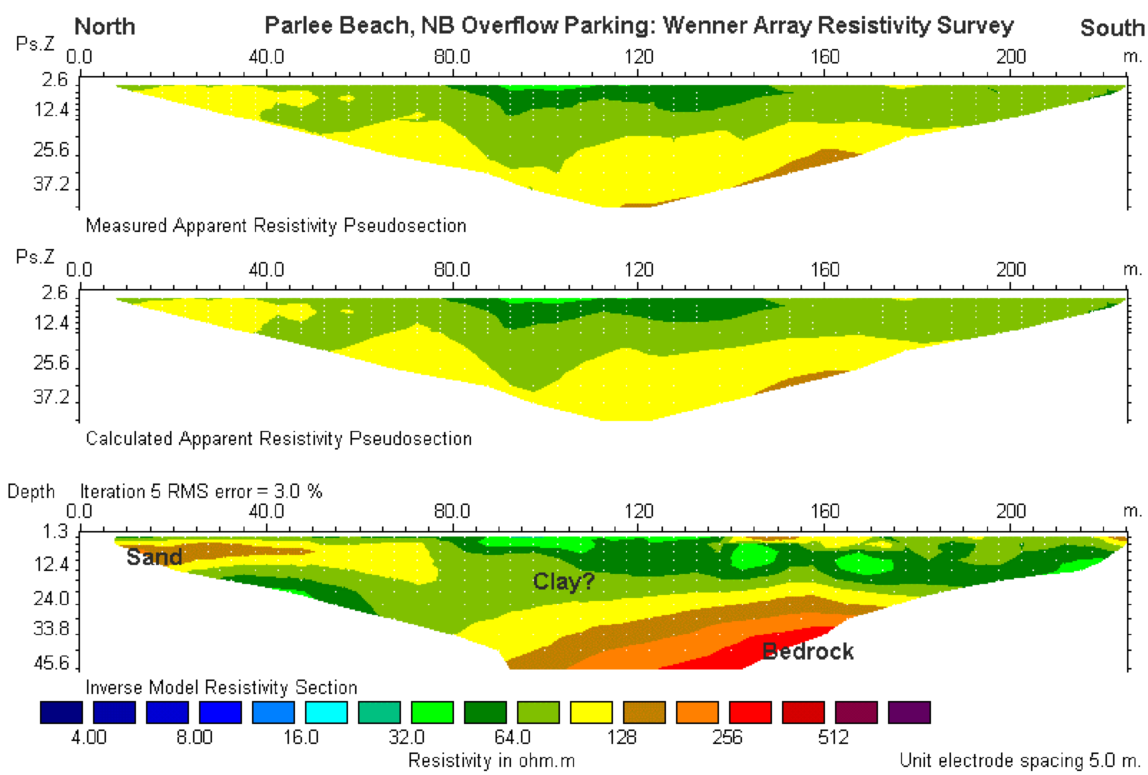


Figure B-4: Wenner array Electrical resistivity image, overflow parking lot, Parlee Beach NB

The second image was acquired along a line through the beach volleyball court from the lagoon to the beach. The results, shown in Figure B-5, indicate very low resistivity sand on the beach due to infiltration of seawater during the tidal cycle. This is underlain by a higher resistivity layer that likely contains freshwater which is discharging into the sea. The dune area has a very high resistivity layer near the surface, likely due to well-drained dry sand. This is underlain by a lower resistivity layer, possibly clay and silt. The high resistivity zone that occurs at a depth of 40 m is likely bedrock. Saline intrusion from both the sea and lagoon towards the dune are indicated by very low resistivities between 20 to 30 m depth. A high resistivity zone located 20 m below the dune may indicate the presence of a fresh water lens.

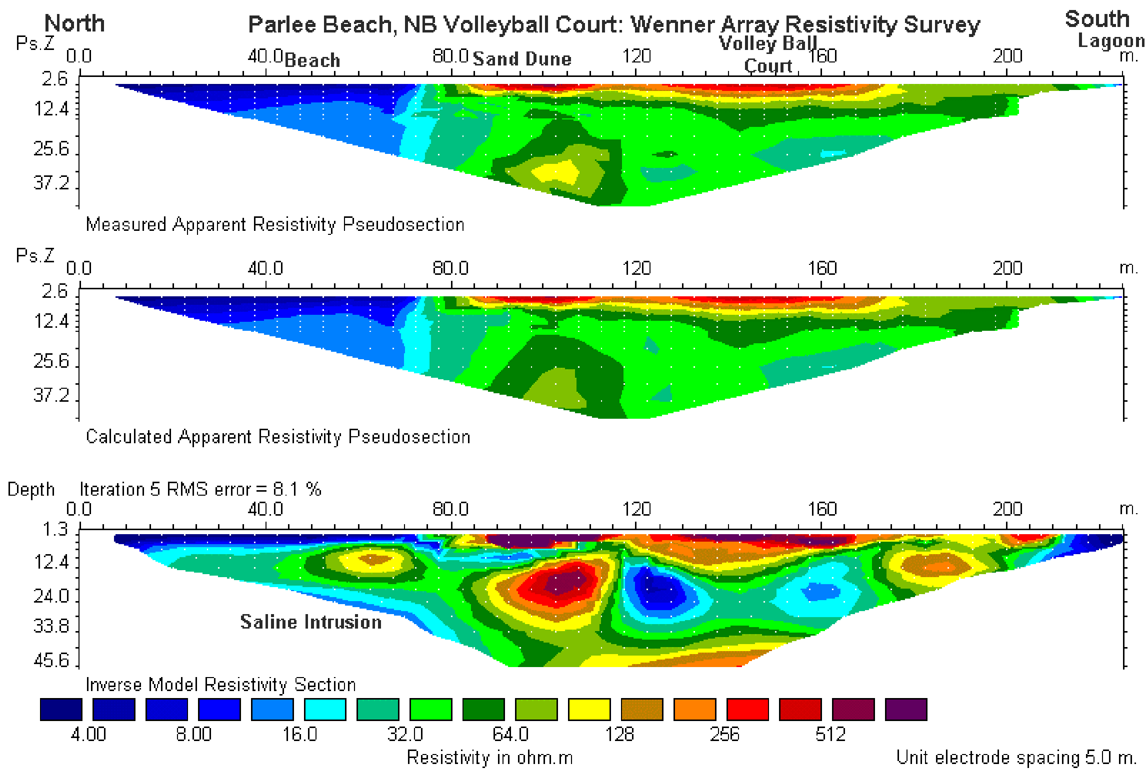


Figure B-5: Wenner array electrical resistivity image, volleyball court, Parlee Beach NB

Murphy Road

A Wenner array electrical resistivity image was acquired perpendicular to the beach, along Murphy Road, 1 km south of Shediac Bridge. Bedrock was observed outcropping along the road. The results, shown in Figure B-6, indicate gently westward dipping strata. The upper layer has a high resistivity and is underlain by a lower resistivity layer. Higher resistivity bedrock is also found at depth. A very low resistivity zone at 20 m depth on the east end of the image indicates saline or brackish water, suggesting that a saline / freshwater interface is located approximately 70 m inshore.

Grande-Digue

A Wenner array electrical resistivity image was acquired along a road located beside the baseball park in Grand-Digue. Bedrock was observed in outcrops along the shore. The results, shown in Figure B-7, indicate a 30 m thickness of gently northwestward dipping high resistivity bedrock. A zone of low resistivity near station 200 may be due to higher groundwater conductivity caused by a livestock operation that was reported to exist previously on the site by one of the residents. A very low resistivity zone at 40 m depth on the southeast end of the image indicates saline or brackish water, suggesting that a saline / freshwater interface is located approximately 100 m inshore at 40 m depth.

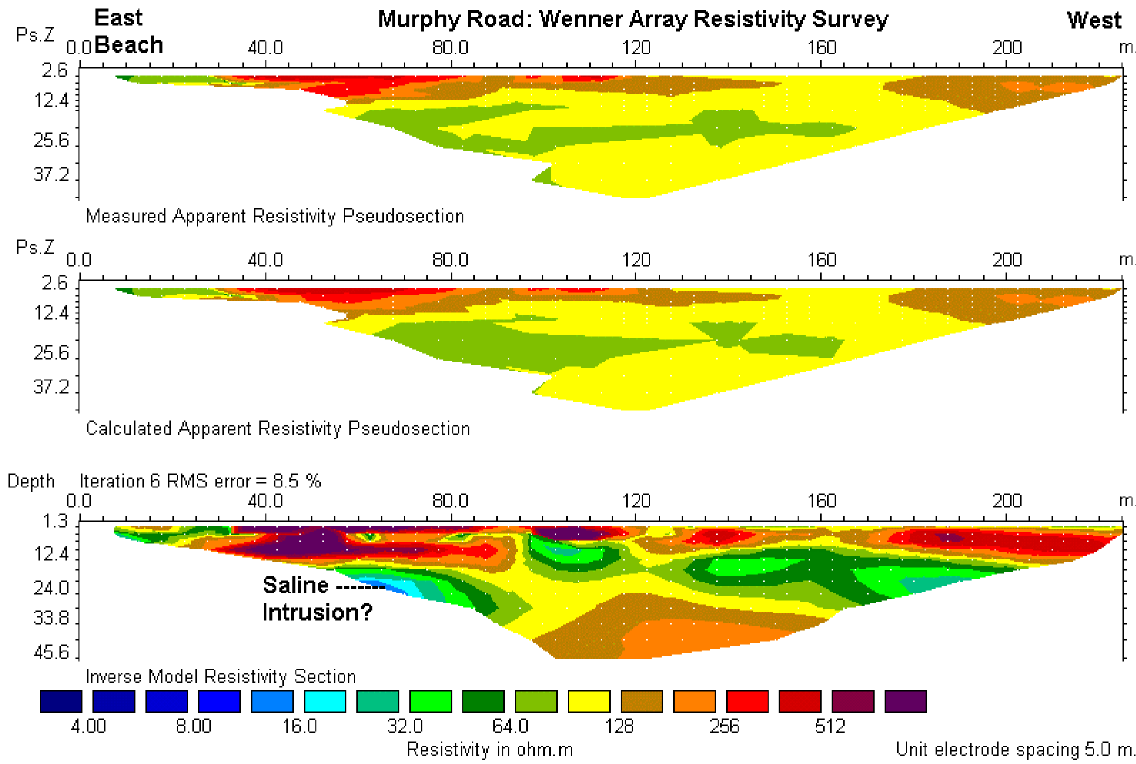


Figure B-6: Wenner array electrical resistivity image, Murphy Road, Shediac Bridge, NB

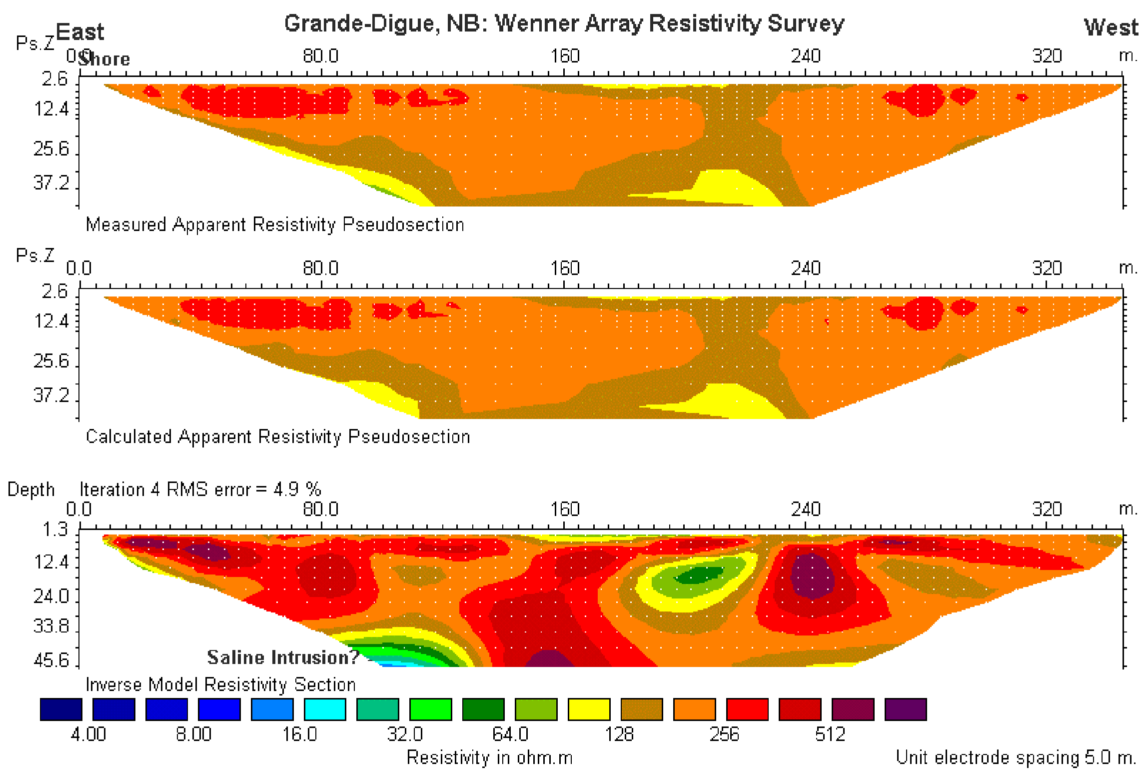


Figure B-7: Wenner array electrical resistivity image, Grande-Digue, NB

Bourgeois

Wenner and pole-dipole array electrical resistivity images were acquired perpendicular to the shore along a road located 2 km west of Bourgeois. Bedrock outcrops were observed in the immediate area. The Wenner array image, shown in Figure B-8, indicates approximately 20 m of high resistivity bedrock underlain by slightly lower resistivity strata. A low resistivity zone near station 480 is interpreted as being due to sub-cropping of lower resistivity bedrock.

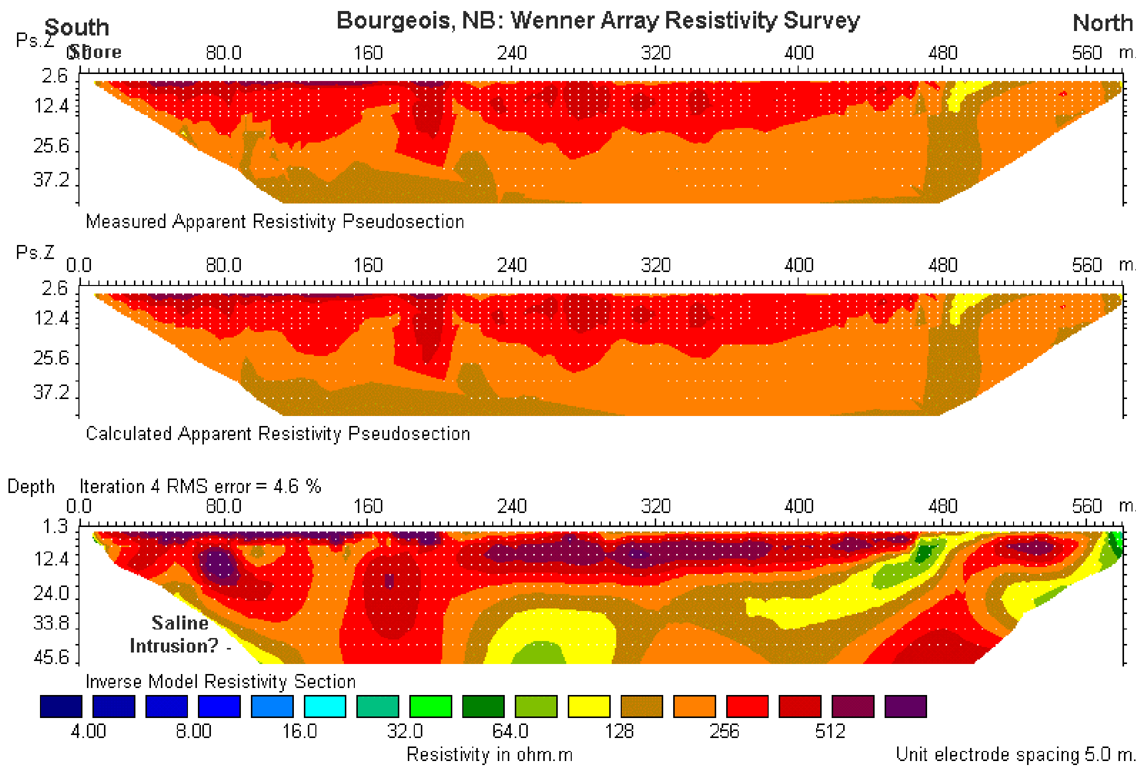


Figure B-8: Wenner array electrical resistivity image, Bourgeois, NB

The pole-dipole electrical resistivity image for Bourgeois is shown in Figure B-9. The interpretation is similar to that of the Wenner array image with the addition of a high resistivity layer below 40 m depth and clearer indication of a possible saltwater-freshwater interface dipping sharply from the shoreline. The low resistivity zone near station 480 is interpreted as being due to sub-cropping lower resistivity bedrock.

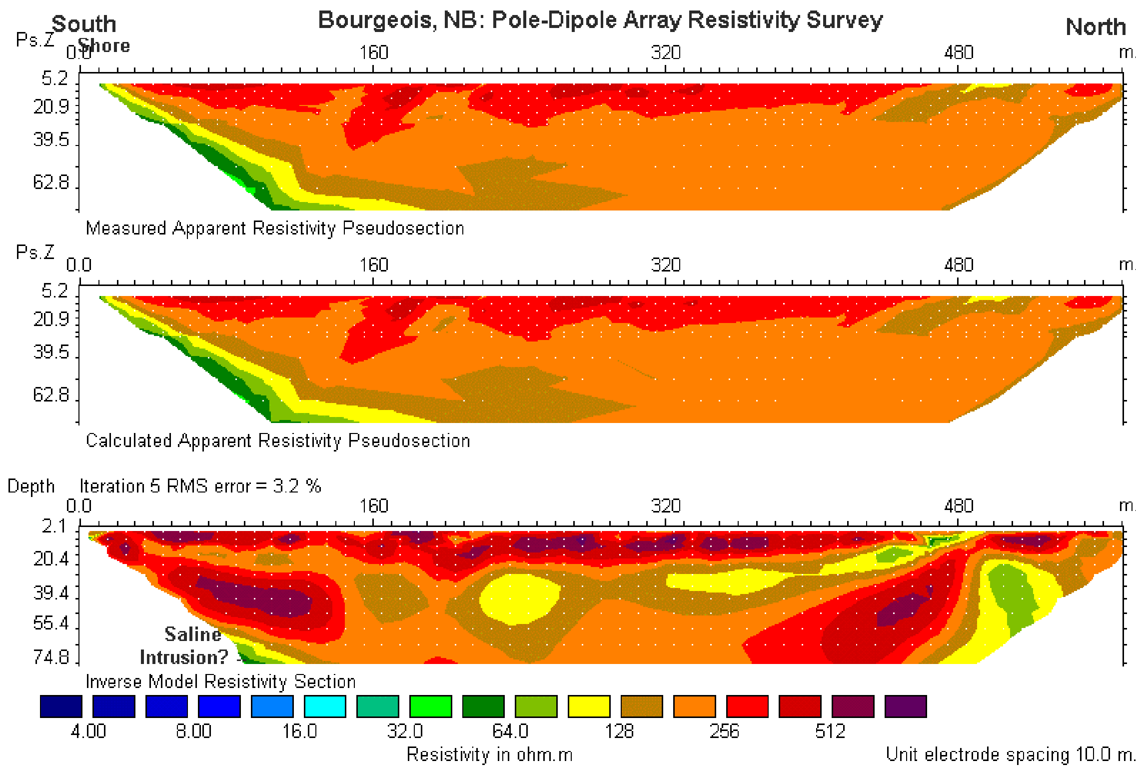


Figure B-9: Pole-dipole array electrical resistivity image, Bourgeois, NB

<u>Sackville, New Brunswick</u>

Three electrical resistivity images were acquired using the pole-dipole array at the Sackville water supply well field located 5 km northwest of Sackville, New Brunswick. The locations of these images are shown in Figure B-10. The first image (Line 1) was acquired along the main access road to the well field. The resulting electrical resistivity image and two-dimensional model are shown in Figure B-11. The north part of the line is underlain by high resistivity bedrock which contrasts sharply to a southward-dipping low resistivity zone near station 480 which may be faulted and/or fractured. In the south portion of the image, the high variability in the near-surface resistivity is likely due to variable thickness of overburden and the presence of rock-fill along portions of the road. Resistive bedrock is interpreted to be at a depth of approximately 20 m. This is underlain by lower resistivity bedrock at 60 m depth.

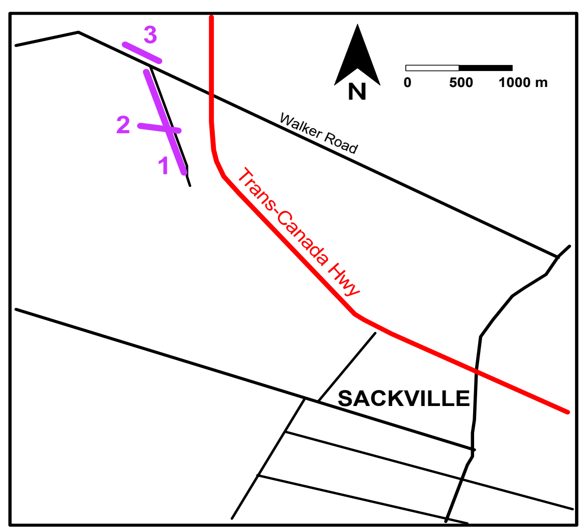


Figure B-10: Location of electrical resistivity images, Sackville, NB

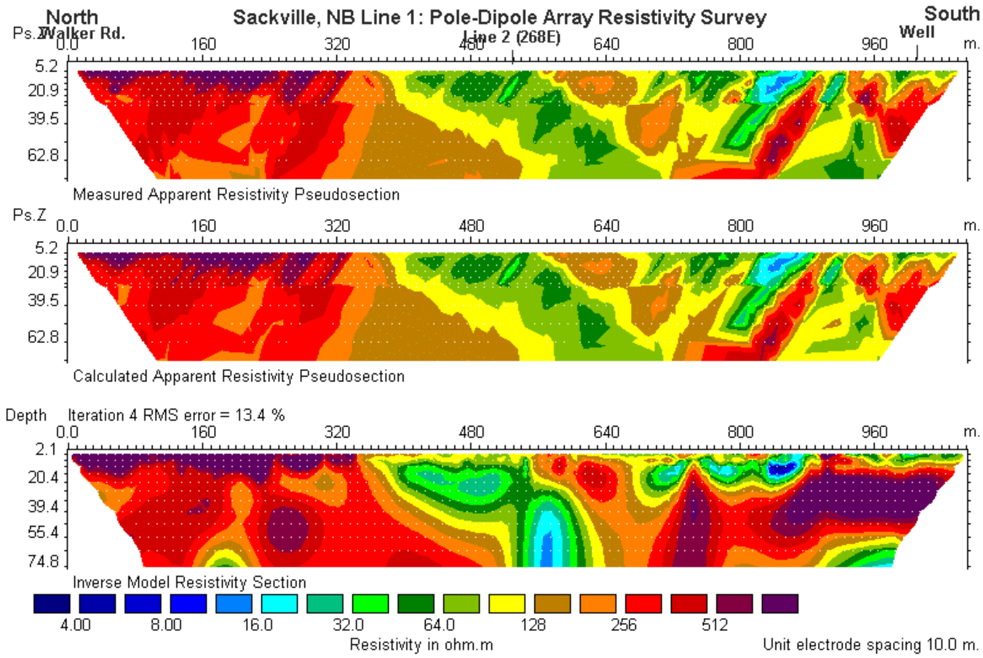


Figure B-11: Line 1 Pole-dipole array electrical resistivity image, Sackville, NB

An electrical resistivity image was also acquired along a line (Line 2) which intersects production wells #3 and #4. The apparent resistivity image and results from modelling are shown in Figure B-12. The resistivity of the upper 10 m is quite variable, likely due to changes in overburden composition. This is underlain by low resistivity bedrock that increases sharply in thickness east of station 160 so that the resistive basement bedrock is too deep to image. This is interpreted to indicate that faulting and fracturing are present.

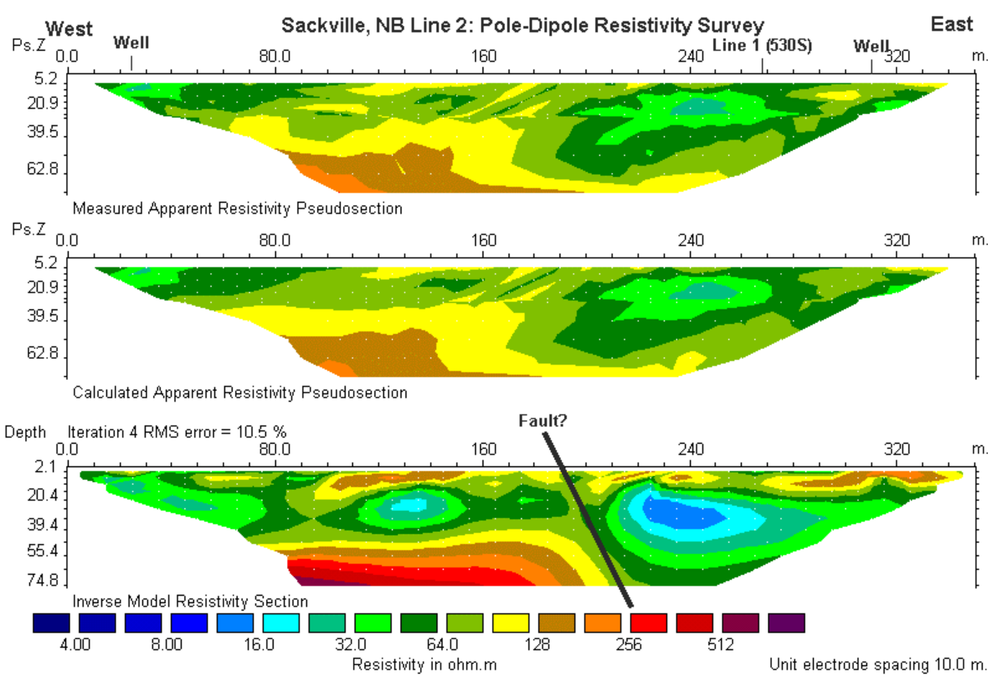


Figure B-12: Line 2 Pole-dipole array electrical resistivity image, Sackville, NB

A third electrical resistivity image (Line 3) was acquired along Walker Road near Well #1. The image and modelling results are shown in Figure B-13. The surface is highly resistive, likely due to shallow resistive bedrock. Resistivity decreases slightly with depth except in the zone between stations 200 and 240 where a zone of lower resistivity occurs. Well #1 is in this zone and it is possible that the lower resistivity is due to fractured bedrock.

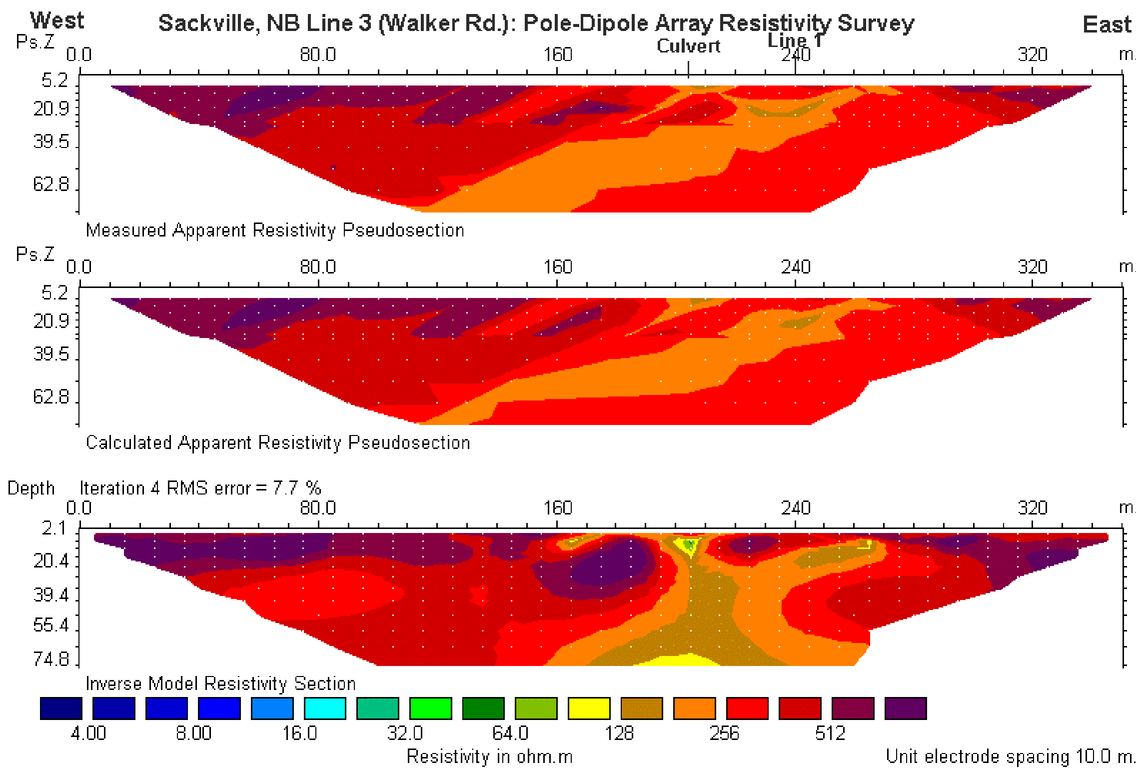


Figure B-13: Line 3 Pole-dipole array electrical resistivity image, Sackville, NB

<u>Rustico Harbour, Prince Edward Island</u>

In order to investigate saline water intrusion on the south shore of Rustico Harbour, Prince Edward Island, electrical resistivity images were acquired along Cemetery Road and Blue Bay Farms. The locations of these images are shown in Figure B-14. The Wenner array results for the Cemetery Road site are shown in Figure B-15. Due to the significant topographic relief along this line, an elevation correction was incorporated during the modelling. The near surface is highly resistive due to thick sandy soils. This is underlain by bedrock consisting of sub-horizontal, southward dipping layers with moderate and high resistivity. None of the lower resistivity zones are of a magnitude that would indicate saline intrusion.

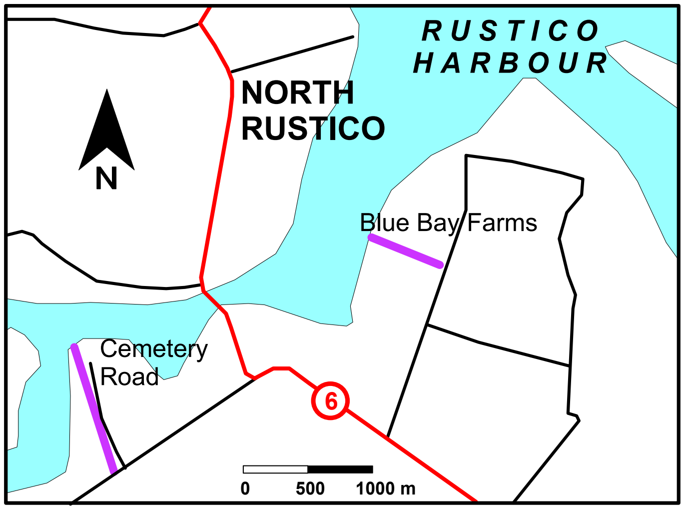


Figure B-14: Location of electrical resistivity images, Rustico Harbour, PEI

Both Wenner array and pole-dipole array electrical resistivity images were acquired at Blue Bay Farms. The Wenner array results are shown in Figure B-16. The east portion of the image indicates a highly resistive bedrock layer near the surface that thickens westward to approximately 20 m at station 400. This is underlain by lower resistivity bedrock which decreases sharply in resistivity west of station 360, indicating the presence of a saltwater-freshwater boundary. The results for the pole-dipole array, shown in Figure B-17, are similar and indicate that the saline intrusion may be confined to a permeable layer between 10 and 50 m depth.

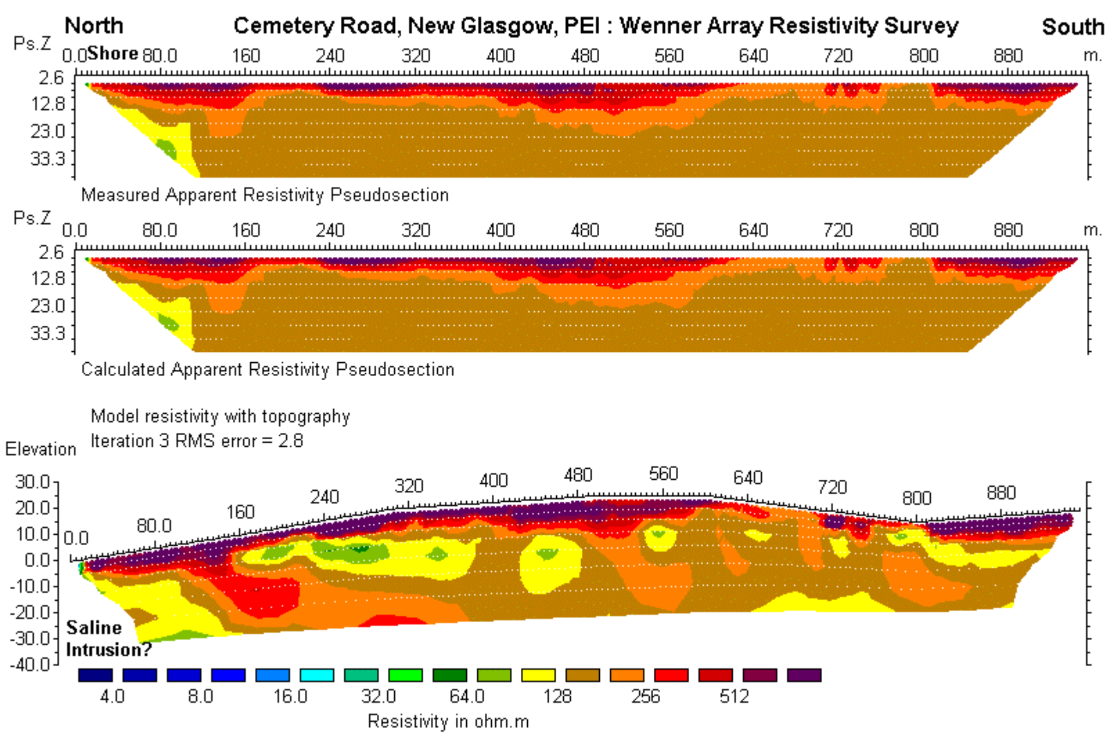


Figure B-15: Wenner array electrical resistivity image, Cemetery Road, New Glasgow, PEI

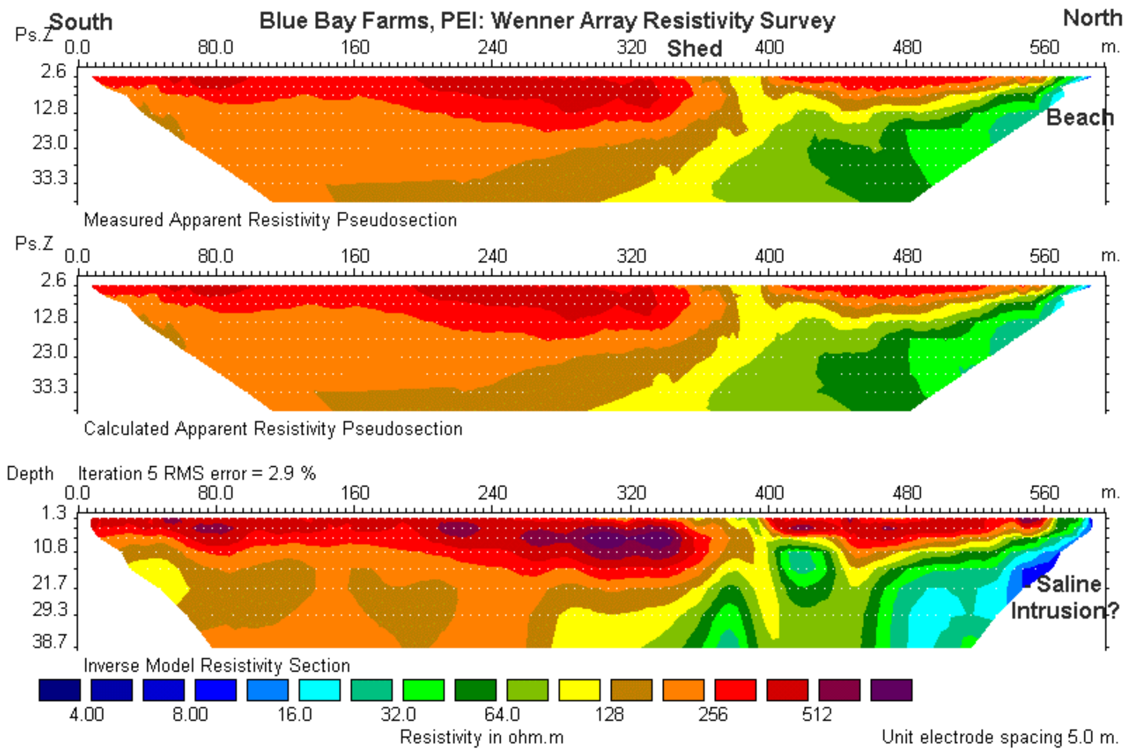


Figure B-16: Wenner array electrical resistivity image, Blue Bay Farms, PEI

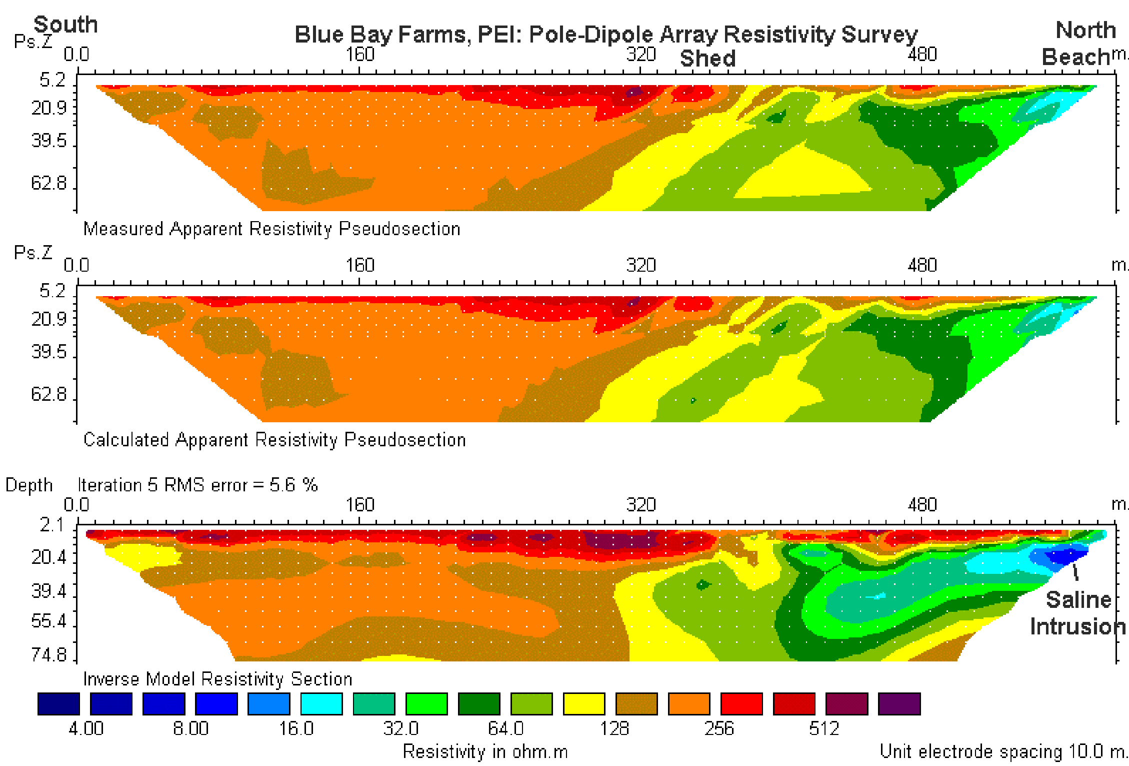


Figure B-17: Pole-dipole array electrical resistivity image, Blue Bay Farms, PEI

Conclusion

The electrical resistivity images proved to be very useful for investigating both stratigraphy and saline intrusion. In the Shediac Bay area, the saline / freshwater interface is found near the shore but dips steeply inland and is not likely to be encountered by water wells. In Rustico Harbour, saline intrusion may present more of a concern, as there is indication it may occur further inland and at shallower depths.

The electrical resistivity images from the Sackville well field indicate that there may be significant faulting and fracturing present. This would affect the interaction between wells during pumping. More electrical resistivity imaging is needed to develop a geologic model of the well field.

Part C

Borehole log descriptions of the wells drilled in 2002

(source: ADI Ltd, 2003)

Borehole logs – ADI Ltd., 2002

Dieppe, NB

D-1 Air rotary drill hole **Dieppe, NB**, on NTS Sheet 21 I/02
Civic address: west end of Rue J.F. Bourgeois, off Rue Armirault, drilled in bush land, 10.2 meters 331° magnetic From NW corner of fence around public play ground.

NAD27 UTM Zone 20	370591 E,	5100421 N,	elevation 84 m;
NAD83	370656 E,	5100628 N	

(by hand held 12 channel GPS unit; 8 satellites, 1.5 minutes averaging).

Vertical 6" diameter hole; 8" casing to 18 feet below surface, with well cap.

Drilled by Walter Chappell Well Drilling Ltd. Of Moncton, N.B., On 9 August, 2002.

Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.

Logged by Donald Hattie, P. Geol. Cuttings were collected in 10 foot intervals into Zip-Lock bags. This log is based on cuttings retained during washing on a kitchen sieve with 1.2 mm square openings. Additional comments are from notes during the drilling.

All rocks encountered are assigned to the Upper Carboniferous. Rocks below about 137 feet belong to Cumberland Group, Boss Point Formation, fluvial channel deposits. Rocks above 137 feet may Belong to Pictou Group, Salisbury formation, deposited in fluvial Channels and on adjacent flood plains.

Abbreviations: cgl = conglomerate; sst = sandstone; slt = siltstone

From feet	To feet	Depths below ground level
0.	10	Overburden: glacial till, clayey, reddish. Washed cuttings are 60% 1-3 mm; 30% 3-10 mm; 10% 1-1.5 cm May include the top of the bedrock. Few 1-2 mm glassy quartz grains. 40% dark grey arenacous slt, sectile 30% dull red-brown quartz-feldspar sst, fine to medium grained. 25% green-grey to grey-white to slightly red-brown-grey feldspathic quartz sst, medium to coarse, mostly well cemented, but some are friable; a few muscovite flakes. One chip: brown-grey granule cgl resembles the sst
10	21	Green-grey sst, mostly medium grained feldspathic quartz sst; fine muscovite flakes. Some sst chips are dark olive grey, appearing weathered. Few %: grey quartz sst and a few chips of coarse Feldspathic quartz sst. A few <6 mm milky quartz grains, from cgl?
21	31	60% dark maroon mudstone, soft, flaky 40% dull dark grey-green slt, soft, flaky
31	42	70% dark maroon mudstone, soft, flaky 30% light green slt and very fine sst
42	52	At 46-48': green sst and mud noted. 5% dark maroon mudstone, soft, flaky

		75% dark maroon slt and very fine sst, platy part.
		20% light grey-green fine sst; many chips have irregularly intermixed dark maroon patches
		A few chips of pale rose very fine hard quartz sst
52	62	99% dark maroon fine sst, flaky; a few partings are pale grey-green
		Few chips of light green grey soft claystone
62	74	<5% dark maroon fine sst
		95% dark maroon soft mudstone, flaky; some light green-grey partings
		Few chips of light green-grey soft claystone
		Few chips lt grey fine quartz sst, well cemented
72	83	At 75-82: intervals of green mud in returned water
		15% lt grey-white fine quartz sst, well cemented
		85% dark maroon fine to medium sst, flaky; some light green-grey clayey partings
		Rare chips of dark green-grey fine sst
83	93	99% dark maroon fine clayey slt, soft, flaky; minor very fine clayey sst
		Few chips to 3 mm thick of light green-white soft claystone
93	103	>95% dark maroon clayey slt, soft, flaky
		< 5% <4mm thick light green-white soft claystone
103	113	Intervals of green mud in return water from 105’
		Dark maroon clayey slt, fine muscovite on flaky Partings. 10% of chips are mottled to entirely Light green-grey claystone
113	123	Dark grey water to 116’; then maroon
		10% light green-grey very fine to fine sst, soft
		90% dark maroon clayey slt, soft, flaky parting
123	133	From 126’: green intervals, becoming steady green
		65% dark maroon soft slt; some chips are red-brown claystone
		10% light green claystone, soft
		25% grey-green very fine to medium sst, friable; few muscovite flakes
133	143	From 137’: green sst
		2% dark maroon slt (from above?)
		98% grey-green medium feldspathic quartz sst; friable, well sorted and close packed, minor matrix; not limy; lacks muscovite; feldspar is salmon to cream coloured
143	153	Sst to 149’; then cgl
		20% grey-green medium sst (as above) to coarse sst; rare muscovite; not limy
		Few chips soft grey-green slt
		80% cgl, with rounded pebbles which are not cemented to matrix. Pebbles are:
		55% milky to clear quartz, to > 1 cm
		40% light to dark grey dense quartzite and black chert; few chips of jasper; possibly some maroon rhyolite
		5% dark green-black mafic volcanic?
		Few quartz porphyry in cream white groundmass
153	163	90% cgl rounded pebbles, rock types as above; many are > 1 cm; a few chips are fine quartz-epidote rock; 1 chip fine diorite?; one chip salmon feldspar-milky quartz leucogranite?
163	173	98% cgl pebbles, most are <1 cm, rounded, not cemented to matrix; >50% are milky to clear quartz, rest are rock types as above
		2% pale green claystone, soft
173	183	Green slt-claystone interbedded in <1’ sections
		95% cgl or granule cgl: most clasts are <3 mm:

		80% are translucent to milky quartz; >15% are dark green-black mafic volcanic? < 5% are jasper, brown, grey, black chert
		5% medium grey soft claystone, flaky
183	193	Interbedded units
		60% cgl or granule cgl, as above; few grains of jasper
		>20% dark green-grey quartz-lithic medium sst, silty matrix, porous, poorly cemented; not limy
193	203	20% < 3mm quartz grains (from granule cgl); few jasper and black chert grains
		75% grey quartz-minor feldspar-lithic medium sst, poorly sorted, little matrix, poorly cemented, minor muscovite; not limy
		<5% medium grey soft claystone
203		End of hole (205’ from top of casing)

No notable influx of water into the hole.

Legerville, NB (diamond drilling, 2.5")

LV-2 diamond drill hole **Legerville, NB**, on NTS Sheet 21 I/06
Civic address: 1460 Route 485, drilled in pasture at 0.4 km South of Route 485.

NAD27 UTM Zone 20 345645 E, 5129048 N, elevation 72 m
(by hand held 12 channel GPS unit)

Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative. Drilled 14 to 17 August, 2002.

Drilled with 5 foot core barrel; Hq core, 62 mm diameter.
Core placed in 30 three-row plywood core boxes, 3.8′ (1.11 m) long
Each box weighs about 75 pounds.

BOX LIST

Box	Feet	Ends of runs (feet)
Box 1	9.5 - 18.7	11.5, 14.3, 16.6
2	18.7 - 28.8	21.6, 26.5
3	28.8 - 38.9	31.5, 36.5
4	38.9 - 52.3	41.5, 41.7, 46.5 (3.3′ lost), 47.0, 47.8, 51.5
5	52.3 - 62.8	56.5 (0.2′ lost), 61.5 (0.2′ lost)
6	62.8 - 72.5	66.5, 71.5 (0.4′ extra core)
7	72.5 - 82.3	76.5, 81.5
8	82.3 - 92.5	86.5, 91.5
9	92.5 - 102.6	93.4, 94.5, 96.5, 101.5
10	102.6 - 112.8	106.6, 110.1
11	112.8 - 123.2	115.5, 116.5, 121.5
12	123.2 - 133.2	126.5, 131.5
13	133.2 - 143.8	136.5 (0.3 lost), 141.5
14	142.8 - 154.4	146.5 (0.3 lost), 151.5
15	154.4 - 164.6	156.5, 161.5
16	164.6 - 175.0	166.5, 171.5
17	175.0 - 185.6	176.5, 181.5
18	185.6 - 196.2	186.5, 191.5
19	196.2 - 206.2	196.5, 201.5
20	206.2 - 216.5	206.5, 211.5, 216.5
21	216.5 - 226.5	221.5, 224.0, 224.3, 226.5
22	226.5 - 237.4	231.5 (0.5′lost, apparently at 226.5, 227.7, 228.0), 236.5
23	237.4 - 247.9	241.5, 246.5
24	247.9 - 258.3	251.5, 256.5
25	258.3 - 268.5	261.5, 266.5
26	268.5 - 278.8	271.5, 276.5
27	278.8 - 288.9	281.5, 286.5
28	288.9 - 299.3	291.5, 296.5
29	299.3 - 309.6	301.5, 306.5
30	309.6 - 316.5 (End)	312.3, 316.5.

LV-2 diamond drill hole **Legerville, NB**, on NTS Sheet 21 I/06
Civic address: 1460 Route 485, drilled in pasture at 0.4 km South of Route 485, 80 meters north (348 1/2° magnetic) from LV-1 air rotary hole.
NAD27 UTM Zone 20 345645 E, 5129048 N, elevation 72 m (by hand held 12 channel GPS unit)

Drilled by Lantech Drilling Services, Inc., of Dieppe, N.B. using A track mounted wireline drill, 14 to 17 August, 2002.
Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.
Vertical hole at the collar. No dip tests taken.
Hq core (62 mm diameter), stored in 30 three-row 1 meter boxes, Stored at N.B. Natural Resources core storage, Sussex, N.B.
Logged by Donald Hattie, P. Geol.

SUMMARY LOG

All rocks encountered are assigned to Upper Carboniferous, Pictou Group, Richibucto formation, deposited in fluvial channels and on Flood plains.

From feet	To feet	Depths below ground level
0.	7.5	Overburden: sandy-silty glacial till
7.5	13.9	Coarse sandstone, dull maroon to grey green
13.9	14.9	Plastic soft clay, patchy light green to maroon
14.9	20.2	Maroon siltstone-claystone
20.2	35.2	Maroon fine to medium sandstone with siltstone lenses
35.2	35.5	Pale grey-green siltstone with calcite nodules
35.5	64.6	Units of maroon siltstone, fine sst, and clay
64.6	89.6	Sandstone, mainly green-grey medium grained, but parts are coarse
89.6	93.5	Maroon fine sandstone and siltstone
93.5	95.9	Green grey to dull grey soft claystone (resembles coal underclay)
95.9	103.5	Dull maroon very fine sandstone, siltstone and claystone
103.5	106.2	Dull grey to dark grey clay; yellow ochre in fine sand in-filling of burrows of roots
106.2	135.1	Dark maroon claystone, siltstone and very fine sandstone, including possible soil zones
135.1	187.1	Mainly green-grey sandstone
187.1	191.7	Grey siltstone grading to black claystone
191.7	196.2	Grey-green coarse sandstone
196.2	198.5	Interbedded grey siltstone, very fine and medium sandstone
198.5	211.5	Interbedded green grey fine and medium sandstone, passing downward to medium and local coarse sandstone and minor granule conglomerate
211.5	217.0	Red-maroon siltstone
217.0	220.3	Interbedded maroon very fine to fine sandstone and medium to very coarse grey-maroon sandstone
220.3	226.5^{+}	Green-grey very coarse sandstone to 228.8'; then dominantly granule conglomerate, becoming coarser and more friable, with kaolin or illite in matrix
227.(0)	249.9	Mostly maroon clayey siltstone, silty very fine sandstone (flood plain deposits and possible soil profiles)
249.9	256.3	Interbedded green-grey medium sandstone and dark maroon very fine sandstone and siltstone

256.3	281.5	Green-grey medium arkosic sandstone
281.5	282.8	Massive grey siltstone
282.8	284.9	Grey medium sandstone
284.9	285.5	Grey granule conglomerate
285.5	292.7	Grey medium and coarse sandstone and granule sandstone
292.7	293.2	Massive grey siltstone
293.2	316.5	Grey granule conglomerate, coarse and medium sandstone
316.5	feet	Hole terminated for budgetary reasons.

Legerville, NB

LV-2 Air rotary drill hole **Legerville, N.B.**, on NTS Sheet 21 I/06
Civic address: 1460 Route 485, drilled in pasture at 0.4 km South of Route 485.

NAD27 UTM Zone 20 345645 E, 5129048 N, elevation 72 m
(by hand held 12 channel GPS unit)

Site is 80 meters north (348 1/2° magnetic) from LV-1 air-Rotary hole. Center line of farm road (347 1/2° mag) is About 4 1/2 m east of LV-2

Drilled by Lantech Drilling Services, Inc., of Dieppe, N.B. using A track mounted wireline drill.
Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.
Drilled 14 to 17 August, 2002.

12 feet (two 5' sections + one 2') of H steel casing of which about 1 foot is above ground level.
Drilled with Hq rods, in 5' and 10' units; 5 foot core barrel.
Vertical hole at the collar. No dip tests taken.

Logged by Donald Hattie, P. Geol., on site.

Beds and joints recorded as angles from the core axis.
Colours codes are approximated by Munsell system using "Munsell Soil Color Charts", published by MacBeth, 1992, and "Rock Color Chart", Geological Society of America, 1970.

Grain size terminology by the Wentworth scale
cgl: conglomerate; sst: sandstone; sltst: siltstone

From feet	To feet	
0.	7.5	Overburden: sandy-silty glacial till with cobbles and slabs of grey and maroon sandstone.
7.5	9.5	Hole advanced with auger: debris of granular green-grey soft sandstone, then of dull maroon fine sandstone and siltstone.
9.5	13.5	Coarse sandstone composed of quartz, red-brown feldspar, few lithic grains; 1-3 mm laminations by grain size and white calcite cement. Some calcite cement throughout, but forms visible grey-white matrix in some <3mm beds. Colour patchy along and across beds: green-grey intervals to 15 cm, dull maroon units to 30 cm; rock was probably originally dull maroon. Grey-green : wet 5GY 4.5/1; dry 5GY 4.5/1 Dull maroon: wet 7.5YR 4/2; dry 5YR 4/1 Beds: 86° at 10, 12 and 13.5 feet. At 12.2': 5 cm of soft maroon cohesive clay; At 13.0': 1 cm of <2mm soft green-grey clay interlayered with green-grey sst. 25 partings parallel beds Two partings at 11.0-.5', three partings at 13.5-.9' curve 68 to 90°, crossing the bedding.
13.9	14.9	Plastic soft clay, patchy light green (5G 5.5/1 wet) reduced patches and dull maroon (3YR 4.5/2). Slight calcite in parts. To 14.1': few <1cm chips

of green-grey sst, perhaps emplaced by drilling.
Four parts along bedding.

14.9 20.2 Dull maroon (5YR 4/2 dry) sltst-claystone, soft, carvable but coherent, except 15.1-17.1, 17.5-.7, 18.0-.1, 18.4-.8 which are mostly plastic with some 1 cm thick disks of coherent sltst. Not limy to 19′, then slightly limy. Lower contact is gradational across 6 cm. Beds: 87° at 19′.
As core dried, many bedding partings at 1 mm to 1.5 cm spacing (average 8 mm)
17-18′, 19.4-.6: irregular cracks at <10°.
At 19.8′: joint at 36°.

20.2 35.2 Sst, dull maroon (dry 5YR 5/2, wet 5YR 3.5/2), non- to very slightly limy in fine to medium sst to about 21.9′: then fine sst, faintly cm-banded, grading to medium sst with 1-3mm thick dark maroon sltst lenses; limy cement in coarser sst beds but not in finer massive beds.
Except 21.0-.3′: 60% 1-3 cm bands of dark maroon plastic clay interlayered with dark maroon soft but coherent sltst.
From 24.7′: < 1 cm high ripple drift cross beds.
Maximum grain size in medium sst at 27.4-28.1 with 10% calcite cement (dry 5YR 5.5/2; wet 7.5YR4.5/2); muscovite on bedding partings.
At 28.1′: >1 cm deep scour at base of 11 cm thick cross beds layered at 70°.

29.0-.5 slumped or bioturbated sst with irregular dark maroon sltst lenses.

29.5-.7 cross-bedded coarser medium sst.

29.7 32.8 1-5 mm laminated grey sst with 20% 1-2 mm dark maroon laminations; <1 cm high ripple drift cross beds are common, layered at 70°, except 31.9-32.4 which is massive medium sst with slight calcite cement.

32.8 35.2 pale green-grey coarser medium sst with calcite cement, interlaced with 30% 1-3 mm lenses and laminations of maroon fine sst; <1 cm high ripple drift cross beds.
32.9′: <5 mm clay layer
At 35′: beds at 88°.
Bed partings: 20.2-21.0: three partings
21.0-.3: 3 mm to 1 cm spaced
21.3-.9: five partings + a joint parallel to core
21.9-35.2: 33 partings, spaced 9 to 18 cm (two <1 cm spaced partings at 32.5 and 33.2′)

35.2 35.5 Pale grey-green sltst with 1-3 mm calcite nodules; <2 mm thick dark maroon sltst layers.
As core dries: bed partings at 2-3 cm.
One irregular joint parallel core.
At 35.5: 2 cm soft plastic dark maroon clay.

35.5 58.3 Units of maroon sltst, fine sst, and clay.

35.5 (41.7) Siltstone, dark dull maroon, massive to very faintly bedded; <5% <2 mm calcite nodules. Pale green clay lenses with <3 mm calcite nodules at 35.9-36.0, 37.2, 41.4′.
39.8-.9: fining upward pale green-grey medium sst.
Soft plastic maroon clay >2 cm beds at 36.6, 36.9, 37.3-.4, 38.0-.2, 39.7 (< 1cm), 40.0.
Bed partings mostly at 5-10 cm spacing, but 1.5-2cm at 36.0-.9 and 37.3-.9.
Single joints at 18° at 36.7, 39.9. One joint at 38° at 40.5′.

Note: 41.7-46.5': only 1.5 feet of core recovered; the lost material was probably clay bands.

(41.7) 47.1 Interbedded dull maroon sltst and plastic maroon clay. The siltstone totals 1.2' of core recovered, in broken pieces 2 to 4 cm long; some pieces appear to be bounded by joints at <30°. Sltst has a few <1 cm light green reduced spots and bands. The plastic clay totals 0.9' of recovered material. The clay encloses some <1 cm fragments of coherent sltst, possibly emplaced during drilling or core removal.

47.1 58.3 Maroon (dry 5YR 4.5/2; wet 5YR 3/2) very fine sst with 1-3 mm darker maroon sltst laminations in parts; other parts are nearly massive.
1 cm high ripple drift cross beds at 51.3'.
1 cm plastic clay bands at 47.8, 48.7, 55.3;
4 cm plastic clay at 49.7'.
Beds at 77° at 51'; 83° at 57'.
Bed partings at 15 to 30 cm intervals, except 1-2 cm spacing at 47.7-.9, 48.4-49.1, 51.4-.5, 52.8-53.0, 54.1-.7. Incipient bed partings as core dries at 1-3 mm at 57.1-.7.
One joint at 18° at 52.0-52.6; one joint at 40° at 53.2; one joint at 50° at 54.3; one joint at 36° at 54.8; one joint at 12 to 40°; one joint at 0 to 10° at 56.9-57.2'.

58.3 64.6 Interbedded dark maroon sltst, faintly to well 1-2 mm laminated, and red brown to grey brown (weathered) very fine to fine sst, laminated by dark to very dark maroon. Not limy.

58.3 60.2 mainly fine to very fine sst, with <1 cm high ripple drift cross beds; brownish weathered (dry 5YR 4.5/2; wet 2.5YR 3.5/2) and porous at 59.6-.9, 60.15-.2. Dark maroon sltst at 56.9-60.15.
58.3-60.2: four bedding partings at 88°. 59.3-.6: one joint at 22° is truncated upward by beds.

60.2 62.2 dark maroon (dry 5YR 4.5/2; wet 2.5YR 3/2) sltst or very fine sst, faintly laminated.
Four bedding partings at 8 to 20 cm spacing, except 1 cm at 60.3'.

62.2 64.6 maroon (dry 5YR 4.5/2; wet 2.5YR 3.5/2) fine sst with darker very fine grained sst as 1-2 mm laminations; mostly with <1 cm high ripple drift cross beds; <0.5 cm thick lenses are light green reduced at 63.6-64.5; interlaminated coarse and fine sst in 2.5 cm section at 64.6'. 62.2-64.6: 11 and 30 cm sections of solid core, but a total of 6 bed partings at 2 to 3 cm spacing at 62.2-.5 and 0.5 to 2 cm spacing at 64.4-.7'.

64.6 89.6 Sst, mainly green-grey (dry 5GY 5.5/2; wet greener than 5Y 4/1 but less green than 5GY 4/1); mostly massive to faintly laminated with parallel 1-2 mm dark maroon lamination in parts. Sst is mostly medium grained, but parts are coarse. Sst is >50% quartz, 30% green lithic grains, 20% white, cream and reddish feldspar, some jasper? grains; muscovite on bedding partings.
Beds: 80° at 64.7'; 77° at 68'; 83° at 75.5'; 88° at 88'.

64.6 66.3 massive to faintly laminated medium sst with some coarse sst beds which coarsen upward; several 10-15 cm sections are well laminated with dark maroon layers. Only one bed parting.

66.3 69.7 Interbedded: green grey (greener than 5Y 4/1 dry) medium sst in 21 to 35 cm units at 66.3-67.7, 68.5-69.2′; and laminated very fine sst (5YR 4.5/2 dry) in 12 to 25 cm units at 67.7-68.5 and 69.2-.7. Three bed partings in medium sst at 8, 9 and 25 cm spacing; 7 partings in very fine sst at 1 to 15 cm spacing.

At 68.5′: 1 cm maroon plastic clay "bed".

69.7 89.6 mostly massive green-grey to slightly maroon-green-grey fine to medium sst. Non- to very slightly limy, except <1/2 cm patchy calcite cement at 72.8-73.2. Locally laminated by <3 mm maroon layers in parts of 74.1-75.6, 83.0-85.3, 86.0-.5, 88.6-89.6 which are slightly finer grained than the massive sections. 69.7-89.6: 25 bedding partings (core sections are, in cm, 7, 20, 33, 25, 2, 29, 14, 13, 1, 21, 3, 15, 55, 40, 36, 23, 22, 24, 51, 6, 16, 3, 35, 13, 14, 10, 21 cm).

Joints: 36° at 70.0′; irregular 12° at 75.1-.5 truncated upward by a bed; 62° at 78.6′; curving 15-26° at 83.1-.6 truncated upward by a bed.

89.6 93.5 To 91.6′: Dull maroon (dry 5YR 4/1; wet 2.5YR 3/1) non-limy very fine sst with 1 cm high cross beds; >10% of rock is 1 cm (only one to 5 cm) light green reduced (dry 5GY 6/1; wet 5G 4.5/1) lenses elongated along beds. Five bed partings. Joints: 26° at 89.8-90.2′; 36° curving at 90.3-.6; 50° at 90.3-.5 (100° clockwise from the other joint).

90.0′: beds at 87°.

91.6′: grades to similar coloured sltst, to 93.5. as dried, incipient partings at 1-3 cm intervals.

Joints at 92.0-93.5′: two at 10°, one at 20°; three incipient cracks parallel core, 3 cm apart, as core dried.

93.3′: 1/2 com maroon plastic mud seam, non-limy.

93.5 95.9 Green grey to dull grey (N 4/, gley coloured) soft but coherent, non-limy claystone (resembles coal underclay). At 94.5-95.8′: 20% patchy, irregular <1 cm thick lenses stained by yellow (limonitic) ochre to red (hematitic) ochre (possible rooted zone). At 93.6, 94.7, 95.3: 1/2 cm grey plastic clay seams at <10° from beds.

Twelve bed partings when drilled, at 3 to 6 cm spacing. As core dried, incipient bed partings at 1/2 to 2 cm spacing, plus a few partings parallel to the core.

95.9 103.5 Dull maroon very fine sst, sltst and claystone

95.9 100.3 dull maroon (dry 2.5YR 4.5/2; wet 5YR 3/2) very fine sst with three 3 to 8 cm medium sst beds, two of which coarsen upward. <5% of rock is <1 to 2 cm irregular dull green-grey reduction spots in very fine sst; also patchy reduction in parts of medium sst. Beds: 60 to 65° at 99.9′.

Originally 8 bed partings, in two cases at 1.5 and 2 cm apart; others are spaced (cm) 10, 26, 46, 11, 6, 10 cm apart.

Joints: 46° at 96.1′; 20-35° curving at 96.4′.

100.3 103.5 dull maroon (dry 2.5YR 4.5/1; wet 5YR 2.5/2) sltst, passing to claystone from 101.7′; brighter red-brown (dry 10R 3/2; wet 10R 3/3) in final

0.7′. Pale green-grey reduced 1/2 cm thick lenses in final 3cm in plastic semi-coherent clay.
Eight bed partings at 10-18 cm spacing when drilled; as core dried, incipient partings at 1.5-2 cm spacing in most of core, but two 9 cm pieces are solid. Curving cracks at 10 and 40° at 100.0-.5′ and 102.6-103.3′.
Maroon plastic clay beds?, 2 cm thick at 100.5′, 4 cm at 100.9-101.1′.

103.5 106.2 Dull grey to dark grey (gley colours: dry N6.5/ to N5/ ; damp N5/ to N4/) clay; 10% yellow ochre in <1 cm ovals of fine sand (in-filling of burrows or roots?). Lower boundary is gradational as green-grey extends into maroon sltst below. Plastic grey clay beds? at 103.6-.8, 1cm at 104.0, mainly clay at 104.2-.5, 105.3-.6, 3 cm at 105.8.
Eight bed partings spaced 6-12 cm when drilled; as dried, incipient partings < 1cm apart.
Joint at 38° at 104.8′.

106.2 135.1 Dark maroon claystone, siltstone and very fine sst, including possible soil zones (caliche).

106.2 112.3 dark maroon (dry 2.5YR 4.5/2; wet 2.5YR 3/2) sltst and claystone, faintly to distinctly laminated. 0 to 30% (highest at 110.2-.6, 111.6-112.0′) light green reduced patches, many enclosing 3 to 8 mm cream limestone nodules. Bulk of rock is non-limy. To 107.0′: <1 cm diameter limy light grey-green very fine sand (possible rooted zone).
60% 1-2 cm non-limy very fine sst beds at 107.9-108.5′. Beds: 88° at 107′; 90° at 112.3′.
109.1′: 1 cm red-maroon plastic clay bed?
106.2-108.0′: eight bed partings at 2 to 16 cm.
108.0-112.3′: core sections (cm) 30, 10, 18, 13, 40, 10 cm; 1 cm slice at 110.1′.
109.0-110.1: incipient partings as core dries.

112.3 115.5 red-maroon (dry 2.5YR 3.5/2; wet 2.5YR 3/2) claystone, 1-3 mm laminated. Several few cm light green reduced patches with cream calcite cores.
114.4′: >3 cm maroon laminated plastic clay bed, flanked above by broken rock in clay.
Eleven bed partings, 3-16 cm spacing (most 4-12 cm); as core dries, incipient partings at <1 cm.
112.5-113.1: joint at 5°.

115.5 121.3 dark maroon (dry 2.5YR 3.5/3; wet 2.5YR 3/3) more massive sltst. 3 cm light green reduced band along a joint at 62° at 119.2′.
119.9-120.6: 80% green reduced in irregular patches, slightly limy, enclosing 5% <1 cm calcite nodules (up to 40% of rock at 120.9-121.2).
Eleven partings are not beds but joints at 30-75° (most 50-60°), at 4 to 18 cm (most 7-14) spacing.
Joint at 118.3′ at 66° has slickenside-like grooves along major axis of ellipse through core.

121.3 128.2 dark maroon (dry 2.5YR 3.5/2; wet 2.5YR 3/3) sltst to 123.5′, then red-brown mudstone, with 10-40% calcite network (caliche) at 123.5-122.7, 123.6-124.7 and 125.3-.5. Five 1-5 cm light green reduced irregular patches, elongated across beds.
17 bed partings when drilled spaced 3-24 cm (most 6-12 cm). As core dried, incipient partings at <2 cm at 126.7-127.7′. Joints: 26°, truncated downward by a bed, at 125.9-126.0′; 40° truncated

upward by a bed, at 127.3-.5
124.7-125.0: red-maroon plastic clay bed?
127.7-128.2: “beccia” of 1-2 cm dull grey claystone/sltst with maroon stockwork; non-limy (a dessication structure?).

128.2 135.1 dark dull maroon (dry 2.5YR 4.5/2; wet 2.5YR 3/2) very fine sst and sltst; non-limy. Seven patches with light green reduction in <1 cm thick irregular lenses and ovoids, along and across beds. The very fine sst is faintly laminated to massive. Few <2 cm red sltst clasts at 132.4, 134.8-135.0’. Some silt and clay films into very fine sst (by dewatering?) at 130.0, 132.7. Last 9 cm of very fine sst has been reduced to grey-green. Sltst at 129.4-130.0, 131.5-132.5, 132.7-134.8 is slightly redder.
Beds: 76° at 131’, 133’, 134.6’.
17 bedding partings at 1 to 25 cm (most about 15) spacing. Abundant incipient partings as core dries at 0.5-1 cm at 129.4-.9, 133.2-134.5’.
Joint at 128.9-129.3: irregular at 25°. Joints at 128.2-.6, 130.9-131.5: irregular at 0-15°, truncated up and down by beds. 134.6-.7: Joint parallel core, truncated by beds up and down.
132.4-.7: probable site of 0.3’ of core lost between 131.5 and 136.5.

135.1 187.1 Mainly green-grey sandstone.

135.1 140.4 nearly massive medium sst, dull purple-maroon grading to dull maroon-green-grey (damp 2.5Y 3/1). Top 8 cm is dull grey-green reduced (wet and dry 5GY 4.5/1), and is slightly coarser than rest of interval; <1/2 mm quartz, feldspar and lithic grains. Not limy except in a few <1 x 2 cm calcite cemented patches at 139.3-.6, and up to 30% <3-8 mm calcite cemented patches at 140.1-.4 Three bedding partings; no joints.

140.4 145.5 grades to laminated green grey (wet and dry, between 2.5YR 3.5/1 and N5/ with slight olive shade) medium sst with dull maroon shades in patches and in <1 cm bands. 50% calcite cemented patches at 140.6-.7, 141.1-.3; some <1/2 cm patches at 142.0.
From 141.9’: < 1cm thick ripple drift cross beds in fine sst. 142.1’: 1.5 cm bed dull maroon sst. Six bed partings at 7-27 cm spacing, except at 144.7-145.5 where there are at least 6 <1/2 to 2 cm thick slices, and 9 cm of core may have been crushed in drilling, in dull grey (dry 10YR 5/1; wet 2.5Y 3.5/1) very fine sst and sltst; fine mica on beds. Beds: 87° at 144’.

145.5 151.4 green grey (damp 5Y 3.5/1) medium sst, very faintly bedded, probably a thick cross bed; beds at 65° at 148-150’. Not limy. 151.3’: 1 cm x 3 mm coalized plant fragments.

151.4 158.2 gradations top and bottom to coarse sst, colour as above, massive to very faintly bedded; grains are close packed, well sorted but poorly rounded, 70% quartz, 20% feldspar, 10% dark green rock grains, scattered muscovite on bed partings. 1-2 mm thick discontinuous coal at 157.2-.6 at 78° and at 160.5’ at 53°.

158.2 164.0 medium sst, nearly massive, colour as above.

		At 163.0′: 12 mm thick band at 88°, along beds, with 60% pyrite, 40% coal.
164.0	172.7	coarse sst, massive; encloses one 1 cm grey shale clast; upper contact is gradational; lower is sharp at 65°. 164.1′: <1 mm coalized film at 78°.
172.7	175.2	medium sst, colour as above, massive to 174.4, then faintly laminated, with <1 mm carbon films at 85°.
175.2	175.7	coarse sst, massive
175.7	187.1	medium sst, very faintly laminated, grading downward to massive, except for carbon in 1 mm laminations at 3 mm to 5 cm spacing at 178.7-179.9, at 80°. 145.5-147.0′: two bed partings, 30 and 12 cm spacing Solid core at 147.0-151.5, 151.5-156.5, 156.5-159.1. At 159.1′: one 1/2 cm thick slice; then core pieces 51, 14, 5, 47, 20, 4, 20, 56 cm. 166.5-171.5: solid core. 171.5-176.5: core pieces 58, 9, 23, 6, 2, 4, 16, 26, 2 cm 176.5-181.5′: core sections 28, 36, 56, 76 cm 181.5-186.5′ and 186.5-187.1′: solid core
187.1	191.7	Grey sltst grading downward to black claystone.
187.1	187.3	4 cm of grey plastic clay (wet N5.5/)
187.3	190.0	massive grey (dry 5.5/; wet N3/) clayey siltstone, coherent but soft. 187.4, .6′: two irregular stepped joints at 40 and 80°, 150° counterclockwise from the set below. 188.8-189.4′: five planar joints at 2-3 cm spacing at 38 to 54°. 189.5-.7′: one stepped joint at 42 and 23°, 180° from the joints above; also other incipient joints as the core dries.
190.0	191.7	dark grey (wet N3/) mudstone. Bed partings at 82° at 1-10 mm spacing. Light grey plastic clay bands parallel beds, 2 cm 190.6′, 4 cm at 190.7-.85, 1.5 cm at 191.5, 4 cm at 191.7-.85.
191.7	196.2	Grey-green coarse sst, massive except for orientation given by six 1-2 mm thick x 1 to >5 cm long black mudstone rip-ups. 1/2 cm at 191.7′ is cemented by >10% pyrite. Also scattered pyrite <1 mm grains through sst; in some places there are several along a “bed”. At 195.0′: one 1 x 1.5cm solid pyrite nodule. Last 5 cm is slightly darker, medium sst. This unit forms one solid core piece.
196.2	198.5	Interbedded dark grey (dry N.5/; wet 5GY5.5/1) sltst, light grey very fine sst, and light grey medium sst (both sst: dry N6.7/; wet more grey than 5GY4.5/1); not limy. Ten bed partings (8 at 196.5-197.2), coated by dark grey silt films.
196.2	196.8	60% dark grey <1 mm laminated sltst and 40% fine sst with black silt laminae. “Climbing ripple” at 196.35: a ripple deformed by loading at 196.4′. Beds at 88°.
196.8	197.0	medium sst with dark grey sltst as 3 mm x >10 mm plates plus many 1 x 2 mm grains. Scour at base.
197.0	197.1	dark grey very fine sltst.
197.1	197.3	medium sst with dark sltst clasts. Tongues of sst appear to have injected sltst above and below.
197.3	197.4	Lenses of medium sst, dark grey sltst and very

	fine sst.
197.4 198.5	Thin bedded fine sst with <1 mm thick dark grey silt laminae (plus possible plant debris); muscovite disseminated along beds; beds are lensy, with some classic climbing ripples.
198.5 211.5	Gradation at top to interbedded non-limy green grey fine sst and medium sst; progressing downward to more massive medium sst with local coarse sst and one 11 cm bed of slightly limy granule conglomerate. Sst colour: dry 5GY 6.5/1; wet more grey than 5GY 4.5/1. Beds: 73° at 199′; 90° at 206′; 84° at 210′. 206.5-210.5 was solid core; only 5 bed partings in rest of section, at 19 to 50 cm spacing.
198.5 199.5	Interbedded 1 to 5 cm fine sst with black sltst and carbon films, and 1 to 4 cm medium quartz-feldspar sst, more massive. At 199.5: 4 to 10 mm thick lenses of solid pyrite along edge of a 1 mm carbon layer.
199.5 202.3	coarsening downward medium and coarse sst, becoming all coarse after 200.8′. Massive to faintly bedded at 80°. At 199.7′: 1.5 x >3 cm dark grey sltst clast; also a few <1 cm clasts. 200.2: pyrite disseminated along one 1 mm “bed”.
202.3 203.1	nearly massive medium sst.
203.1-.5	granule cgl; few <6 mm clasts of white leucogranite; grains of quartz, reddish feldspar, green metavolcanic?. few of jasper: few <1mm coal grains; slight calcite in matrix of cgl. Up to 60% pyrite in a 1 x >6 cm lense; also one 4 mm nodule, and other disseminated grains.
203.5 209.0	green grey medium sst, nearly massive, with 1 to 3 cm thick beds and lenses of coarse sst at 206.0-207.0. At 209.0′: base of a coarse sst bed. 204.9, 205.0′: 3 mm x >5 cm lenses elongated parallel to beds have 40% pyrite between sand grains.
209.0 211.5	medium sst, nearly massive, with a few grey-green sltst pebbles and a few <1 mm grains of coal.
211.5 217.0	dark red-maroon (dry 10R 4/1; wet 10R 3/1) non-limy sltst with 10 to 40% irregular 1 to 10 cm green (dry 5GY 6/1; wet 5GY 5/1) patches. 30% 1 cm patchy yellow ochre in last 35 cm (roots?). At least 15 partings sub-parallel to beds, spaced 6 to 10 cm, plus a network of incipient irregular cracks at 20 to 40°, spaced 2 to >5 cm. 211.5′: 1.5 cm of grey plastic clay. 215.45-.7′: 6 cm of light green plastic clay 216.5′: >1 cm red to green plastic clay seam at 40°
217.0 220.3	Interbedded non-limy dull dark maroon (dry 2.5YR 4.5/1; wet 2.5YR 3.5/1) very fine to fine sst in 5 to 15 cm beds, and 2 to 26 cm units of medium to very coarse speckled dark and light grey-maroon (dry 2.5YR 5/1; wet 2.5YR 3.5/1) sst, poorly sorted and with a few <4 mm white leucogranite clasts, also various dull green and yellow-brown metavolcanic? clasts; also < 1 mm grains of pale yellow green soft altered epidote or serpentinized olivine; also dark red-brown sltst rip-ups and coalized plant fragments; muscovite on bedding partings. Beds 90° at 218.5′. Cross beds at 56° are 5 cm high in coarse sst at 218.5-.7 Dark maroon fine sst at 217.0-.3, 218.2-.5, 219.6-

		.75, 219.8-220.3. Very coarse sst at 217.3-.6, 219.4-.6; the rest of the section is speckled coarse sst. Four bedding partings. Sharp lower boundary at 83° of dark maroon fine sst-sltst against coarse sst below.
220.3	226.5^{+}	Green-grey (dry: greener than N 6/; wet greener than N 4.5/) very coarse sst with lenses of granule cgl to 222.8′; then dominantly granule cgl, becoming coarser and more friable downward; not limy; white kaolin or illite in matrix of close packed sst, especially in lower part. Abundant quartz, feldspar, green chloritic schist, red-maroon rock chips in granule cgl; also a few <1 mm grains of soft yellow-green altered epidote or serpentine after olivine. Beds: 80° at 222′. Five bed partings to 224.9; core broken in five <5 cm pieces to 225.9; then coherent but friable.
226.5^{+}	227.(0)	Mechanical drilling problems led to the grinding of some core in this position; there are also a few polished core ends at 227.7′ and 228.0′.
227.(0)	249.9	Mostly maroon clayey siltstone, silty very fine sandstone and fine sandstone (flood plain deposits and possible soils with roots or burrows).
227.(0)	228.1	dull dark maroon (dry 2.5YR4.5/1; wet 2.5YR 3.5/1) sltst and claystone; dull grey green patches after 227.8 Six bed partings at 3-6 cm spacing; other incipient partings as core dries, especially at 227.4-.55 at 2-5 mm spacing. Joint at 40° at 227.2′, truncated upwards on a bed
228.1-.8		patchy dull grey-green with dark maroon remnants in fine sst with significant clay content; poorly cemented. Soft clay on some bedding planes at 228.6-.8′. 228.3: joint at 20°. Incipient cracks <5 cm apart at 20 and 35° as core dries.
228.8	231.2	dark dull maroon (dry 2.5YR 3/1; wet 2.5YR 4/1) massive fine sst, grading finer downward to 230.4; then red maroon sltst with <20% <1 cm thick lenses of brown porous fine sst (root/burrow filings?); irregular <1 cm thick dull green patches to 229.1. Seven bed partings at 5 to 12 cm spacing, except one 28 cm core piece. 228.8-229.2: net of incipient cracks as core dries at 1-2 cm spacing, parallel beds and at 20° to core axis.
231.2-.9		dark maroon (as above) clayey sltst; faint bedding laminations at 87°. Two bed partings at 6 and 8 cm; more incipient partings as core dries.
231.9	(237.7)	Interbedded dark maroon (dry 2.5YR 3.5/2; wet 2.5YR 3/2) sltst and very fine sst, mostly in few-cm thick units. Sharp base of a 25 cm thick very fine sst unit at 79° at 234.7′. Few % of rock is pale green reduced lensy very fine sst, <3 mm thick, 10 to 35 cm apart. 231.9-236.5: seven bed partings at 4 to 36 cm spacing. One joint at 48° at 232.5′. 236.5-237.7: eight bed partings, 1-8 cm apart. Smooth joint at 15° at 237.4-.8′. Irregular joint at <10° at 237.7-238.1

237.7	241.9	Old soil zone? Dark maroon (as above) clayey sltst, with a few % 1-2 cm irregular lenses and patches of dull green. Resembles above section but the bedding is disrupted by dewatering on healed fractures at <10°, especially at 239.0-240.2. Disrupted very fine sst <5 mm thick lenses at 238.0-239.2. Minor yellow ochre at 239.9-240.3, flanking pale green sections. <10% <3 mm calcite nodules and calcite on cracks at 240.2-241.2 238.0: <1 cm dark maroon plastic clay along bed. 240.3: <1 cm plastic clay along bed; lensy green-grey and dark maroon. 237.7-.9: incipient partings at <1 to >3 cm spacing at 0-10° 237.7-239.4: seven incipient bed partings at 65-70° as core dries; dark maroon clay on irregular joints at 0-10° and 70° (160° clockwise from beds) 239.4-240.2: solid core 240.2-241.7: seven bed partings at 2 to 12 cm spacing, plus incipient partings with clay coatings (by dewatering?) at 0-10°. 241.7-.9: two bed partings with clay coatings, 2 and 6 cm apart.
241.9	244.7	dark maroon (as above) silty fine sst in 1-6 cm beds, interbedded with sltst in 1-7 cm beds. Some sst beds have sharp bases, others grade downward to sltst. Sst is arkosic, with 20% green rock grains. Several <1 mm seams of clay cross sst at 30° (from dewatering?). 243.8-244.7: bedding is disrupted; <1/2 mm clay seams at 25 and 70°, plus some irregular ones; few pale green <1 x 3 cm patches in fine sst Twelve bed partings spaced 1 to 20 cm (core pieces are 1.5, 20, 2, 3, 8, 1, 10, 4, 1, 3, 13, 2, 3 cm) 242.0, 242.9, 244.4: 1/2 to 1 cm maroon plastic clay plus sand along beds. Beds: 88° at 139.8'.
244.7	246.4	dark maroon sltst with disrupted very fine sst lenses; 20% pale green reduction patches; at 245.0-246.4 with 10% 5-10 mm calcite nodules. Dark maroon clay films on rims of calcite, and a few films along and crossing beds (by dewatering?) Bed partings bound 30, 4, 14 cm core segments.
246.4	247.3	dark maroon (dry 2.5YR 4.5/1; wet 2.5YR 3/2) clayey sltst. Beds at 86° Incipient bed partings at <5 mm. One irregular joint at 0-5° with green reduction.
247.3	249.2	dark maroon sltst grading downward to very fine sst; pale green reduction at 248.1-.6. 30% 1-2 cm white calcite nodules at 247.9-248.5; also a few to 249.2. Bed partings bound core pieces 11, 7, 10, 5, 24 cm Globular incipient parting throughout. 1-2 cm sst surrounded by 1-2 cm sltst at 248.6-249.2. At 247.3-.6: two joints at 15°, 50° apart
249.2	-.9	dark maroon clayey sltst. Incipient bed partings at 1 to 15 mm, and irregular clay-coated cracks at 10-30° and 60-70° at <2 cm spacing.

249.9 256.3 Interbedded green-grey medium sst and dark maroon very fine sst and sltst.

249.9 251.3 green-grey (dry greyer than 5GY 4/1; wet 5GY 5.5/1) laminated to banded medium sst, arkosic with green lithic grains; dull maroon shades in less sorted beds. Green reduced in >5 cm patches with clayey matrix, across the beds. Minor calcite in some 1-3 cm beds. At 250.8-251.3: local very limy cement; upper edge is not parallel to beds. Solid core

251.3 252.0 dull grey-green-maroon laminated to banded medium sst, less well sorted than above; muscovite scattered on bedding; few % dark maroon silt films <1/2 mm x 2 cm. Limy cement at 251.4-252.0
One bed parting. Beds at 86°.

252.0 254.6 dull maroon (dry 5YR 4/1; wet 5YR 3.5/1) medium sst, poorly sorted; few % <1/2 x 3 mm to > 4 cm long maroon sltst rip-ups. Some 1-5 cm thick beds of better sorted, slightly coarser medium sst with green shading. Calcite cement at 253.2-.6, 254.3-.6. Irregular <2 x >5 cm green reduced patches in maroon sections; <5 mm grey-white limestone nodules are mainly within these green sections at 252.5-.9, 253.6-.8, but a few are within 3 cm beyond them.
One bed parting.

254.6 256.3 dark maroon sltst, changing downward from well to faintly laminated; scattered muscovite on beds. 254.6-.7: <1 cm x >2 cm lenses of green sltst; <3 mm x <2 cm grey white limestone lenses.
Two <1 cm thick green-grey medium sst beds at 255.9-256.1. Beds at 88°.
Eight bed partings, plus many 1/2-2 cm incipient partings, some connected by incipient cracks at 50°-70°. Joint at 52° at 255.0′.
Upper contact is sharp; lower contact is gradational.

256.3 281.5 Green-grey (dry greyer than 5GY 5.5/1; wet greyer than 5GY 4/1) medium arkosic sst, mostly faintly bedded, well sorted, mostly not limy; muscovite on partings. White calcite cement in 1/2 cm spots and >6 cm patches crossing beds at 260.4-.8. At 261.2, 261.8, 262.8, 270.9: <1 cm x up to >4 cm ovals of calcite cement, elongated along the beds.
256.3-257.1: many maroon fine sst laminations, mostly <1 mm (rarely 2 mm) thick; a few such laminations to 265.0. Laminations mark <3 cm high low-angle cross beds at 256.7 and 262.8′.
265.0-276.2: sst is slightly coarser, nearly massive, some quartz and feldspar grains to 1 mm.
276.2-278.3: traces of carbonized plant debris parallel beds gives a faint layering. 278.3: gradation to nearly massive sst, with a few 1-2 mm quartz and feldspar grains after 280.1′.
280.5-.7: granule cgl with close packed quartz, feldspar, <5% green metavolcanic? clasts; few jasper and pale green altered epidote or serpentine grains; <1 mm x >2 cm soft grey sltst rip-ups. At 281.0′: up to 2 mm thick lenses of coalized plant debris.
Scour at base of sst at 281.5 has 2 cm relief.
Rock cored in 5 foot solid pieces at 265.5-276.5; bedding partings at 278.8 and 281.0.

281.5	282.8	Massive grey (dry slightly greener than N5.5/; wet N3/) sltst, very fine mica on partings. Beds at 88-90°. 282.4-on: <3% <2 mm disseminated pyrite grains, and pyrite on a joint at 10° at 282.5'. 1 to 3 mm thick pyrite along beds at 282.5, 282.8. At 1/2 cm above 282.8: 1/2 cm thick grey medium sst bed has <3 mm pyrite aggregates. 282.8: 1/2 cm soft grey clay on a fracture at 60°. Five bed partings, 4 to 6 cm apart. Incipient partings at 1 to 1.5 cm spacing along and across beds (like a brick wall). 281.5-.7: two joints at 40 and 50° cross each other, 170° rotation (around core axis) apart.
282.8	284.9	Grey medium sst composed of quartz and feldspar, minor lithic grains. 282.9-283.4: grey sst has interweaving coalized plant films spaced at 0.3-1.5 cm. Up to 6 x 12 mm pyrite nodules at 283.0. Few disseminated pyrite grains at 283.0-.6 and 284.0. 283.4: 1 cm x >5 cm coal lense with specks of pyrite. 285.5-.6: thin carbon films along beds at <1 mm spacing. 284.1: 1 x >3 cm lense of soft dull grey-green claystone (rip-up clast). 282.9-283.4: four bed partings; 283.4-284.9: solid core.
284.9	285.5	Grey granule cgl with <3 mm quartz and white to pale salmon feldspar, <5% dark green lithic grains, few grains of jasper, pale green altered epidote or serpentine; 10% rip-ups <0.6 x 2 cm of soft dull grey claystone. 3-6 mm at base is permeated by pyrite, flanking a coal lense >4 mm thick.
285.5	292.7	Grey medium sst, coarse sst and granule sst.
285.5	288.9	Grey medium sst with <1 mm coal laminations and <5 mm pyrite nodules to 285.8, grading at 286' to massive grey speckled coarse sst, 10% dark green lithic grains, few grains of jasper and pale epidote or serpentine; <2% soft grey claystone clasts <2 mm x 15 mm. Limy cement at 285.7-286.2.
288.9	289.6	To 289.2: 20% clasts of dark grey claystone to 0.8 x >5 cm, plus a few dark olive green claystone clasts <0.5 x >3 cm in granule coarse sst. Granule sst continues to 289.6, with 10% <0.2 x 2 cm clasts of grey to black claystone; few jasper granules, <1 mm epidote/serpentine grains; some quartz-feldspar granules appear to be gneissic leucogranite.
289.6	292.7	grey massive medium sst; sharp base. One bed parting in grey claystone clast at 288.9; also bed partings at 291.3, 291.5, 292.2 at 90°
292.7	293.2	Massive grey (dry greener than N5/; wet N3/) sltst. One bed parting. Other incipient joints as core dries: <3 mm spaced partings parallel beds; <1.5 cm spaced cracks across beds (like a brick wall). Two joints at 48°.
293.2	316.5	Grey granule cgl, cores sst, medium sst.
293.2	-.4	granule cgl, < 3mm green claystone chips, <2 mm quartz and white to reddish feldspar, fine mica and black probable carbonized plant films on the three bed partings.

293.4	297.3	grey medium sst, not limy, laminated by films of carbonized plant debris, up to 5% of rock, especially at 294.5-296.3. >10% pyrite in matrix in first 5 mm at 293.4; few <2 mm pyrite grains throughout sst. Solid core to 295.8; partings at 296.2, 296.9.
297.3	303.4	To 299.5: non-limy interbedded 1/2 to 5 cm grey speckled porous coarse sst and 1 and 4 cm grey medium sst. Especially porous at 297.4-303.4. 299.5-303.4; coarse sst with faint grain size banding; speckled by quartz and brownish to orange brown feldspar, few grains green altered epidote or serpentine. 1 cm bed at 299.8, 1/2 cm bed at 301.5 with 10% pyrite. Pyrite nodules < few mm at 301.25, .4. Bed partings at 301.5, 303.4'.
303.4	310.5	grades to massive porous coarse medium and fine coarse composed of quartz, 20% feldspar, 10% green chloritic? rock grains, few epidote/serpentine. Especially porous at 305.8-310.4 At 305.7: 1 x 2 cm patch with pyrite in matrix. 310.4-.5: <2 mm thick carbonized plant films at 82°. One bed parting at 307.7'.
310.5	313.0	Massive medium sst, more porous near base. Bed partings at 310.7, 312.2, 312.3.
313.0	314.2	Grey interbedded medium and coarse sst in 1-3 cm units, becoming coarser downward. At 313.8, .9: <1/2 x 1 cm pyrite nodules. At 314.0: 2 cm bed with 20% pyrite flanking <2 mm thick lenses of coalized plants. Bed partings at 313.9, 314.0.
314.2	316.5	porous granule and pebble cgl, except 315.0-.5 which is coarse sst. Cgl clasts are supported by coarse sst. Clasts are dull grey claystone, grey to red-brown quartzite?, feldspar and quartz. Few >3 mm pyrite grains at 315.0, 315.9-316.3. 314.2: >10% pyrite in 1 cm bed in coarse granule sst with <2 mm thick lenses of coalized plants. 314.6-.7: 3 cm thick x >5 cm coal and pyrite. Bed partings at 314.3, 314.7.
316.5 feet		Hole terminated for budgetary reasons. All rocks encountered are assigned to Upper Carboniferous, Pictou Group, Richibucto formation, deposited in fluvial channels and on flood

Riverview, NB

R-OW1 Observation Well Drilled on **Pine Glen Road, NB** for the Town of **Riverview**.

UTM Co-ordinates 5092372 Northern 20 360102 Eastern(by hand held 12 channel GPS unit; 8 satellites, 1.5 minutes averaging).

Vertical 6” diameter hole; 8” PVC casing to 18 feet below surface, 4 ½ ft protective metal casing with well cap.
Drilled by Walter Chappell Well Drilling Ltd. Of Moncton, N.B., On 7 August, 2002.

Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.

Logged by Forrest Carter BSc., ET, of ADI limited, Moncton. Cuttings were collected at 10 foot intervals into Zip-Lock bags. This log is based on cuttings retained during washing on a kitchen sieve with 1.2 mm square openings. Additional comments are from notes during the drilling.

From	To	Depths below ground level
feet	feet	
0.	10	Overburden: glacial till, clayey, reddish
11	20	Green-grey sandstone, some broken grey shale with trace quartz
21	30	Light brown to grey siltstone, some sandy siltstone
31	40	Light grayish-brown sandy siltstone Approximately 10 gal/min water flow rate.
41	50	Light brown to mostly grey sandy siltstone
51	60	Grey silty sandstone
61	70	Grey silty sandstone
71	80	Grey sandstone with less grey silt, Manganese seam (dark grey sheen on water’s surface) encountered at 75 ft
81	90	Grey sandstone with white and orange quartz, manganese still present
91	100	Grey sandstone with white and orange quartz, manganese still present
101	110	Grey sandstone with white and orange quartz, manganese still present, Approximately 50 gal/min water flow rate.
111	120	Grey sandstone with white and orange quartz, manganese still present, Grey shale encountered at 115 ft.
121	130	Grey sandstone with white and orange quartz. Approximately 100 gal/min water flow rate.
131	140	Grey sandstone with white and orange quartz. Trace grey shale present.
141	150	Grey sandstone with some reddish brown shale, manganese present.
151	160	Grey sandstone with some quartz conglomerate. Water become muddy, reddish brown. Mud and black shale present.
161	170	Grey sandstone with some red and grey shale. Manganese present.
171	180	Grey sandstone with some quartz conglomerate. Water become muddy, reddish brown. Manganese present.

181	190	Grey sandstone with some red and grey shale. Water become muddy, reddish brown. Manganese present. Major fracture at 185 ft, approximately 200 gal/min water flow.
191	200	Grey sandstone with some quartz conglomerate. Manganese present.
201	210	Grey sandstone with some red and grey shale. Manganese present.
210	220	Grey sandstone with some red and grey shale. Manganese present.
220		End of hole.

Salisbury #1, NB

S-OW1 Observation Well Drilled on Redder Road, **Salisbury NB**.

UTM Co-ordinates 5099502 Northern 20 340598 Eastern
(by hand held 12 channel GPS unit; 8 satellites, 1.5 minutes averaging).

Vertical 6" diameter hole; 6" diameter PVC casing to 18 feet below surface plus 3 ft, 8" diameter steel protective casing with well cap.

Drilled by Walter Chappell Well Drilling Ltd. Of Moncton, NB., On 7 August, 2002.

Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.

Logged by Forrest Carter BSc., ET, of ADI limited, Moncton. Cuttings were collected at 10 foot intervals into Zip-Lock bags. This log is based on cuttings retained during washing on a kitchen sieve with 1.2 mm square openings. Additional comments are from notes during the drilling.

From	To	Depths below ground level
feet	feet	
0.	15	Overburden: glacial till, clayey, reddish
15	23	Grey sandstone. Approximately 1 gal/min water flow rate
23	30	Brown siltstone
31	37	Brown siltstone
37	48	Grey sandstone with multicolored sandstone conglomerate. Approximately 15 gal/min water flow rate
49	60	Brown siltstone
61	70	Brown siltstone
71	80	Brown siltstone
81	90	Brown siltstone
91	102	Brown siltstone
103	108	Grey sandstone
109	120	Brown sandy siltstone to grey sandstone. Approximately 25 gal/min water flow rate
121	130	Grey sandstone with multicolored conglomerate
131	140	Brown siltstone with trace sand
141	150	Brown siltstone
151	160	Brown siltstone
161	170	Brown siltstone
171	180	Brown siltstone
181	190	Brown siltstone
191	195	Grey sandstone
196	205	Brown siltstone
205		End of hole.

Salisbury #2 NB

S-PW1 Observation Well Drilled on Redder Road, **Salisbury NB**.

UTM Co-ordinates 5099419 Northern 20 340445 Eastern
(by hand held 12 channel GPS unit; 8 satellites, 1.5 minutes averaging).

Vertical 6″ diameter hole; 8″ casing to 18 feet below surface with well cap.

Drilled by Walter Chappell Well Drilling Ltd. Of Moncton, NB.,
On 7 August, 2002.

Drilled for Geological Survey of Canada, Maritimes Groundwater Initiative.

Logged by Forrest Carter BSc., ET, of ADI limited, Moncton. Cuttings were collected at 10 foot intervals into Zip-Lock bags. This log is based on cuttings retained during washing on a kitchen sieve with 1.2 mm square openings. Additional comments are from notes during the drilling.

From	To	Depths below ground level
feet	feet	
0.	9	Overburden: glacial till, clayey, reddish
10	20	Grey-brown sandstone
21	30	Brown siltstone, some sandy siltstone
31	40	Brown siltstone with some sand Approximately 1 gal/min water flow rate at 35 ft.
41	50	Brown siltstone with some green siltstone.
51	60	Brown siltstone
61	70	Brown siltstone with some green siltstone
71	80	Brown siltstone
81	90	Brown siltstone with grey sandstone seam at 83-86 ft. Approximately 25 gal/min water flow rate
91	100	Grey sandstone to brown sandy siltstone
101	110	Brown siltstone
111	120	Brown siltstone with grey clay layer at 115 ft
121	130	Brown siltstone
131	140	Brown siltstone with trace sand
141	150	Brown sandy siltstone. Approximately 50 gal/min water flow rate
151	160	Brown siltstone
161	170	Brown siltstone with some green siltstone
171	180	Brown siltstone with some green and yellow clayey material
181	190	Grey sandstone
191	200	Grey sandstone with some quartz conglomerate
201	205	Brown siltstone
205		End of hole.

Part D

Quaternary sediment hydraulic testing

Surficial sediments were investigated within the framework of the MGWI project to evaluate their hydrogeological potential and their role in regional groundwater flow systems, in particular their influence on aquifer recharge. The Quaternary study was conducted in the Moncton region (New Brunswick) and covered about 1300 km². This local study includes the Petitcodiac and Memramcook valleys, which have the highest potential for hosting granular aquifers because of their thick Quaternary sediments fill.

To characterize the hydraulic properties of the confined units in the Memramcook valley, drilling was performed (see Figure D-1), tides were recorded, multiple piezometer nests were installed, and pumping and slug tests were conducted. A first nest of three (3) piezometers, one in each confined unit and one (1) in the middle aquitard, was installed 160 m from the Memramcook riverbank (wells #1, 2 and 3, Figure D-2). The second nest, with one (1) piezometer in each confined unit, was installed 25 m east from the first one (wells #5 and 6).

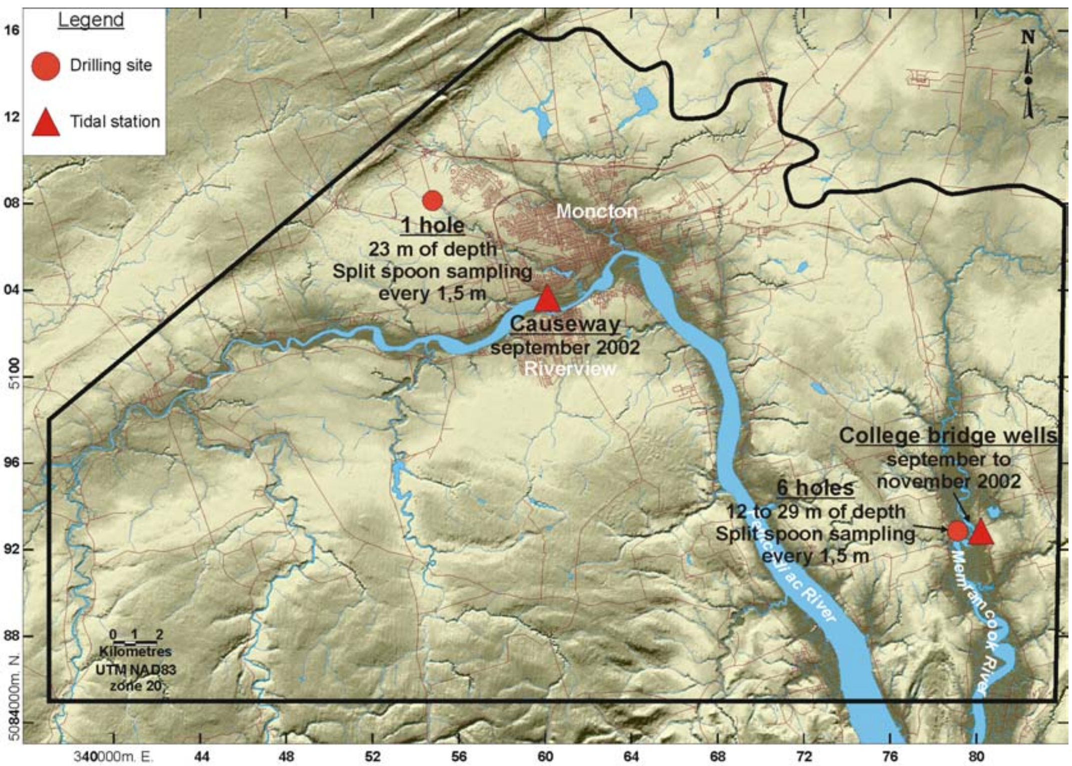


Figure D-1: Location of drilling sites and tidal stations

Pumping test results were interpreted for the pumping and the observation wells with the Theis (1935) solution and the Aqtesolv™ software because of the variable discharge rate of the pump. The tidal influence was recorded every five (5) min for the month of September 2002 for each confined unit, yielding a total of 55 tidal cycles. To interpret the watertable fluctuation, the Ferris (1963) and the Carr and van der Kamp (1969) methods were used. Because no tidal records are available for the Memramcook River, the interpretation was initially based on the Moncton causeway tidal data (Canadian Hydrographic Service, 2002) (Figure D-1) as the tidal source and on well 1 as the observation well. Differences between the timing and height of the tide in the Petitcodiac and Memramcook rivers caused incoherent results; the interpretation was thus based on well 5 as the tidal source and on well #1 as the observation well.

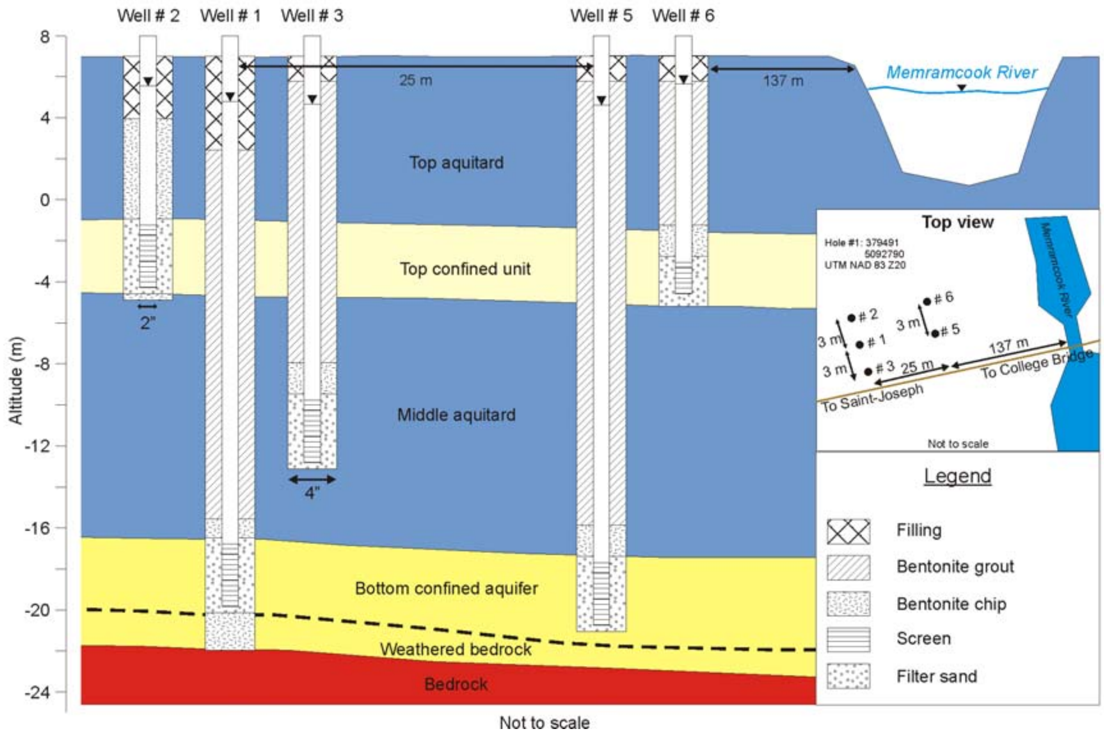


Figure D-2 : Piezometer installation in the Memramcook valley

Two (2) slug tests were carried out by removing water with a one (1) litre bailer in the Memramcook top confined unit, one (1) in the middle aquitard and five (5) in the bottom confined aquifer. Slug test results were interpreted with the Bouwer and Rice (1976) or Butler and Garnett (2000) methods depending on the type of response. Short-term pumping tests were also conducted in each confined unit with a Waterra pump. A discharge measurement was obtained every 15 min of the 86 min test in the top confined unit and every 30 min of the seven (7) hours test in the bottom confined aquifer.

Slug test results

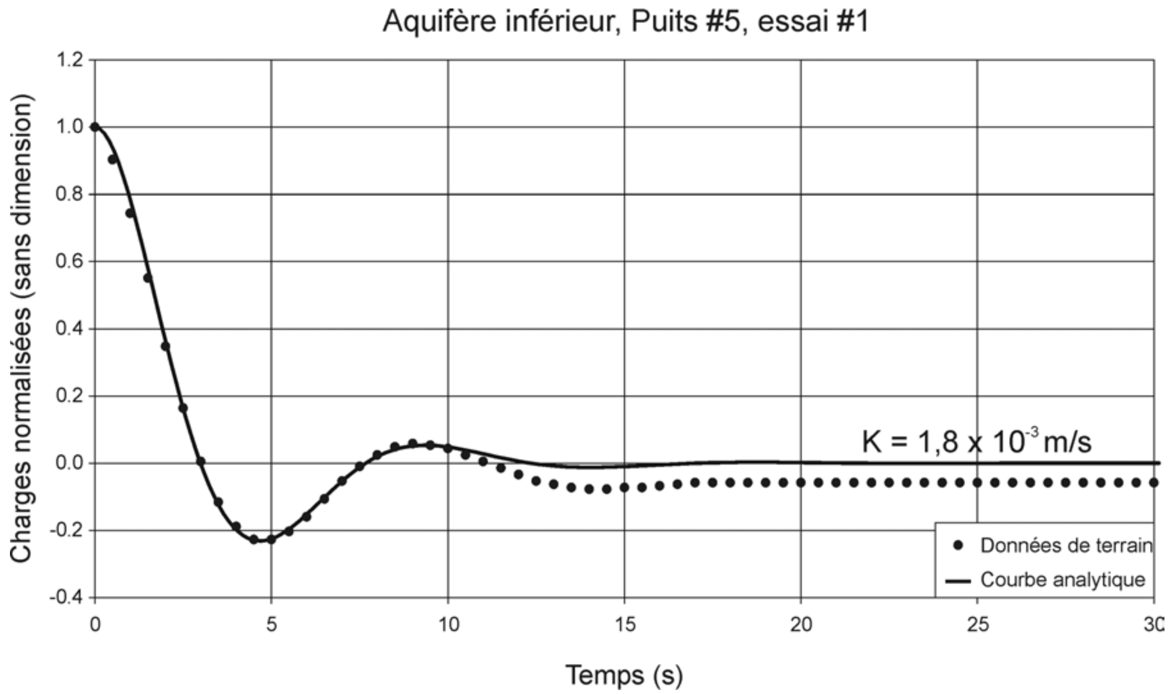


Figure D-3 : Slug test, lower aquifer, well #5, test 1

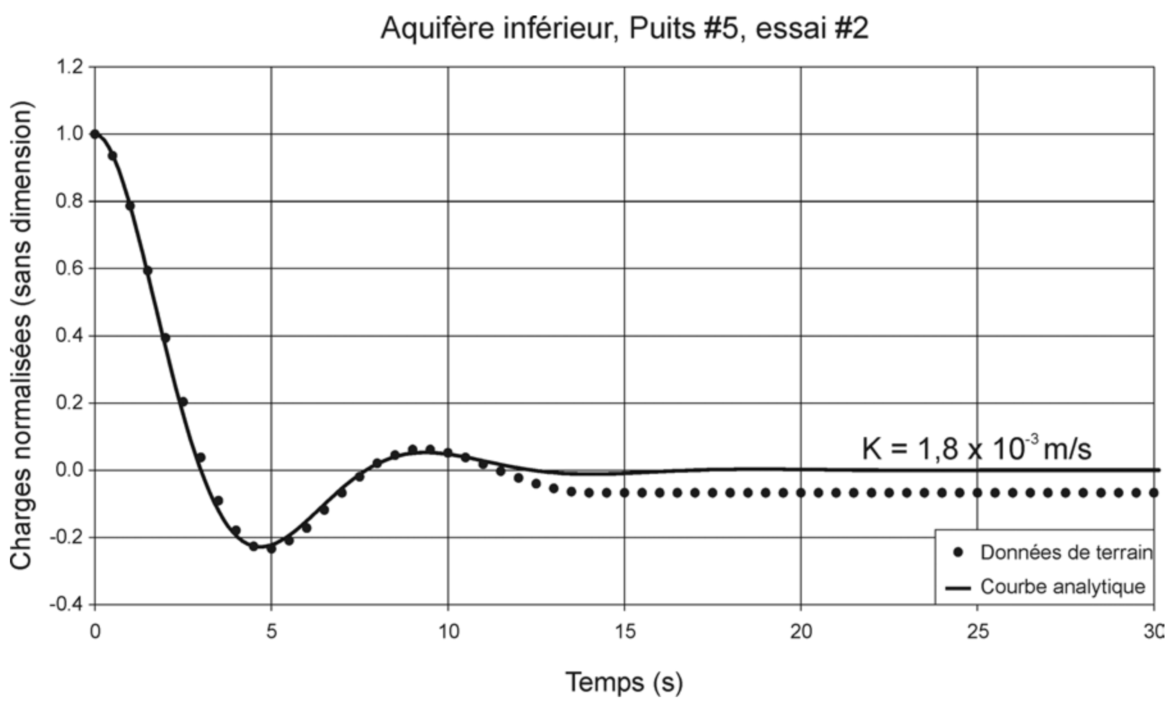


Figure D-4 : Slug test, lower aquifer, well #5, test 2

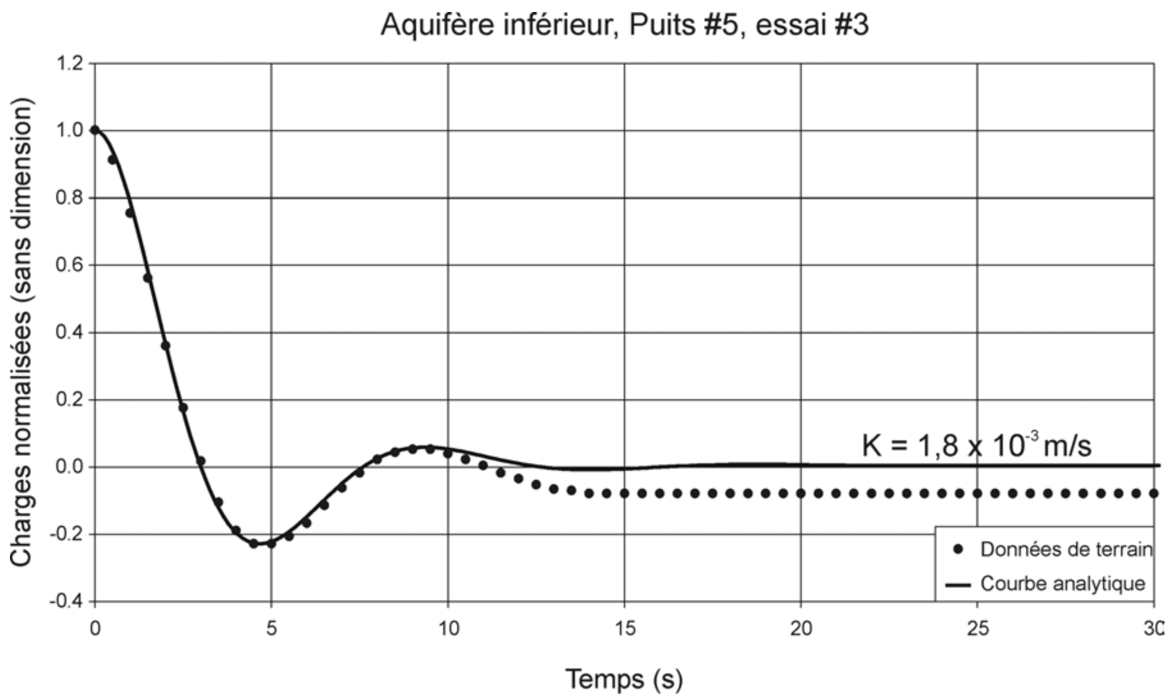


Figure D-5 : Slug test, lower aquifer, well #2, test 3

Aquifère inférieur, Puits #1, essai #1

Aquifère à nappe confinée - Calcul de la conductivité hydraulique

Bouwer and Rice (1976)

Localisation	**Rivière Memramcook**	**Puits d'observation**	**1**
Projet:	**MGWI**	**Test no :**	**1**

Description du forage

Rayon du tubage (**Rc**) :	0.0254	m	d/Rw =	60.00
Rayon du forage (**Rw**) :	0.0508	m	b/Rw =	66.00
Longueur de la crépine (**d**) :	3.048	m		

Longueur du toit de l'aquifère à la base

			A, B & C coefficients		
de la crépine (section ouverte) (**b**) :	3.3528	m		4 < d/Rw < 100	100 < d/Rw < 500
Épaisseur de l'aquifère (**D**) :	5.7912	m	**A =**	3.36	3.46
Porosité du sable filtrant :	0.3		**B =**	0.57	0.57
Rayon équivalent (**Rc'**) :	0.035011484	m	**C =**	3.10	2.97

si Lw < H (puits pénétration partielle)

A = 3.36

B = 0.57

ln (Re/Rw) = 2.81

si Lw = H (puits pénétration complète)

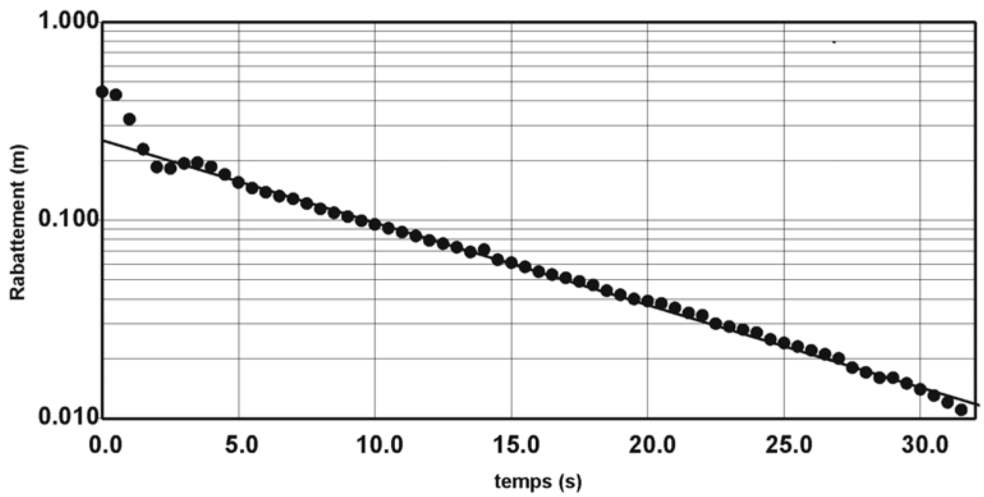
C = 3.10

ln (Re/Rw) = 3.18

Note: Re est le rayon théorique auquel aucune différence de charge n'est mesurée

INTERPRETATION

Date:	18-sept-02	Test fait par :	Vincent Boisvert	
Heure :	11h50	Niveau statique :	488.7	cm
		Rabattement initial calculé :	44.4	cm



CONDUCTIVITÉ HYDRAULIQUE

$$K = \frac{Rc^2 * \ln(Re/Rw) \quad \ln(Ho/Ht)}{2*d*t}$$

Ho =	0.26	m	ln(Re/Rw)=	2.81	
Ht =	0.039	m	Rc =	0.0254	m
t =	20	sec	Rc'=	0.0350	m
			d =	3.048	m

Conductivité hydraulique

si Rc K = **2.85E-05 m/sec** **si Rc' K = 5.41E-05 m/sec**

Aquifère inférieur, Puits #1, essai #2

Aquifère à nappe confinée - Calcul de la conductivité hydraulique

Bouwer and Rice (1976)

Localisation	**Rivière Memramcook**	**Puits d'observation**	**1**
Projet:	**MGWI**	**Test no :**	**2**

Description du forage

Rayon du tubage (**Rc**) :	0.0254	m	d/Rw =	60.00
Rayon du forage (**Rw**) :	0.0508	m	b/Rw =	66.00
Longueur de la crépine (**d**) :	3.048	m		

Longueur du toit de l'aquifère à la base

			A, B & C coefficients	4 < d/Rw < 100	100 < d/Rw < 500
de la crépine (section ouverte) (**b**) :	3.3528	m			
Épaisseur de l'aquifère (**D**) :	5.7912	m	**A =**	3.36	3.46
Porosité du sable filtrant :	0.3		**B =**	0.57	0.57
Rayon équivalent (**Rc'**) :	0.035011484	m	**C =**	3.10	2.97

si Lw < H (puits pénétration partielle)

A = 3.36

B = 0.57

ln (Re/Rw) = 2.81

si Lw = H (puits pénétration complète)

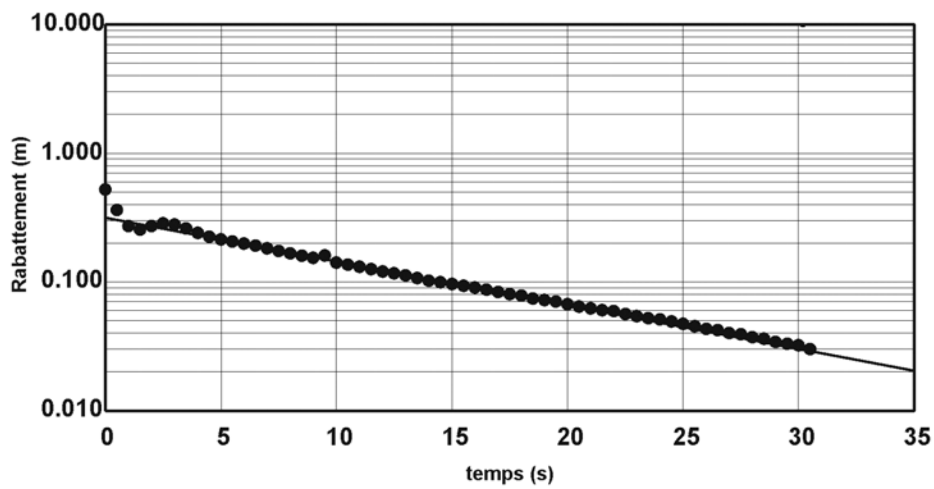
C = 3.10

ln (Re/Rw) = 3.18

Note: Re est le rayon théorique auquel aucune différence de charge n'est mesurée

INTERPRETATION

Date:	18-sept-02	Test fait par :	Vincent Boisvert	
Heure :	11h52	Niveau statique :	488.7	cm
		Rabattement initial calculé :	64.2	cm



CONDUCTIVITÉ HYDRAULIQUE

$$K = \frac{Rc^2 * \ln(Re/Rw) \quad \ln(Ho/Ht)}{2*d*t}$$

Ho =	0.32	m	ln(Re/Rw)=	2.81	
Ht =	0.067	m	Rc =	0.0254	m
t =	20	sec	Rc'=	0.0350	m
			d =	3.048	m

Conductivité hydraulique

si Rc K = **2.33E-05 m/sec** **si Rc' K = 4.42E-05 m/sec**

Aquitard central, Puits #3, essai #1

Aquifère à nappe confinée - Calcul de la conductivité hydraulique

Bouwer and Rice (1976)

Localisation	**Rivière Memramcook**	Puits d'observation :	**3**
Projet:	**MGWI**	Test no :	**1**

Description du forage

Rayon du tubage (**Rc**) :	0,0254	m	d/Rw =	30,00	
Rayon du forage (**Rw**) :	0,0508	m	b/Rw =	54,00	
Longueur de la crépine (**d**) :	1,524	m			

Longueur du toit de l'aquifère à la base			**A, B & C coefficients**		
de la crépine (section ouverte) (**b**) :	2,7432	m		4 < d/Rw < 100	100 < d/Rw < 500
Épaisseur de l'aquifère (**D**) :	11,5	m	**A =**	2,46	2,64
Porosité du sable filtrant :	0,3		**B =**	0,40	0,43
Rayon équivalent (**Rc'**) :	0,035011484	m	**C =**	2,09	1,89

si Lw < H (puits pénétration partielle)

A = 2,46

B = 0,40

ln (Re/Rw) = 2,34

si Lw = H (puits pénétration complète)

C = 2,09

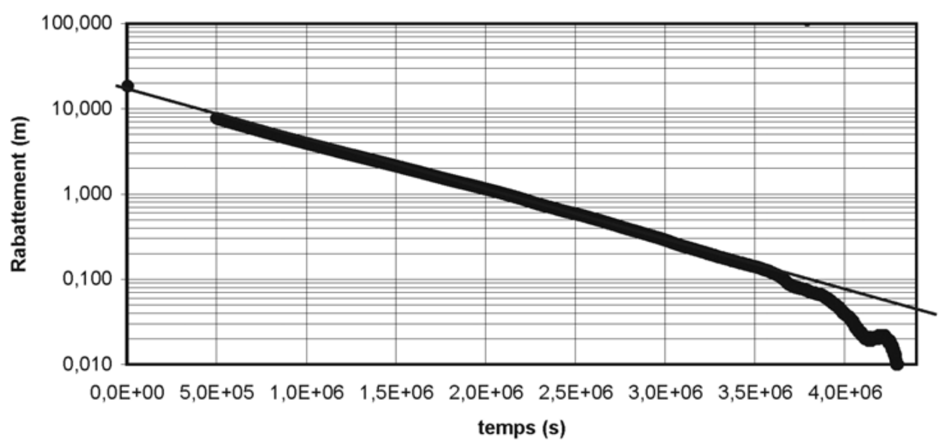
ln (Re/Rw) = 2,90

Note: Re est le rayon théorique auquel aucune différence de charge n'est mesurée

INTERPRETATION

Date:	16-août-02	Test fait par :	Vincent Boisvert	
Heure :	16:08	Niveau statique :	585	cm
		Rabattement initial calculé :	1835	cm

slug 3



CONDUCTIVITÉ HYDRAULIQUE

$$K = \frac{Rc^2 * \ln(Re/Rw) \quad \ln(Ho/Ht)}{2*d*t}$$

Ho =	17,00	m	ln(Re/Rw)=	2,34	
Ht =	0,16	m	Rc =	0,0254	m
t =	3,50E+06	sec	Rc'=	0,0350	m
			d =	1,524	m

Conductivité hydraulique

si Rc K = **6,60E-10** m/sec — si Rc' K = **1,25E-09** m/sec

Unité confinée supérieure, Puits #2, essai #1

Aquifère à nappe confinée - Calcul de la conductivité hydraulique

Bouwer and Rice (1976)

Localisation **Rivière Memramcook** — **Puits d'observation 2**

Projet: MGWI — **Test no : 1**

Description du forage

Rayon du tubage (**Rc**) :	0.0254	m	d/Rw =	60.00
Rayon du forage (**Rw**) :	0.0508	m	b/Rw =	60.00
Longueur de la crépine (**d**) :	3.048	m		

Longueur du toit de l'aquifère à la base

			A, B & C coefficients		
de la crépine (section ouverte) (**b**) :	3.048	m		4 < d/Rw < 100	100 < d/Rw < 500
Épaisseur de l'aquifère (**D**) :	3.3528	m	**A =**	3.36	3.46
Porosité du sable filtrant :	0.3		**B =**	0.57	0.57
Rayon équivalent (**Rc'**) :	0.035011484	m	**C =**	3.10	2.97

si Lw < H (puits pénétration partielle)

A = 3.36

B = 0.57

ln (Re/Rw) = 2.93

si Lw = H (puits pénétration complète)

C = 3.10

ln (Re/Rw) = 3.12

Note: Re est le rayon théorique auquel aucune différence de charge n'est mesurée

INTERPRETATION

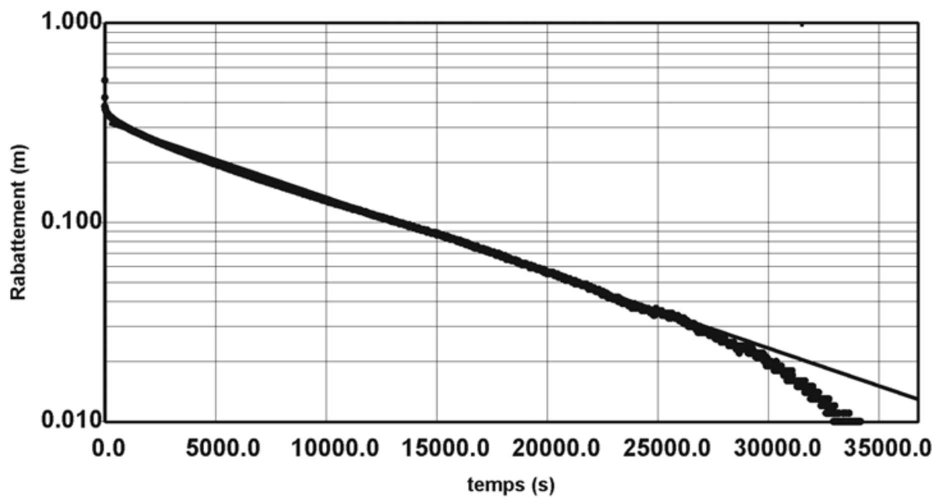
Date: 19-août-02

Heure : 21h45

Test fait par : Vincent Boisvert

Niveau statique : 545 cm

Rabattement initial calculé : 51.5 cm



CONDUCTIVITÉ HYDRAULIQUE

$$K = \frac{Rc^2 * \ln(Re/Rw) \quad \ln(Ho/Ht)}{2*d*t}$$

Ho =	0.31	m	ln(Re/Rw)=	2.93	
Ht =	0.087	m	Rc =	0.0254	m
t =	15000	sec	Rc'=	0.0350	m
			d =	3.048	m

Conductivité hydraulique

si Rc K = **2.62E-08 m/sec** **si Rc' K = 4.98E-08 m/sec**

Unité confinée supérieure, Puits #6, essai #1

Aquifère à nappe confinée - Calcul de la conductivité hydraulique

Bouwer and Rice (1976)

Localisation	**Rivière Memramcook**	**Puits d'observation**	**6**
Projet:	**MGWI**	**Test no :**	**1**

Description du forage

Rayon du tubage (**Rc**) :	0.0254	m	d/Rw =	30.00
Rayon du forage (**Rw**) :	0.0508	m	b/Rw =	54.00
Longueur de la crépine (**d**) :	1.524	m		

Longueur du toit de l'aquifère à la base de la crépine (section ouverte) (**b**) :	2.7432	m		4 < d/Rw < 100	100 < d/Rw < 500
Épaisseur de l'aquifère (**D**) :	3.3528	m	**A =**	2.46	2.64
Porosité du sable filtrant :	0.3		**B =**	0.40	0.43
Rayon équivalent (**Rc'**) :	0.035011484	m	**C =**	2.09	1.89

A, B & C coefficients

si Lw < H (puits pénétration partielle)

A = 2.46

B = 0.40

ln (Re/Rw) = 2.56

si Lw = H (puits pénétration complète)

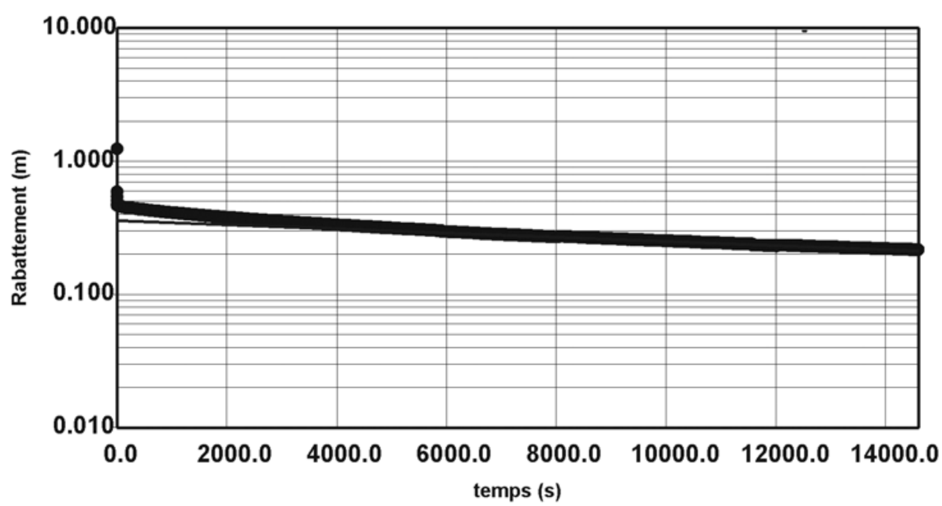
C = 2.09

ln (Re/Rw) = 2.90

Note: Re est le rayon théorique auquel aucune différence de charge n'est mesurée

INTERPRETATION

Date:	19-août-02	Test fait par :	Vincent Boisvert	
Heure :	8h49	Niveau statique :	587	cm
		Rabattement initial calculé :	124	cm



CONDUCTIVITÉ HYDRAULIQUE

$$K = \frac{Rc^2 * \ln(Re/Rw) \quad \ln(Ho/Ht)}{2*d*t}$$

Ho =	0.34	m	ln(Re/Rw)=	2.56	
Ht =	0.27	m	Rc =	0.0254	m
t =	8000	sec	Rc'=	0.0350	m
			d =	1.524	m

Conductivité hydraulique

si Rc K = **1.51E-08 m/sec** **si Rc' K = 2.87E-08 m/sec**

Pumping test results

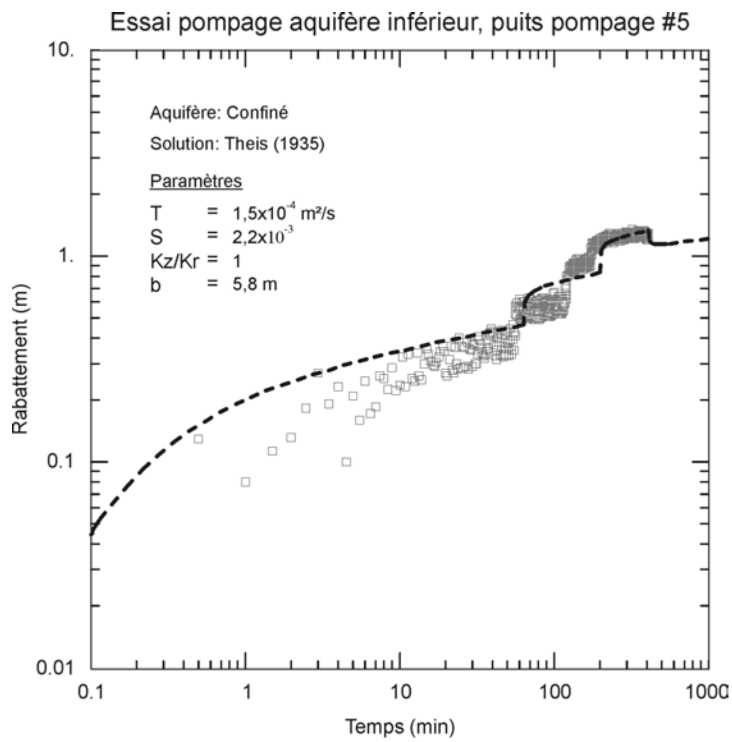


Figure D-6 : Drawdown vs time in the lower aquifer, pumping well #5

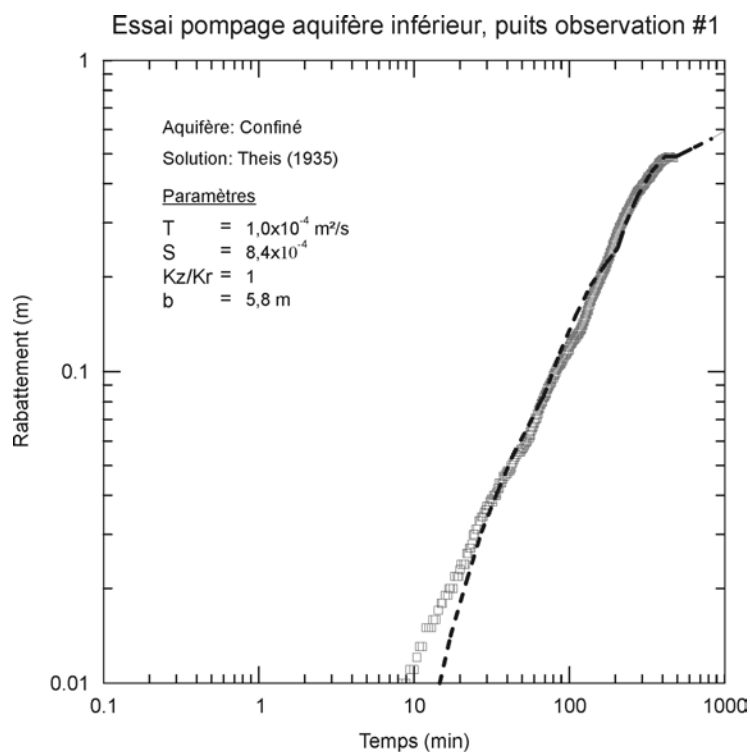


Figure D-7 : Drawdown vs time in the lower aquifer, observation well #1

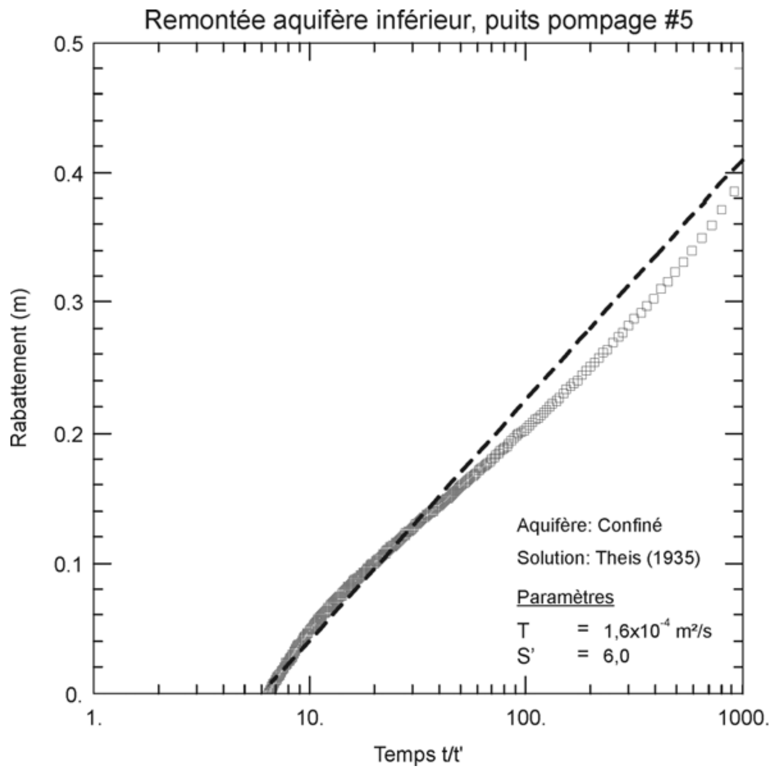


Figure D-8 : Recovery in the lower aquifer, pumping well #5

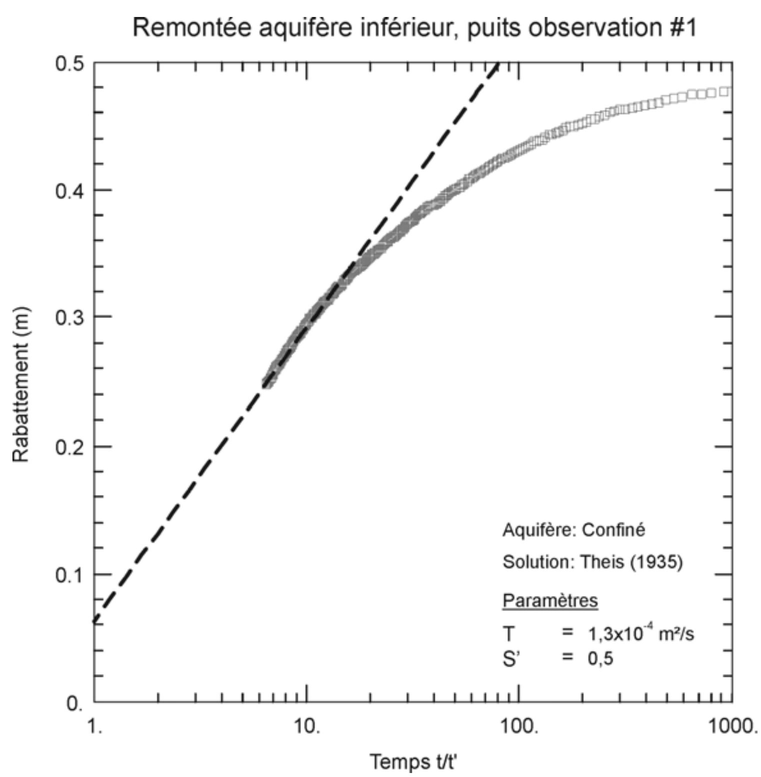


Figure D-9 : Recovery in the lower aquifer, observation well #1

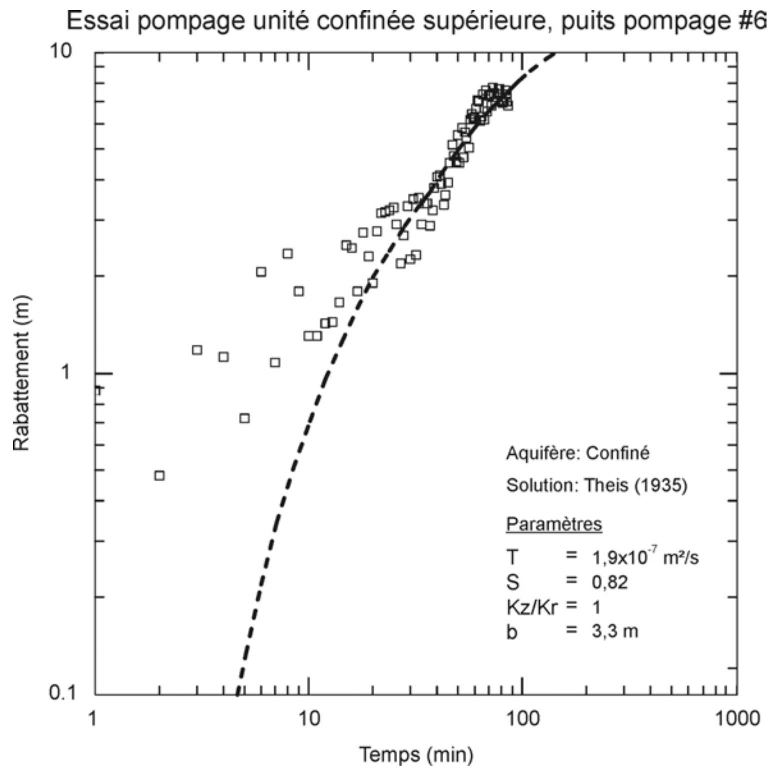


Figure D-10 : Drawdown in the upper confined unit, pumping well #6

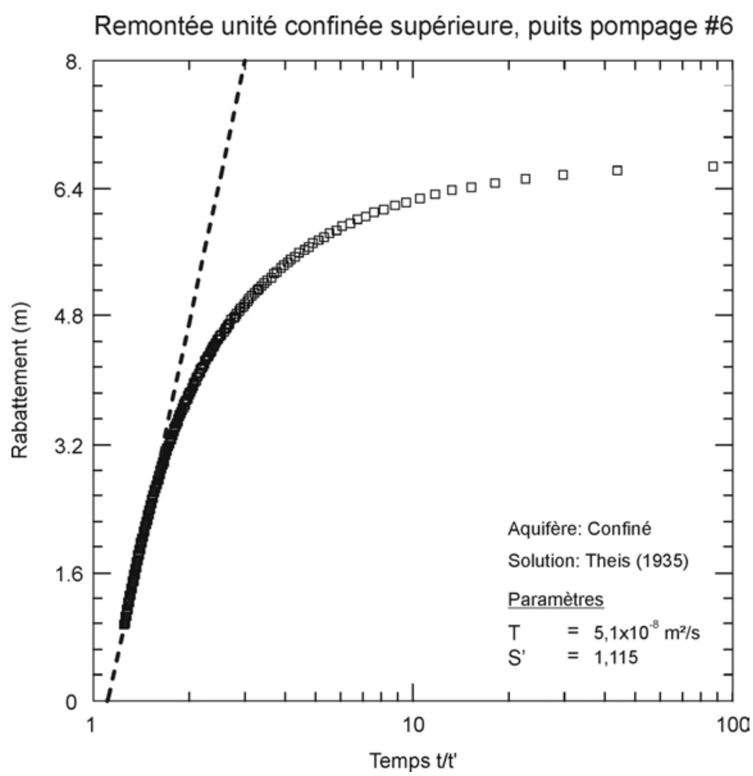


Figure D-11 : Recovery in the upper confined unit, pumping well #6

Tidal fluctuation monitoring

Propriétés hydrauliques **Puits #1**
Source: Petitcodiac causeway **Projet : MGWI**

Méthode de Ferris (1963)

Porosité effective (s) =	0,3			
Distance à la source (x) =	162	**m**		
Coefficient d'emmagasinement (S) =	1,5E-03			
	min	**moy**	**max**	
fluctuation de l'eau souterraine (Sr) =	0,01	0,05	0,10	**m**
Période de l'oscillation à la source (to) =	690,00	745,19	810,00	**min**
Fluctuation de la source (so) =	0,60	2,39	3,36	**m**
Délai entre la source et le puits (t1) =	120,00	228,11	350,00	**min**

Atténuation		**min**	**moy**	**max**	
Transmissivité		3,56E-03	**3,88E-03**	4,18E-03	**(m²/sec)**
Transmissivité	Millham et Howes (1995)	7,01E-02	**1,38E-01**	2,25E-01	**(m²/sec)**

Délai					
Transmissivité		3,07E-04	**8,37E-04**	2,66E-03	**(m²/sec)**
Transmissivité	Millham et Howes (1995)	6,14E-02	**1,67E-01**	5,33E-01	**(m²/sec)**

Méthode de Carr et van der Kamp (1969)

Porosité de l'aquifère q =	0,3		
Compressibilité de l'eau b =	4,80E-10	**m²/N**	Freeze et Cherry (1979)
Poids spécifique de l'eau g =	9800	**N/m³**	Freeze et Cherry (1979)
Délai de base (tb) =	0,44	**min**	
Distance entre la source et le puits (x) =	162	**m**	

	min	**moy**	**max**	
Période de fluctuation (p) =	690,00	745,19	810,00	**min**
Délai observé (to) =	120,00	228,11	350,00	**min**
Efficacité observée (TEob) =	0,30	2,09	5,67	**%**
Temps de réponse (tr) =	0,44	0,44	0,44	**min**
Temps corrigé (tc) =	119,56	227,67	349,56	**min**
Effet d'amortissement (A/A1) =	1,00	1,00	1,00	
Efficacité apparente (TEapp) =	0,30	2,09	5,67	**%**
Efficacité réelle (TEre) =	11,20	16,69	71,41	**%**

	min	**moy**	**max**	
Coefficient d'emmagasinement (S) =	1,41E-06	**1,75E-06**	4,94E-06	**m-1**
Conductivité hydraulique (K) =	5,2E-07	**9,31E-07**	2,55E-06	**m/s**

Propriétés hydrauliques **Puits #1**
Source: Puits #5 **Projet : MGWI**

Méthode de Ferris (1963)

Porosité effective (s) =	0,3			
Distance à la source (x) =	25	**m**		
Coefficient d'emmagasinement (S)	1,5E-03			
	min	**moy**	**max**	
fluctuation de l'eau souterraine (Sr) =	0,01	0,04	0,10	**m**
Période de l'oscillation à la source (to) =	545,00	741,51	920,00	**min**
Fluctuation de la source (so) =	0,01	0,04	0,10	**m**
Délai entre la source et le puits (t1) =	-100,00	23,09	165,00	**min**

Atténuation		**min**	**moy**	**max**	
Transmissivité		7,47E-05	**9,30E-05**	1,26E-04	**(m²/sec)**
Transmissivité	Millham et Howes (1995)	3,68E-02	**1,37E-01**	2,37E-01	**(m²/sec)**

Délai					
Transmissivité		3,36E-05	**7,60E-03**	4,08E-02	**(m²/sec)**
Transmissivité	Millham et Howes (1995)	6,71E-03	**1,52**	8,16	**(m²/sec)**

Méthode de Carr et van der Kamp (1969)

Porosité de l'aquifère q =	0,30		
Compressibilité de l'eau b =	4,80E-10	**m²/N**	Freeze et Cherry (1979)
Poids spécifique de l'eau g =	9800	**N/m³**	Freeze et Cherry (1979)
Délai de base (tb) =	0,44	**min**	
Distance entre la source et le puits (x) =	25	**m**	

	min	**moy**	**max**	
Période de fluctuation (p) =	545,00	743,64	920,00	**min**
Délai observé (to) =	-100,00	23,09	165,00	**min**
Efficacité observée (TEob) =	50,00	95,89	115,15	**%**
Temps de réponse (tr) =	0,44	0,44	0,44	**min**
Temps corrigé (tc) =	-100,44	22,65	164,56	**min**
Effet d'amortissement (A/A1) =	1,00	1,00	1,00	
Efficacité apparente (Teapp) =	50,00	95,89	105,56	**%**
Efficacité réelle (TEre) =	98,41	122,55	414,85	**%**

	min	**moy**	**max**	
Coefficient d'emmagasinement (S) =	2,82E-06	**3,12E-05**	9,74E-05	**m-1**
Conductivité hydraulique (K) =	4,40E-07	**1,54E-04**	1,43E-03	**m/s**

Since the regional groundwater recharge in the study area mostly takes place through a till sheet of variable thickness, hydraulic properties of the till were evaluated during the summer of 2002 with a Guelph permeameter and a double ring infiltrometer (DR). A total of eight (8) Guelph and three (3) DR tests were done in the silty till unit at two (2) different sites (Figure D-3). Three (3) Guelph and two (2) DR tests were also done in the sandy till unit and four (4) Guelph and one (1) DR tests in the silty-sandy till unit. Results of Guelph type and DR infiltration tests were interpreted with the Elrick *et al.* (1989) solution and then compared to obtain the best estimate of the hydraulic conductivity of the till.

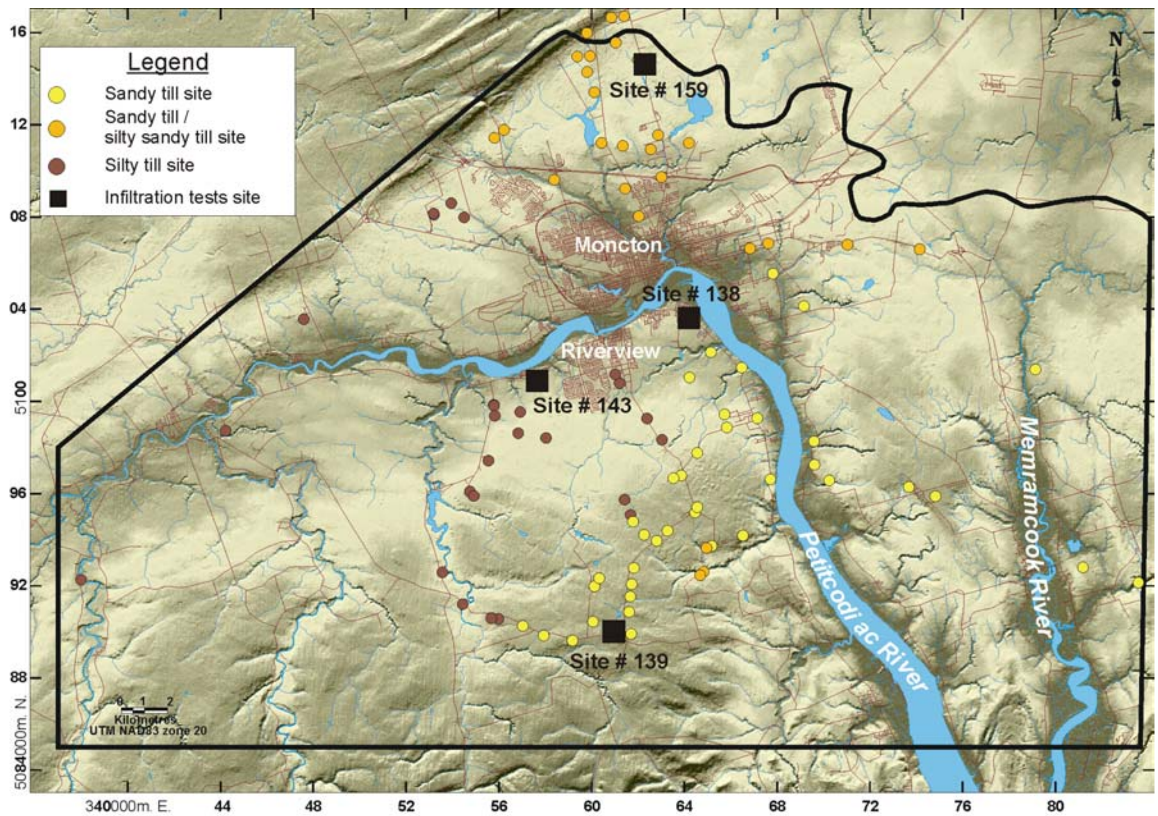


Figure D-12 : Location of till survey and infiltration test sites

Infiltrometer test results

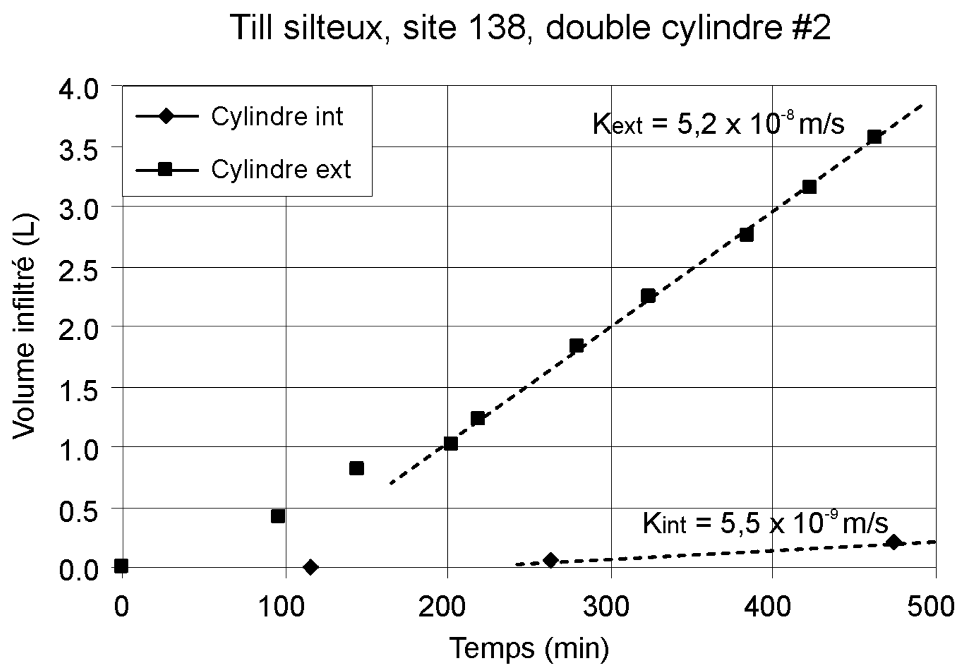


Figure D-13 : Infiltrometer test (DR#2), silty till, site 138

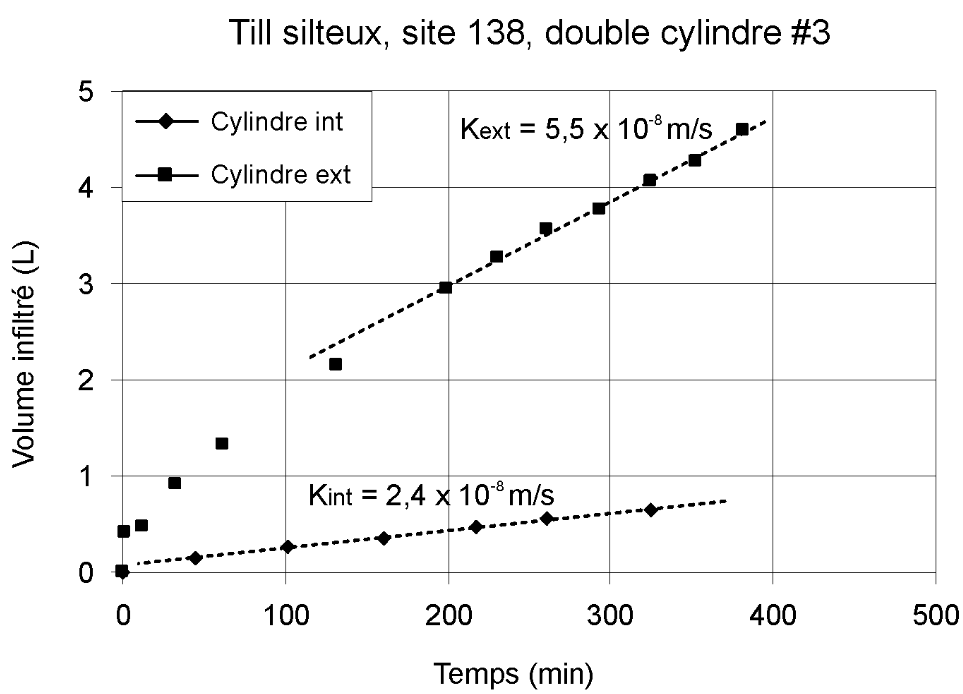


Figure D-14 : Infiltrometer test (DR#3), silty till, site 138

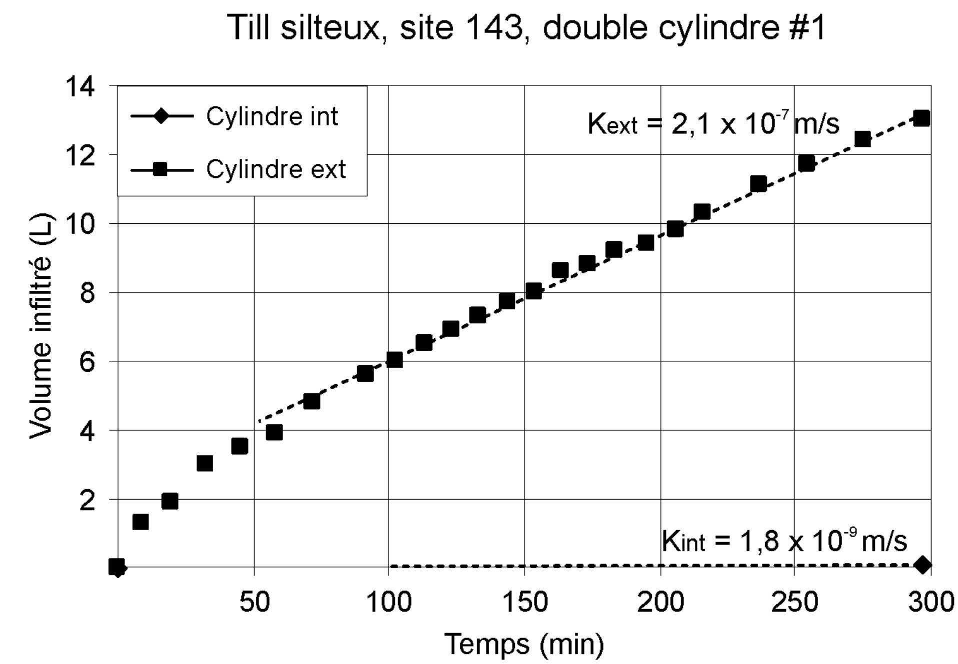


Figure D-15 : Infiltrometer test (DR#1), silty till, site 143

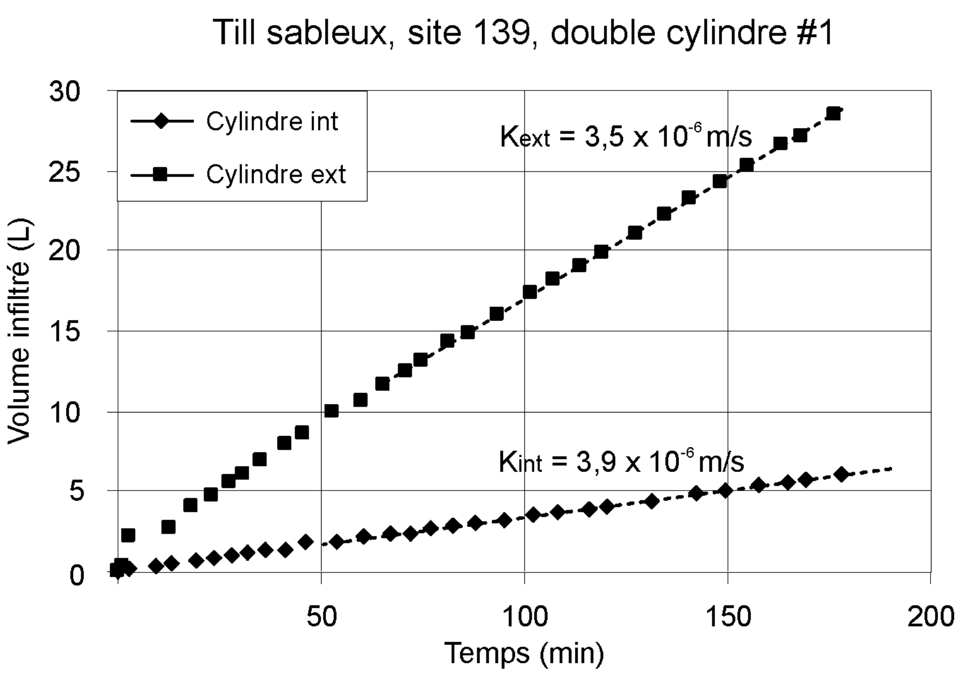


Figure D-16 : Infiltrometer test (DR#1), sandy till, site 139

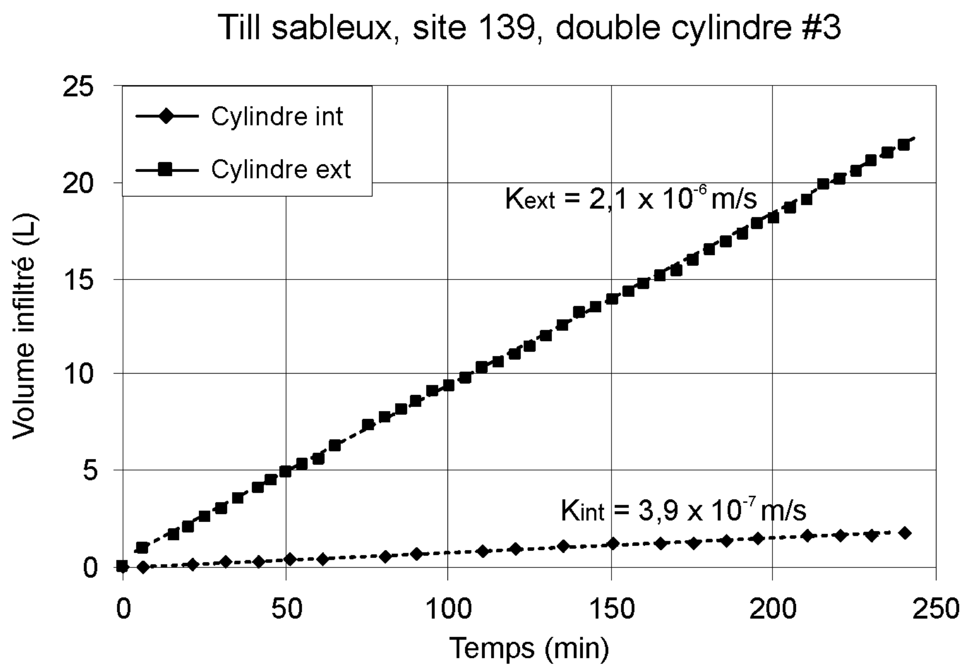


Figure D-17 : Infiltrometer test (DR#3), sandy till, site 139

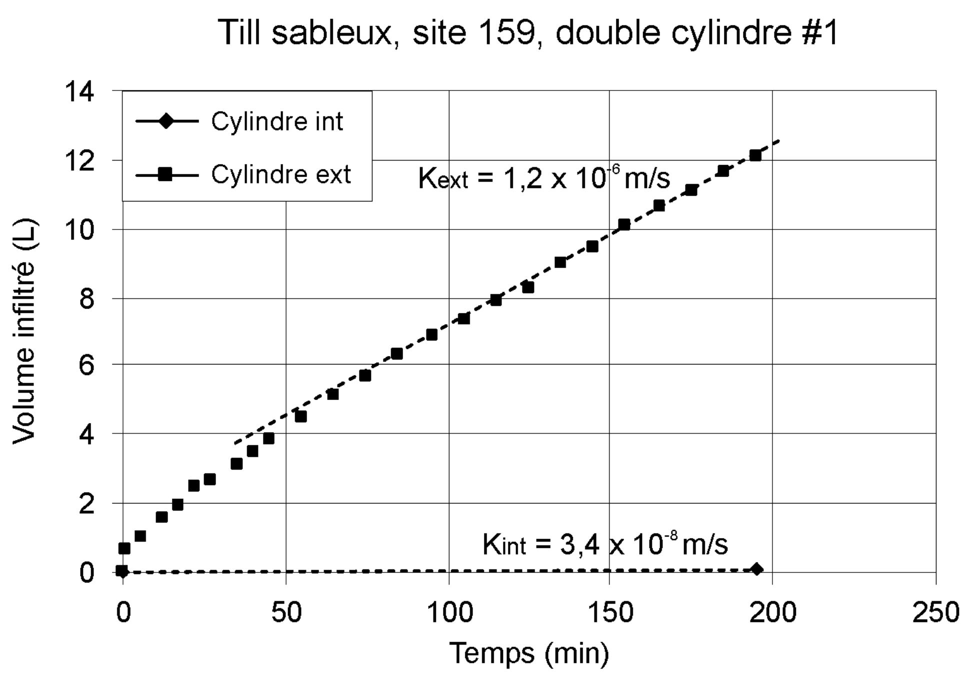


Figure D-18 : Infiltrometer test (DR#1), sandy till, site 159

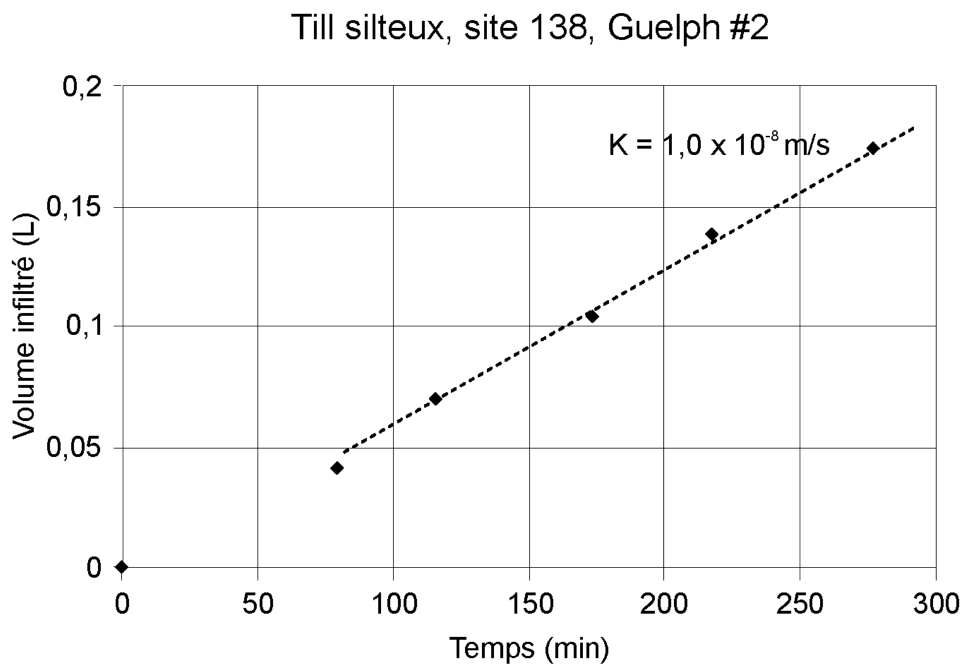


Figure D-19 : Infiltrometer test (Guelph#2), silty till, site 138

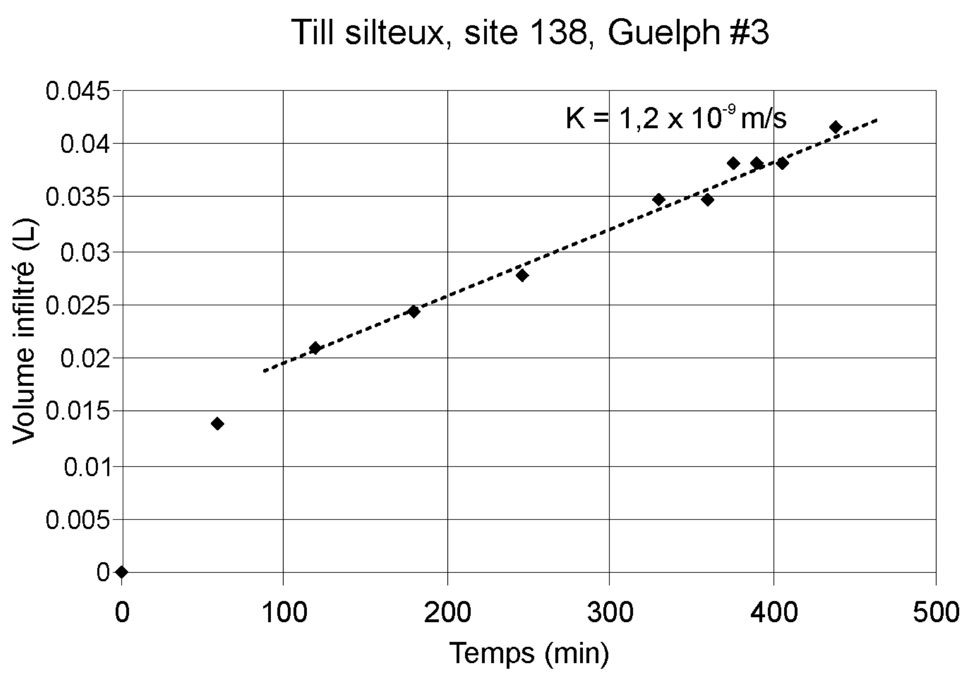


Figure D-20 : Infiltrometer test (Guelph#3), silty till, site 138

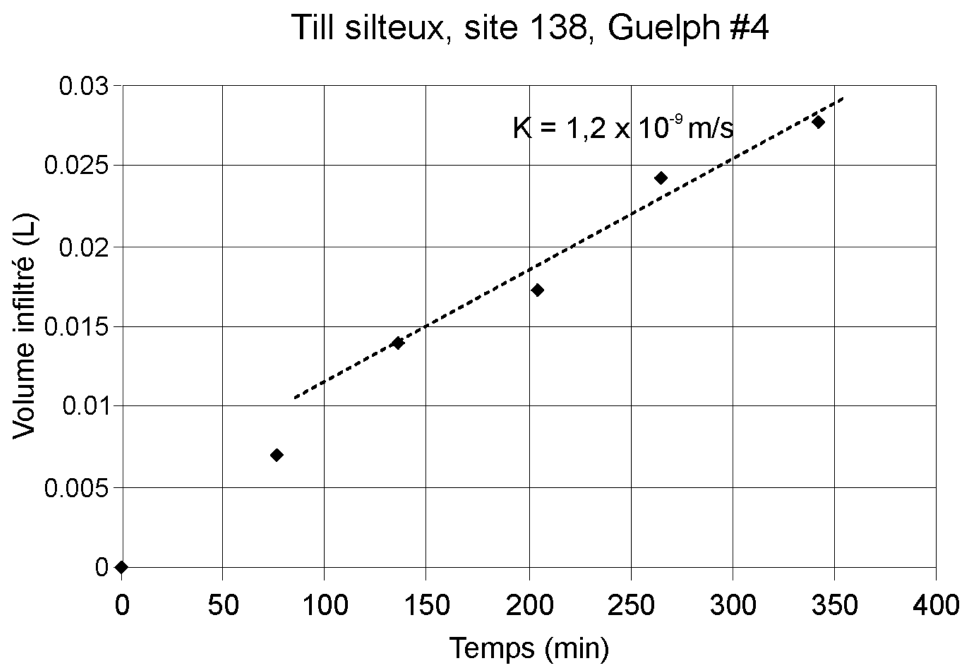


Figure D-21 : Infiltrometer test (Guelph#4), silty till, site 138

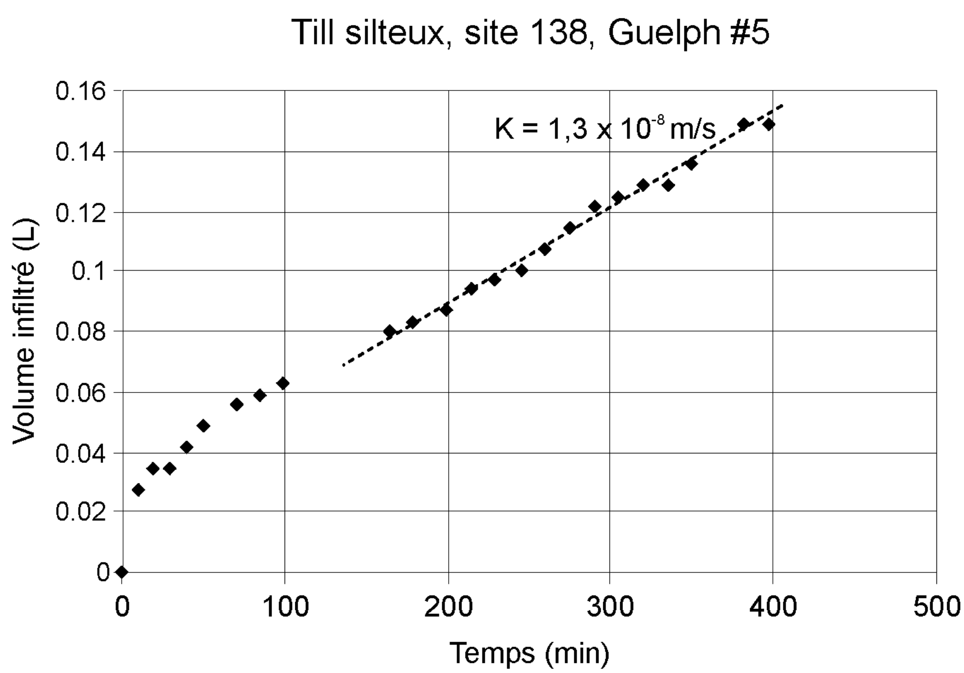


Figure D-22 : Infiltrometer test (Guelph#5), silty till, site 138

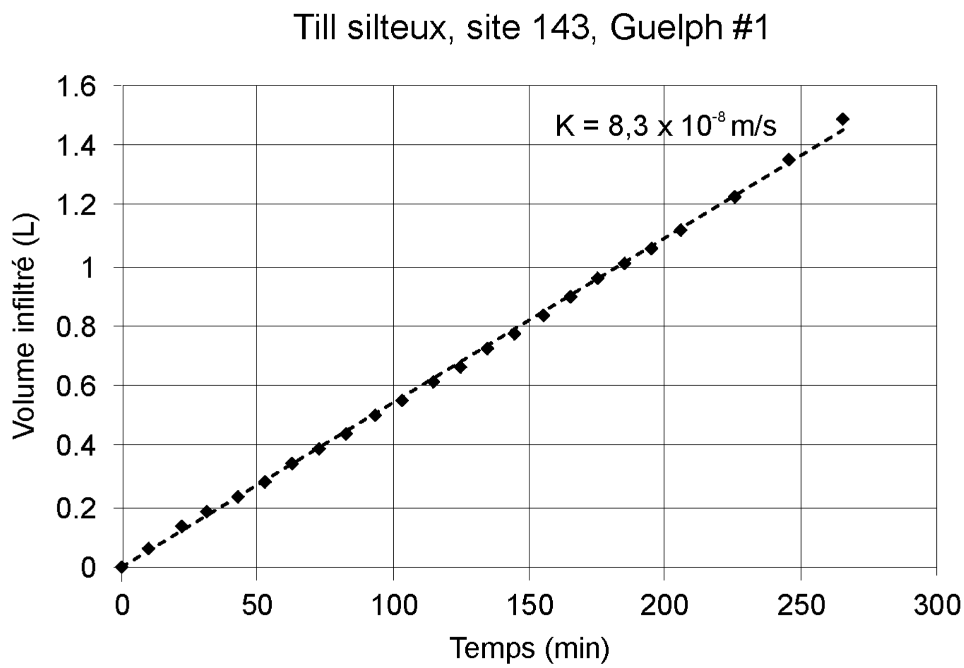


Figure D-23 : Infiltrometer test (Guelph#1), silty till, site 143

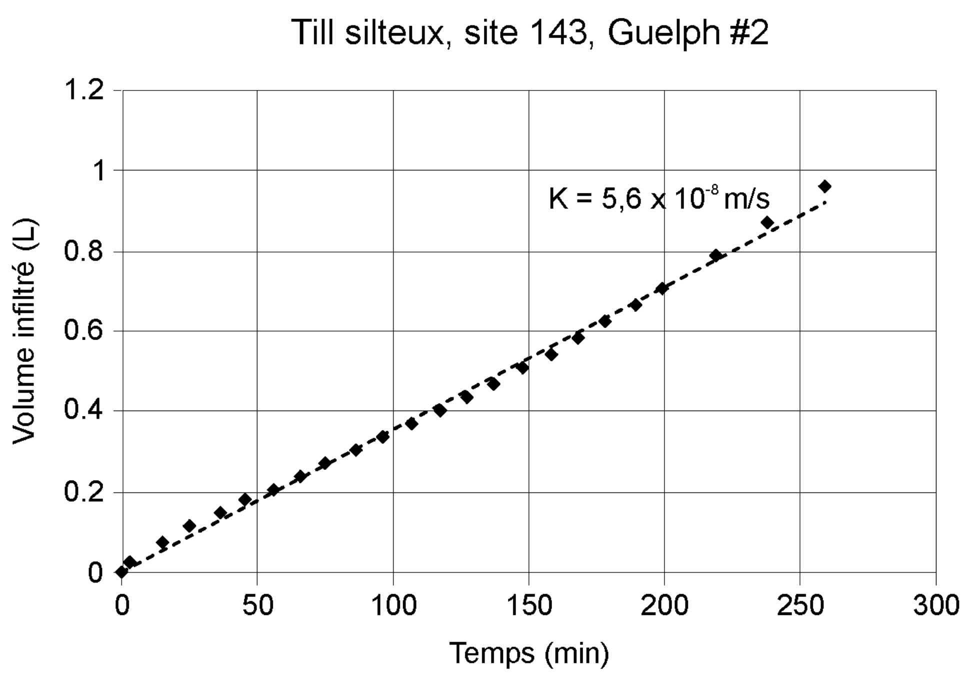


Figure D-24 : Infiltrometer test (Guelph#2), silty till, site 143

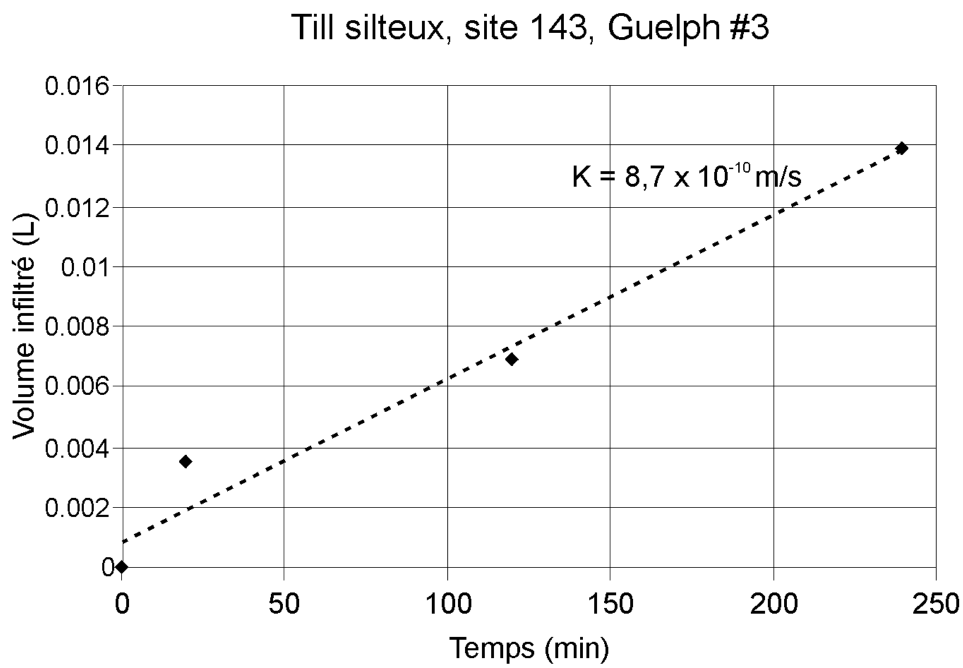


Figure D-25 : Infiltrometer test (Guelph#3), silty till, site 143

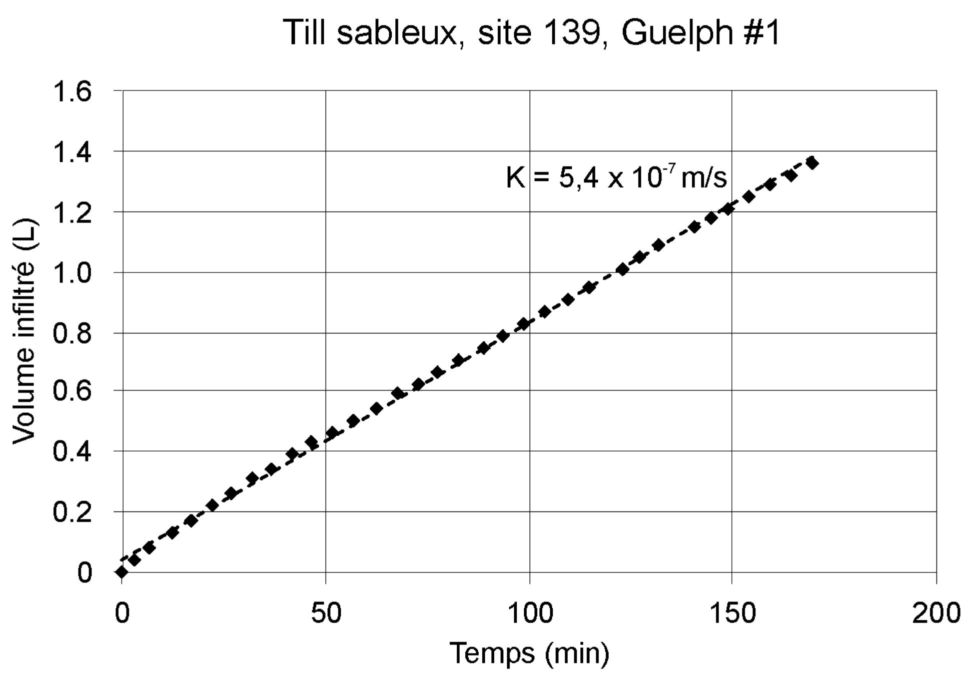


Figure D-26 : Infiltrometer test (Guelph#1), sandy till, site 139

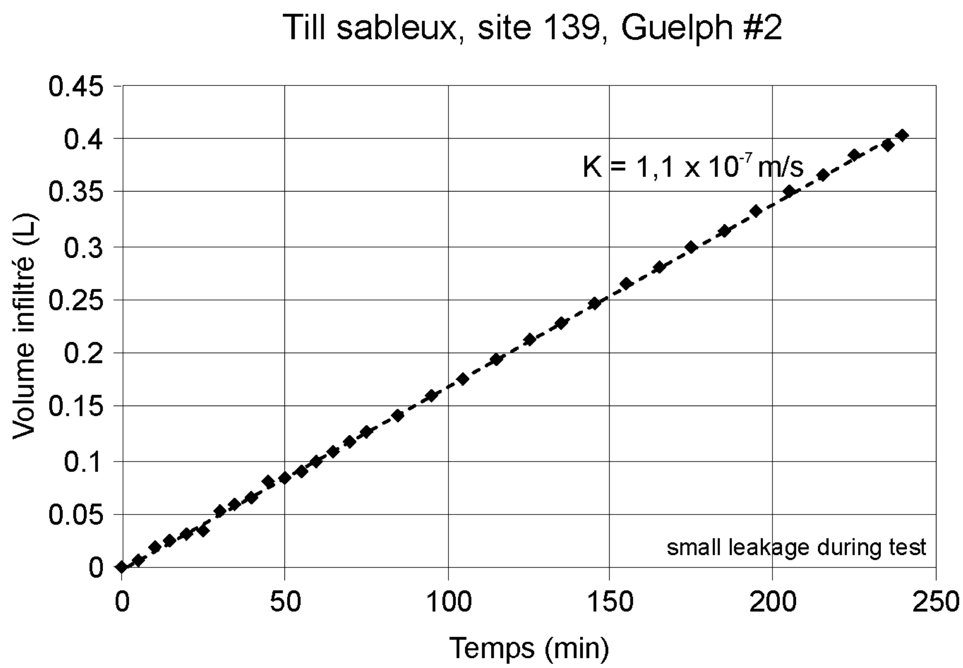


Figure D-27 : Infiltrometer test (Guelph#2), sandy till, site 138

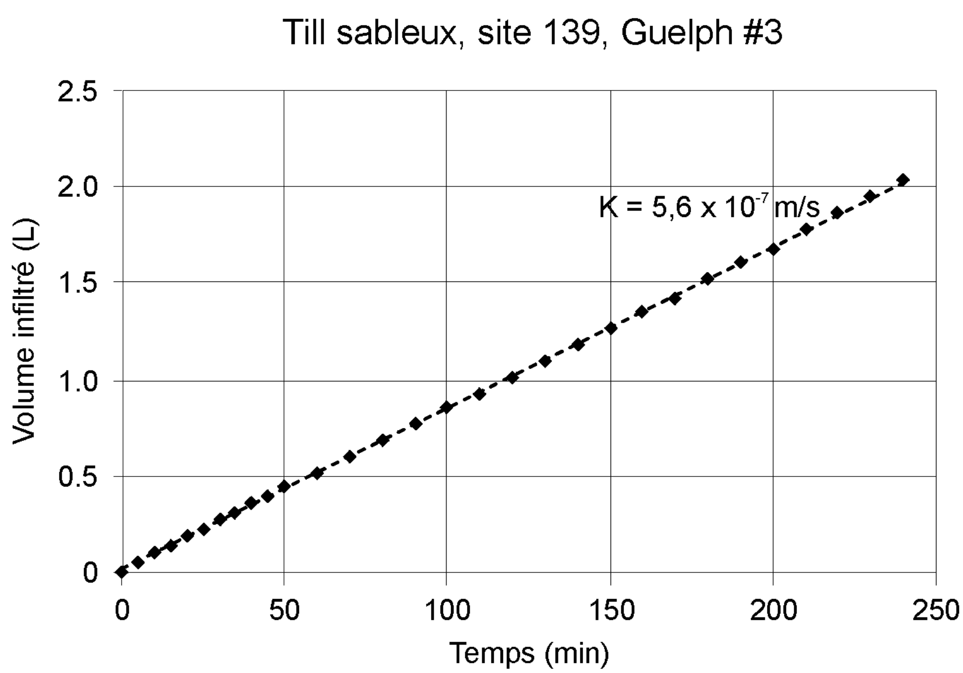


Figure D-28 : Infiltrometer test (Guelph#3), sandy till, site 139

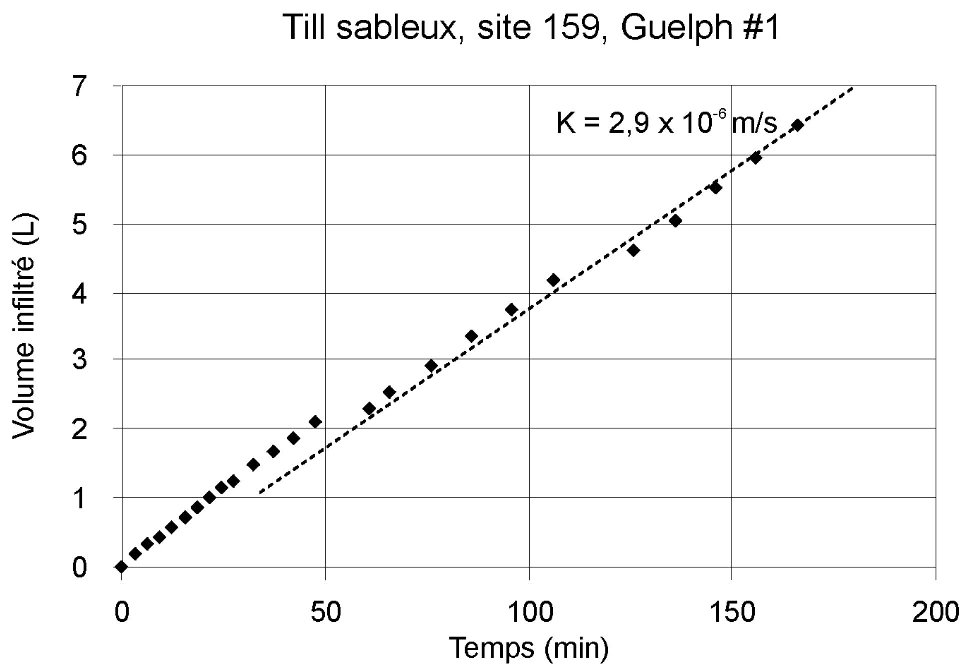


Figure D-29 : Infiltrometer test (Guelph#1), sandy till, site 159

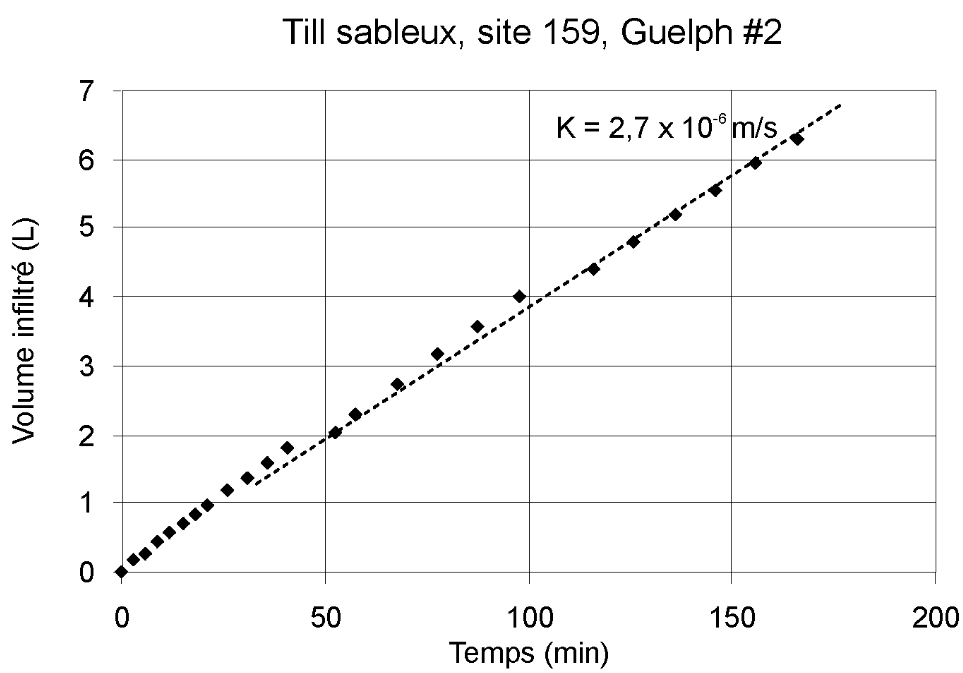


Figure D-30 : Infiltrometer test (Guelph#2), sandy till, site 159

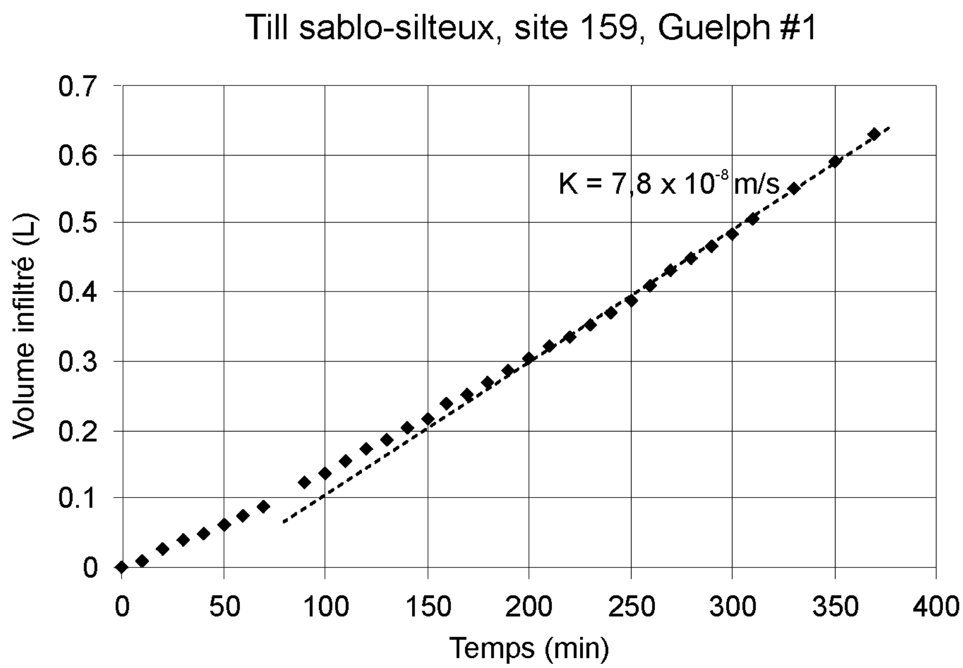


Figure D-31 : Infiltrometer test (Guelph#1), silty-sandy till, site 159

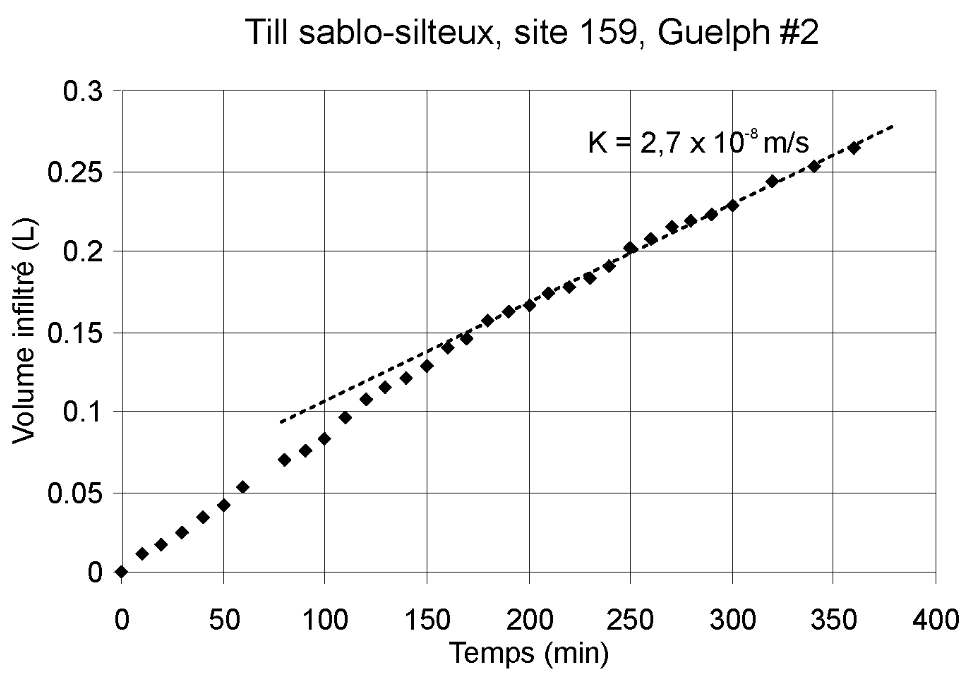


Figure D-32 : Infiltrometer test (Guelph#2), silty-sandy till, site 159

Part E

Borehole geophysics logging

Borehole geophysics logging was performed in 10 wells across the MGWI study area, in the different geological formations present within the Maritimes Carboniferous Basin. Standard logs, such as caliper, natural gamma, and electrical resistivity (16N and 64N) logs, as well as acoustic and optical televiewer images are presented for each well. The 16N electrical resistivity (also known as 16-inch normal resistivity) provides measurements near the hole, while the 64N (also know as 64-inch normal resistivity) provides measurements of resistivity far from the well. The rosette and equal-area (lower hemisphere stereographic) diagrams of the fracture orientations are also given. Geographical locations of the ten wells are presented in Figure E-1, and general information of investigated wells are given in Table E-1.

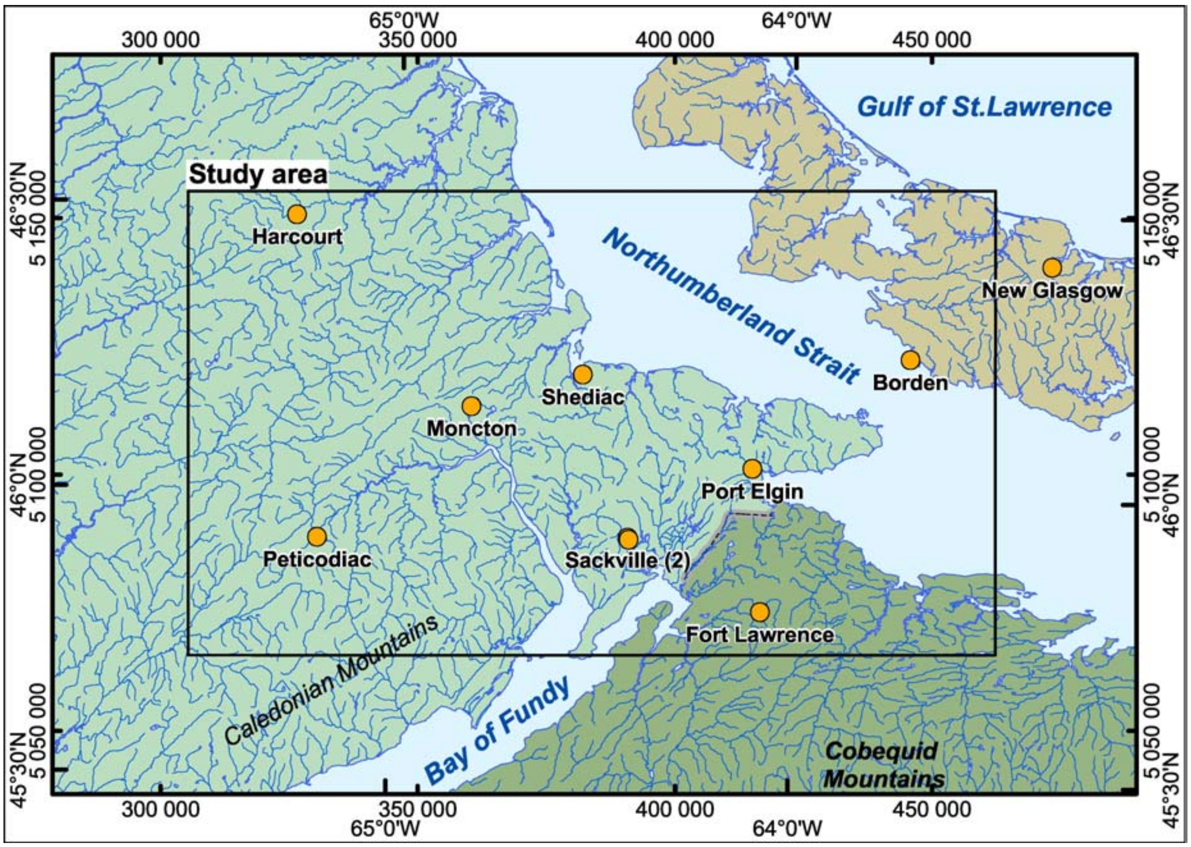


Figure E-1: Location of sites where geophysical logs were obtained in water wells

Table E-1: General information where geophysical logs were recorded

Location	Total depth (m)	Diameter (cm)	Casing depth (m)	Formation	Lithology
Petitcodiac, NB	113	≈ 15.2 to 12.0	12.6	Salisbury	shale, siltstone, congl., sandstone,
Borden, PEI	120	≈ 15.5	12.2	Kildare	sandstone,
Fort Lawrence, NS	69	≈ 16.3	6.1	Balfron	sandstone, siltstone, shale
Harcourt, NB	145	≈ 12.4 to	6.7	Und. Pictou	sandstone, shale
Port Elgin, NB	44	≈ 20.3 to	19.2	Richibucto	sandstone,
Shediac, NB	61	≈ 15.5	42.7	Richibucto	sandstone,
Moncton, NB	88	≈ 30.1 to 25.6	12.2	Salisbury; Richibucto	sandstone, siltstone, shale
New Glasgow, PEI	83	≈ 16.3	17.5	Kildare Capes	sandstone, siltstone
Sackville #4, NB	24	≈ 26.4 to 23.1	12.2	Boss Point	sandstone, siltstone, shale
Sackville #7, NB	54	≈ 22.1 to 17.5	10.1	Boss Point	sandstone, siltstone, shale

Caliper, natural gamma, and resistivity logs; acoustic and optical televiewers
Borden, Prince Edward Island

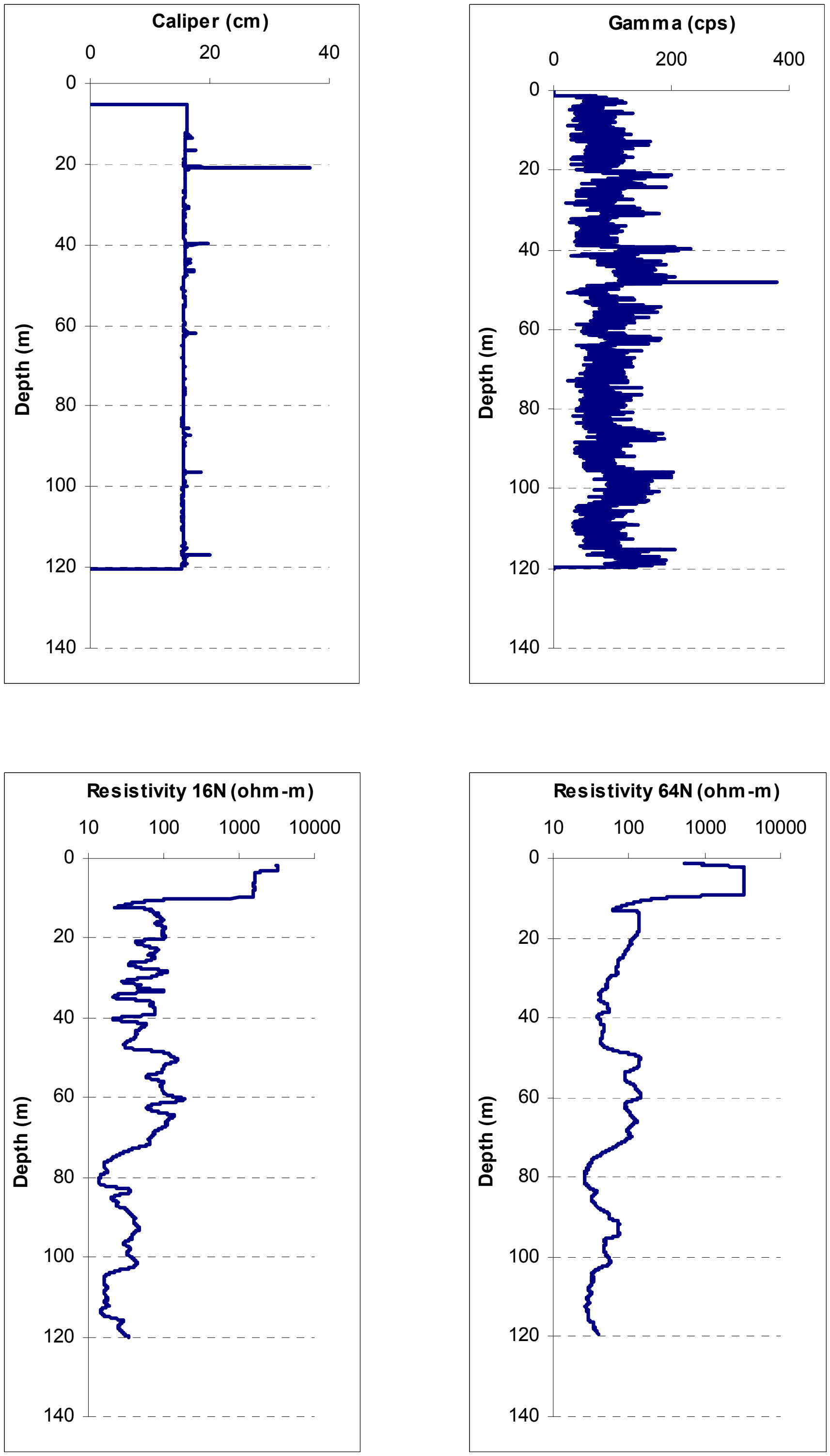


Figure E-2: Geophysics logs as a function of depth, Borden PEI

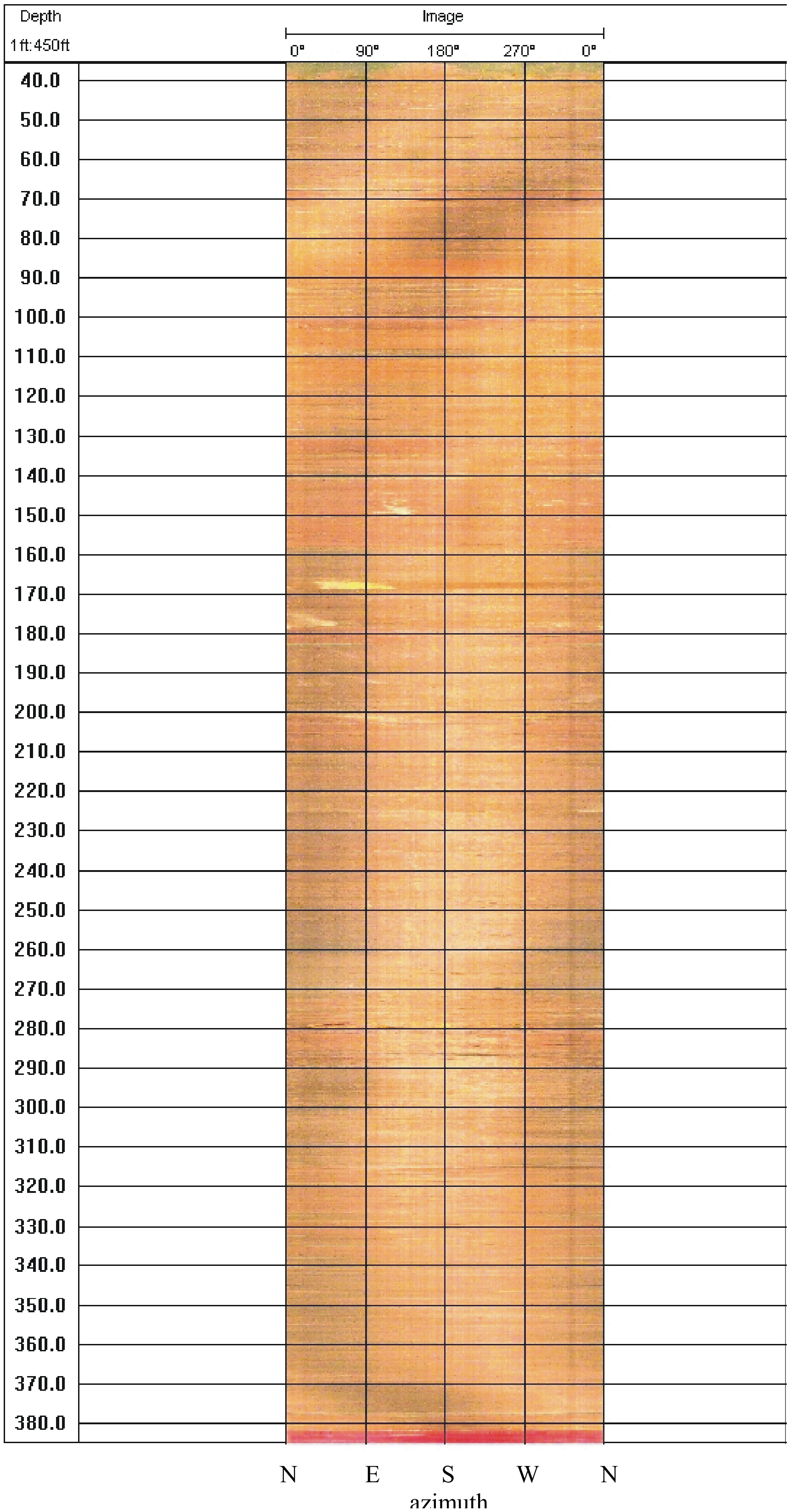


Figure E-3: Optical televiewer, Borden, PEI

Fort Lawrence, Nova Scotia

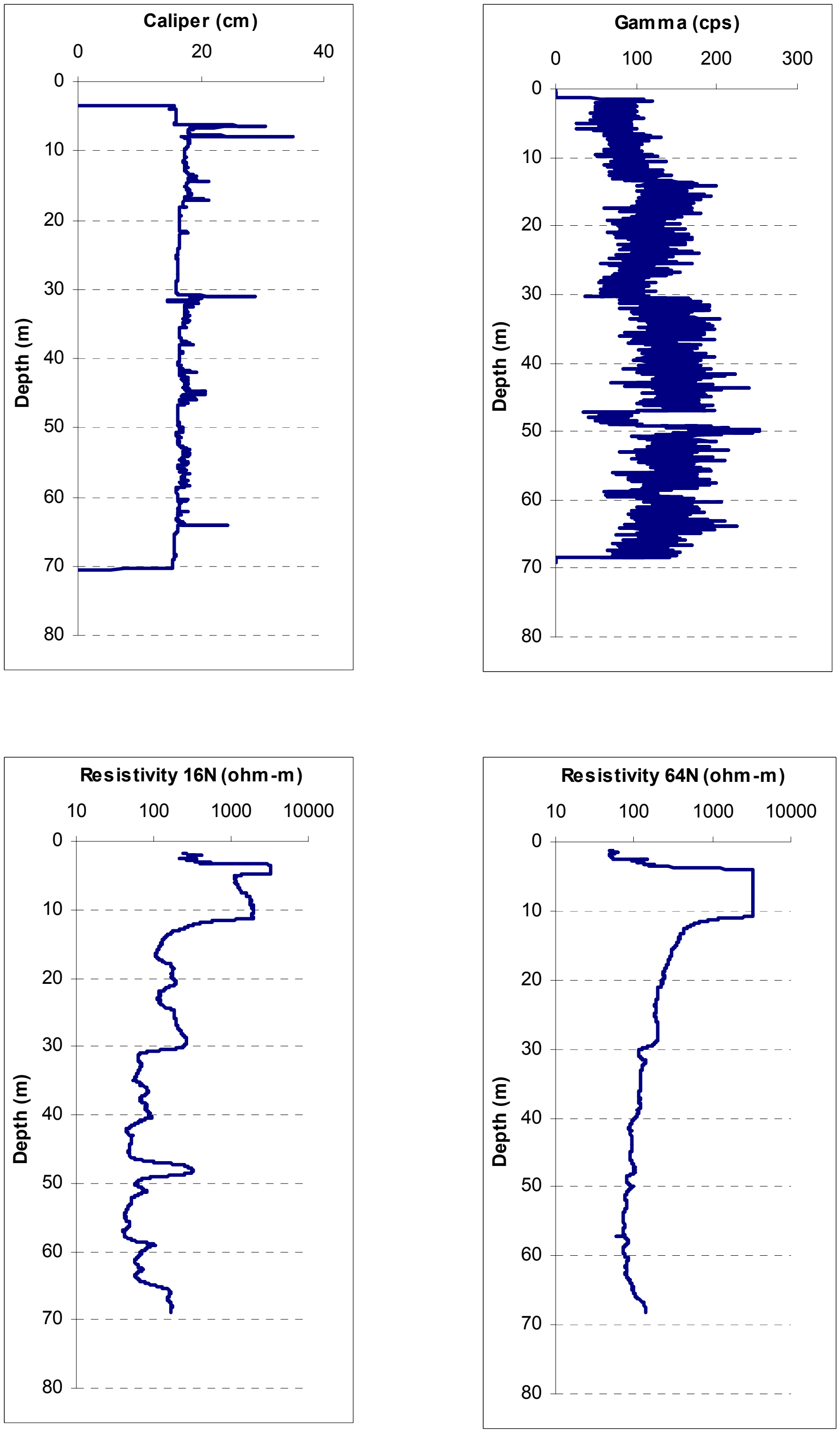
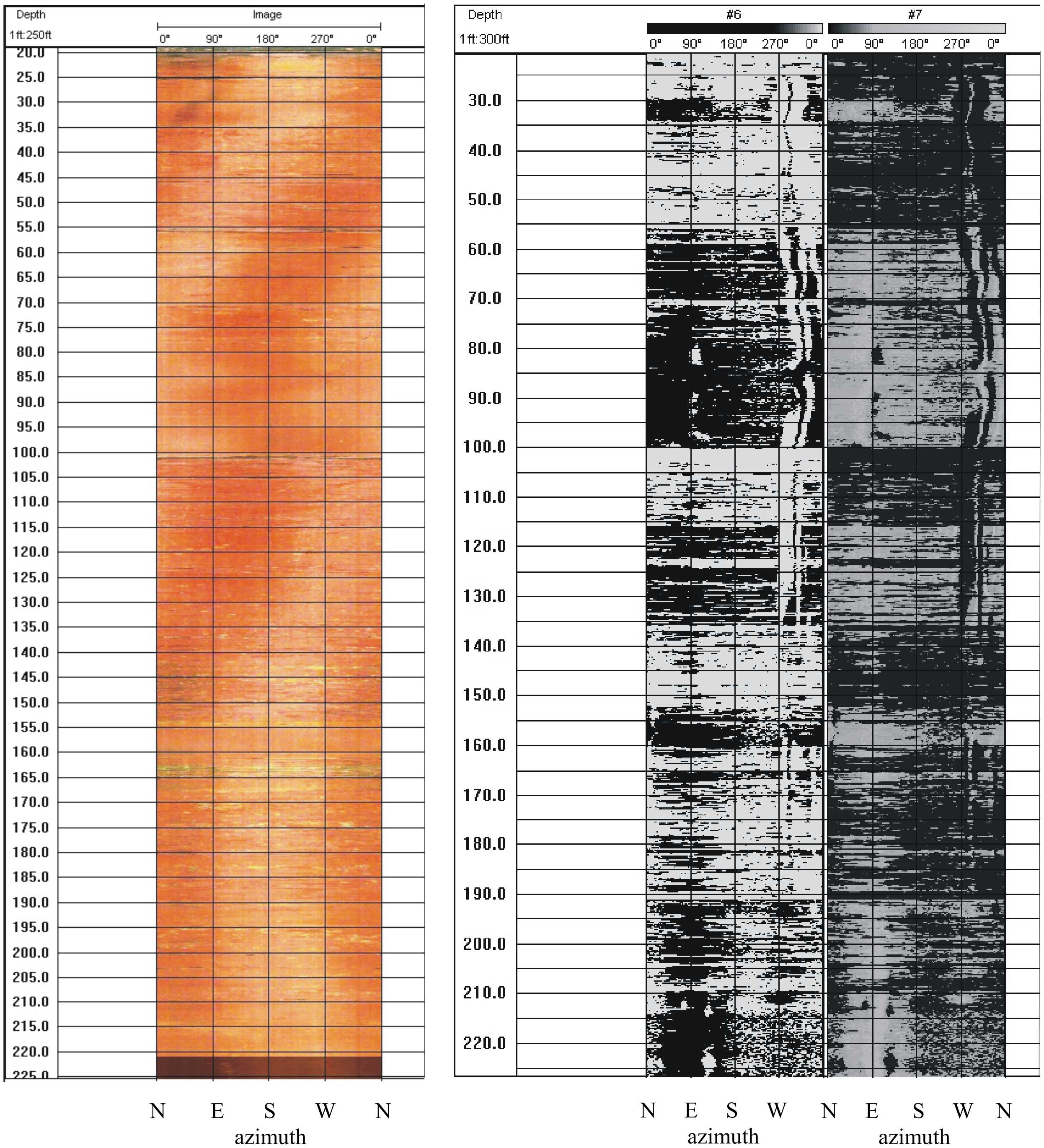


Figure E-4: Geophysics logs as a function of depth, Fort Lawrence, NS



a) b)

Figure E-5: a) Optical televiewer and b) acoustic televiewer, Fort Lawrence, NS

Harcourt, New Brunswick

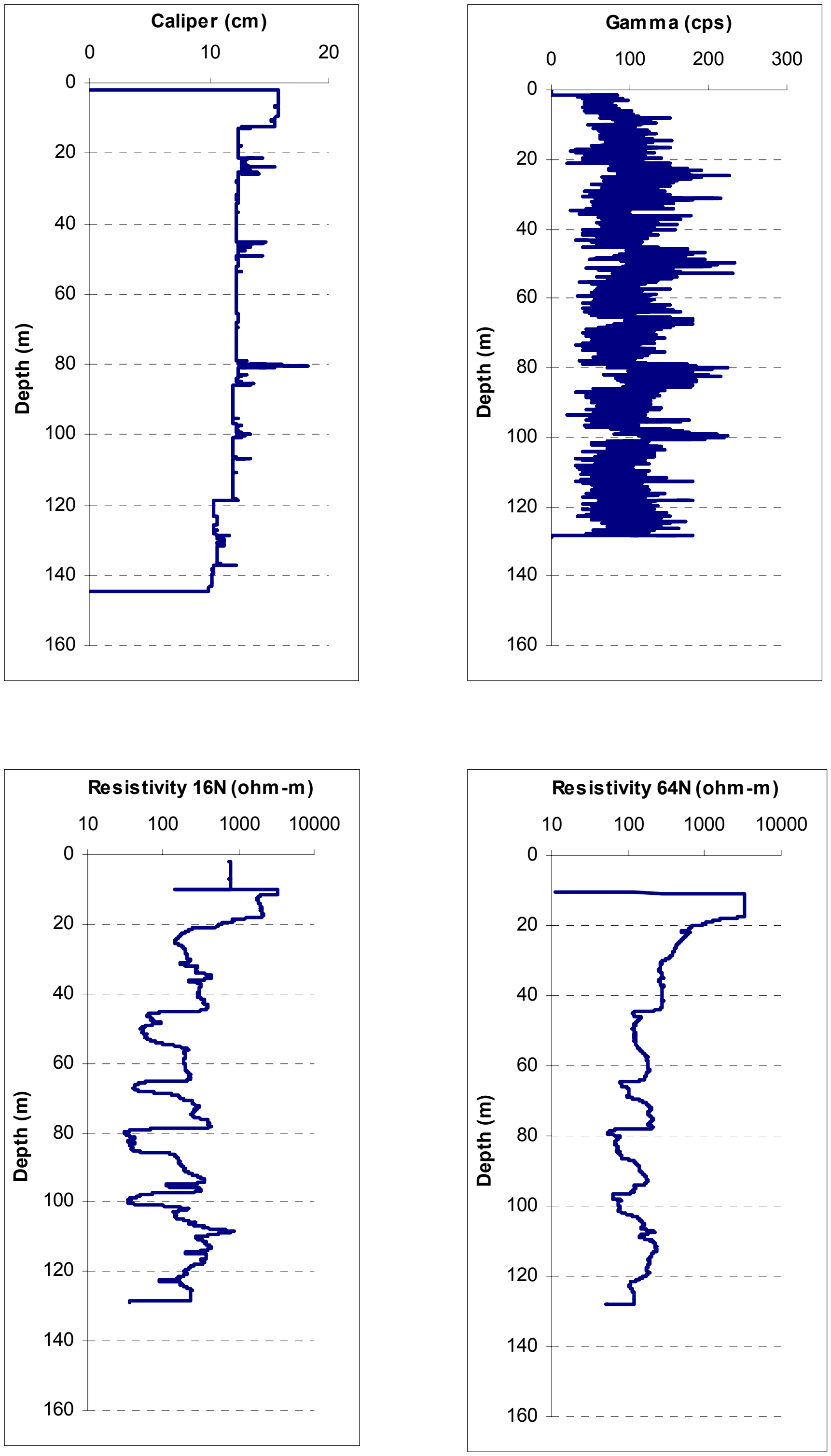


Figure E-6: Geophysics logs as a function of depth, Harcourt, NB

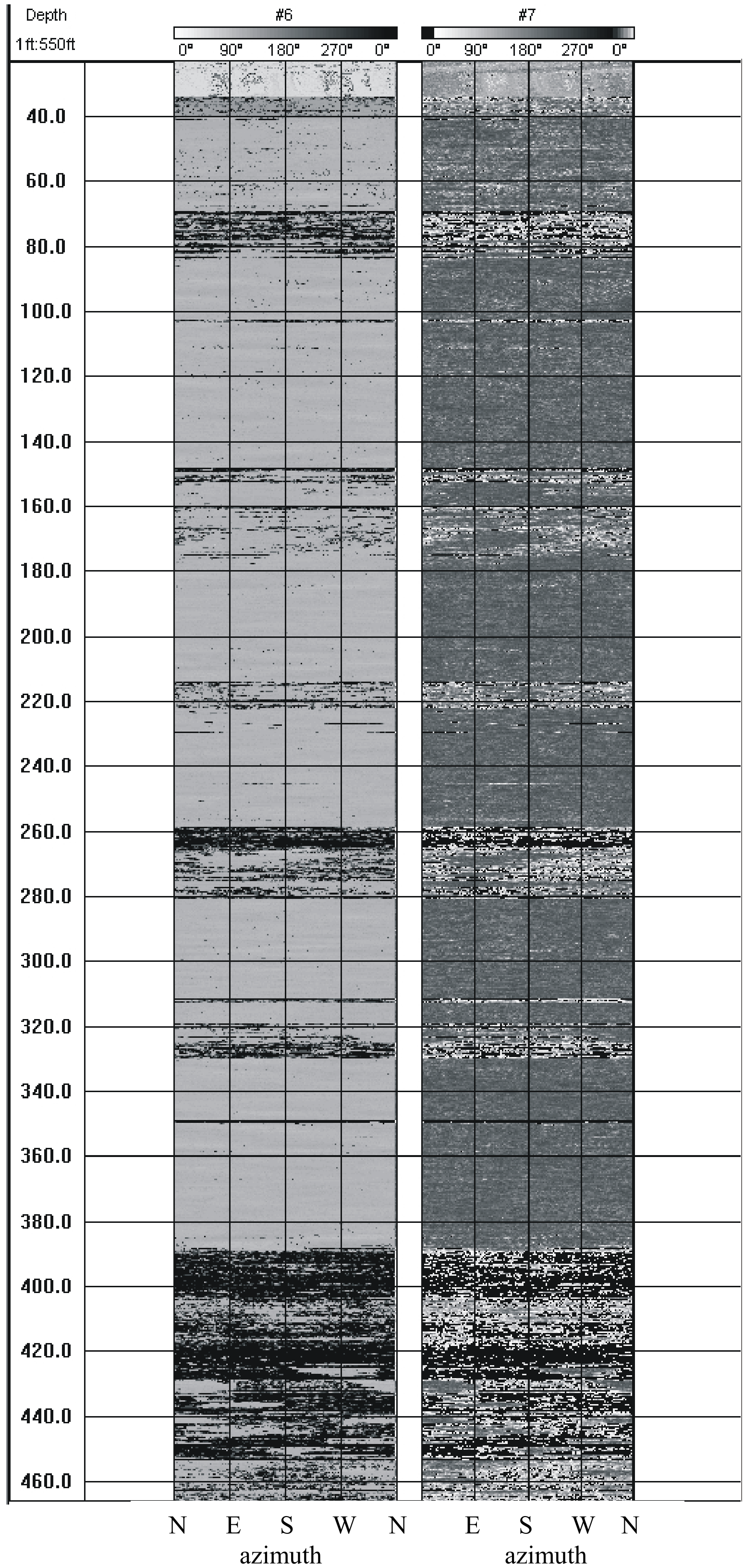


Figure E-7: Acoustic televiewer, Harcourt, NB

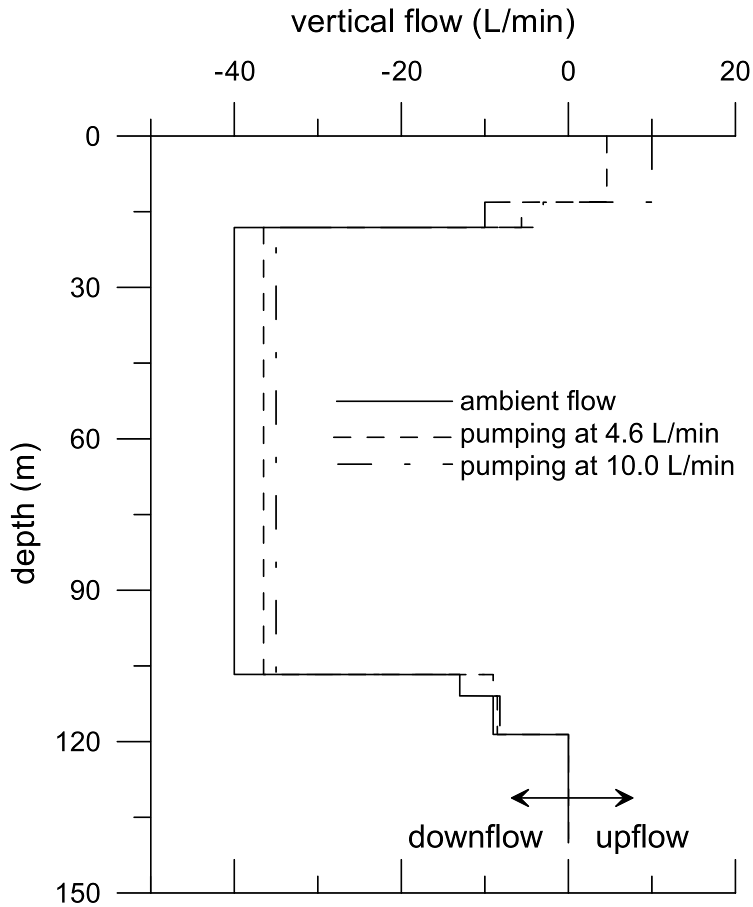


Figure E-8: Flowmeter logs recorded in the Harcourt well under three different hydraulic conditions: ambient, pumping at 4.6 L/min, and pumping at 10.0 L/min from the surface.

Moncton, New Brunswick

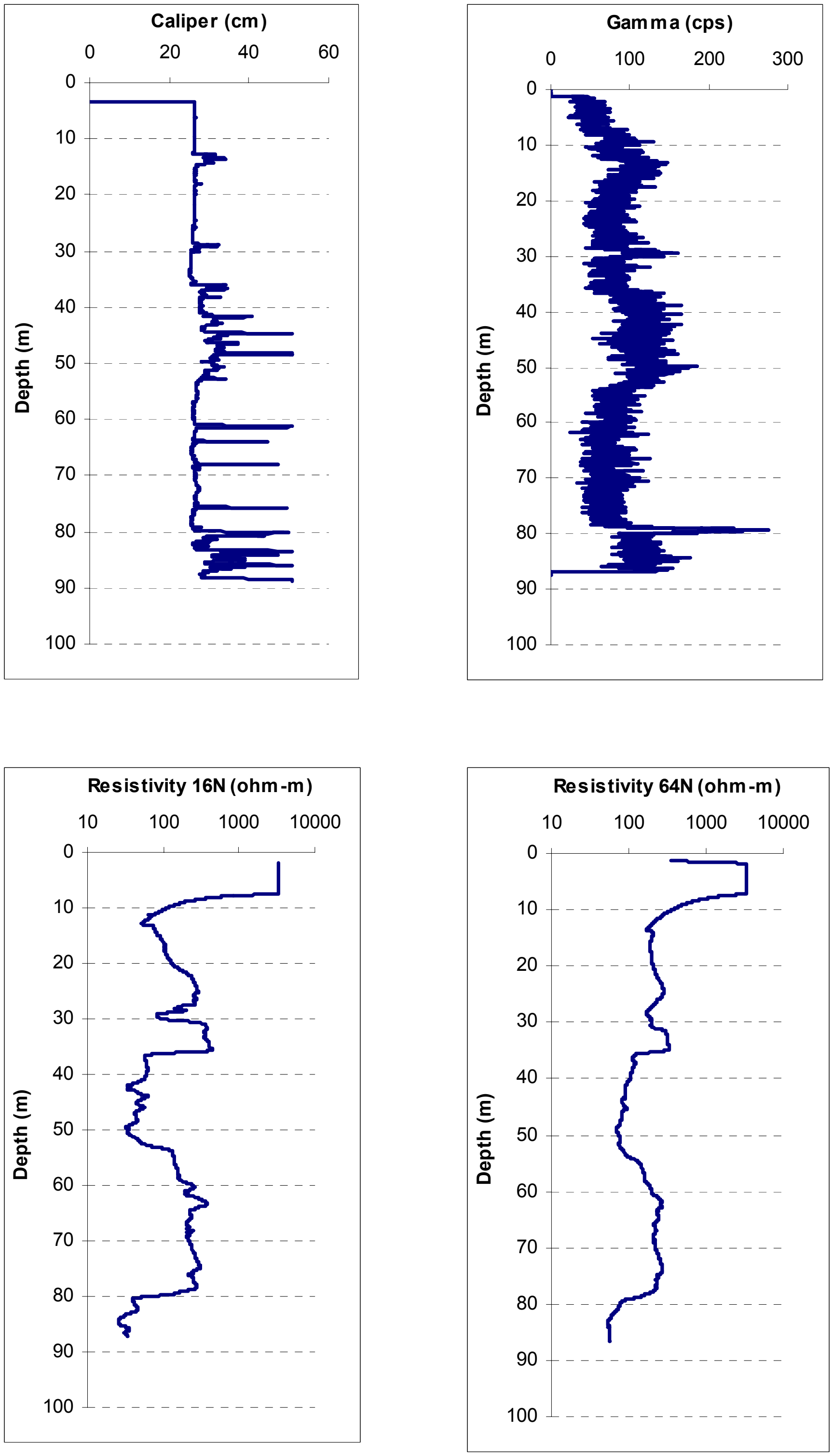


Figure E-9: Geophysics logs as a function of depth, Moncton, NB

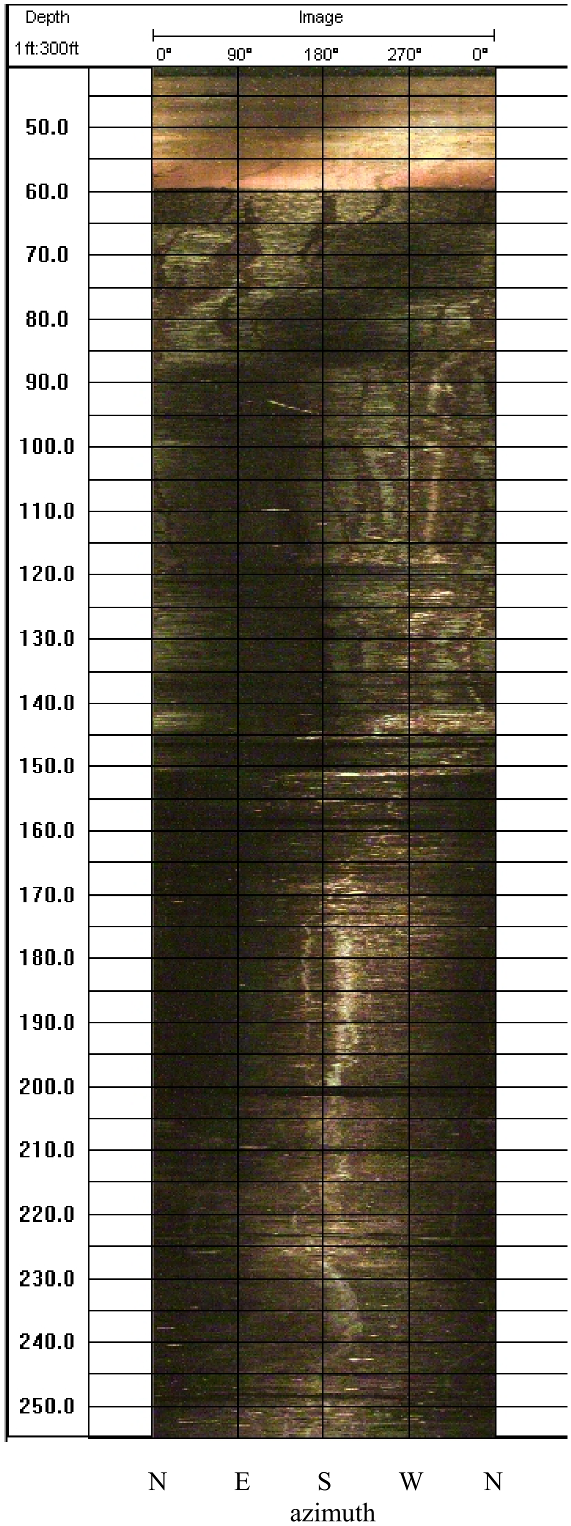


Figure E-10: Optical televiewer, Moncton, NB

New Glasgow, Prince Edward Island

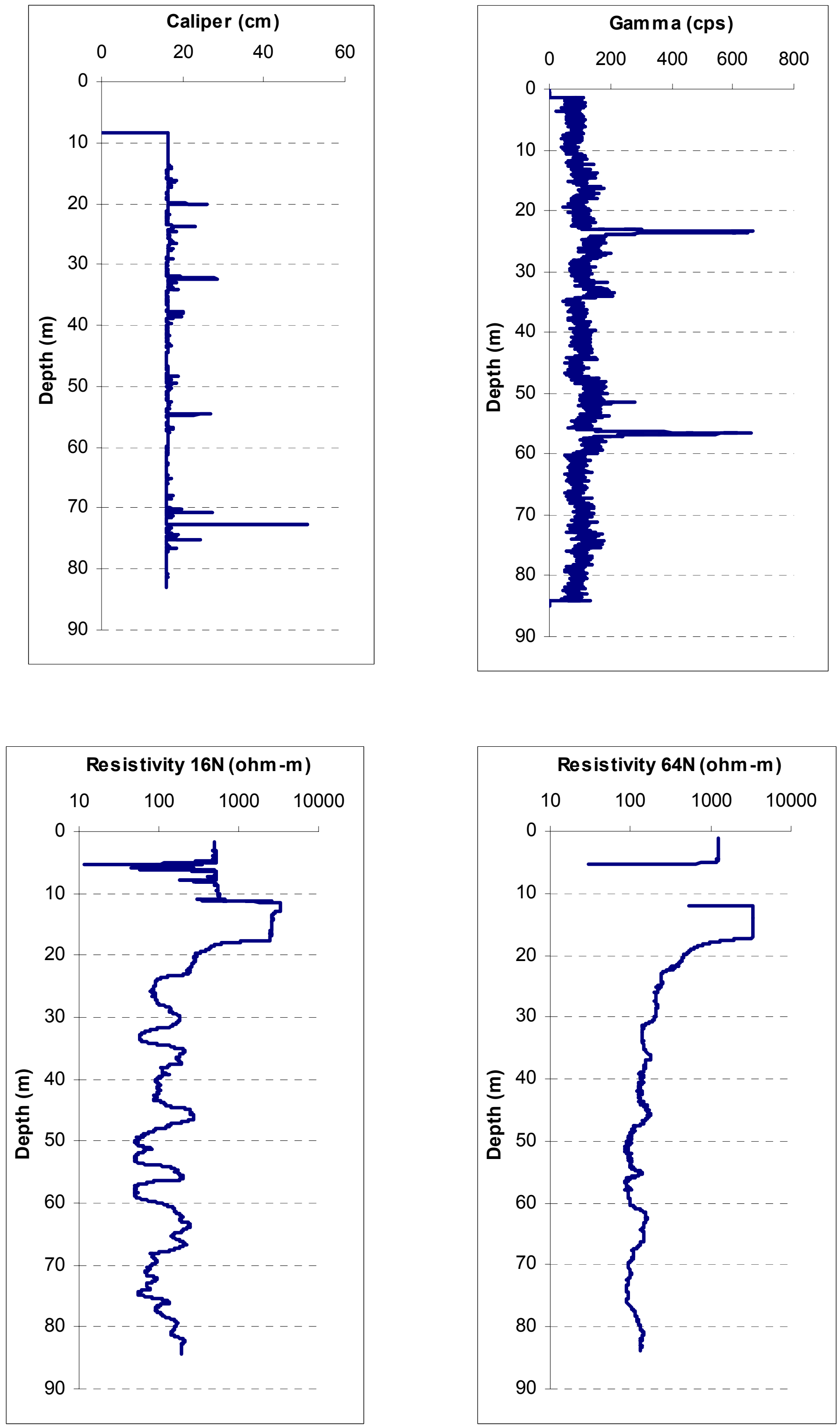


Figure E-11: Geophysics logs as a function of depth, New Glasgow, PEI

Petitcodiac, New Brunswick

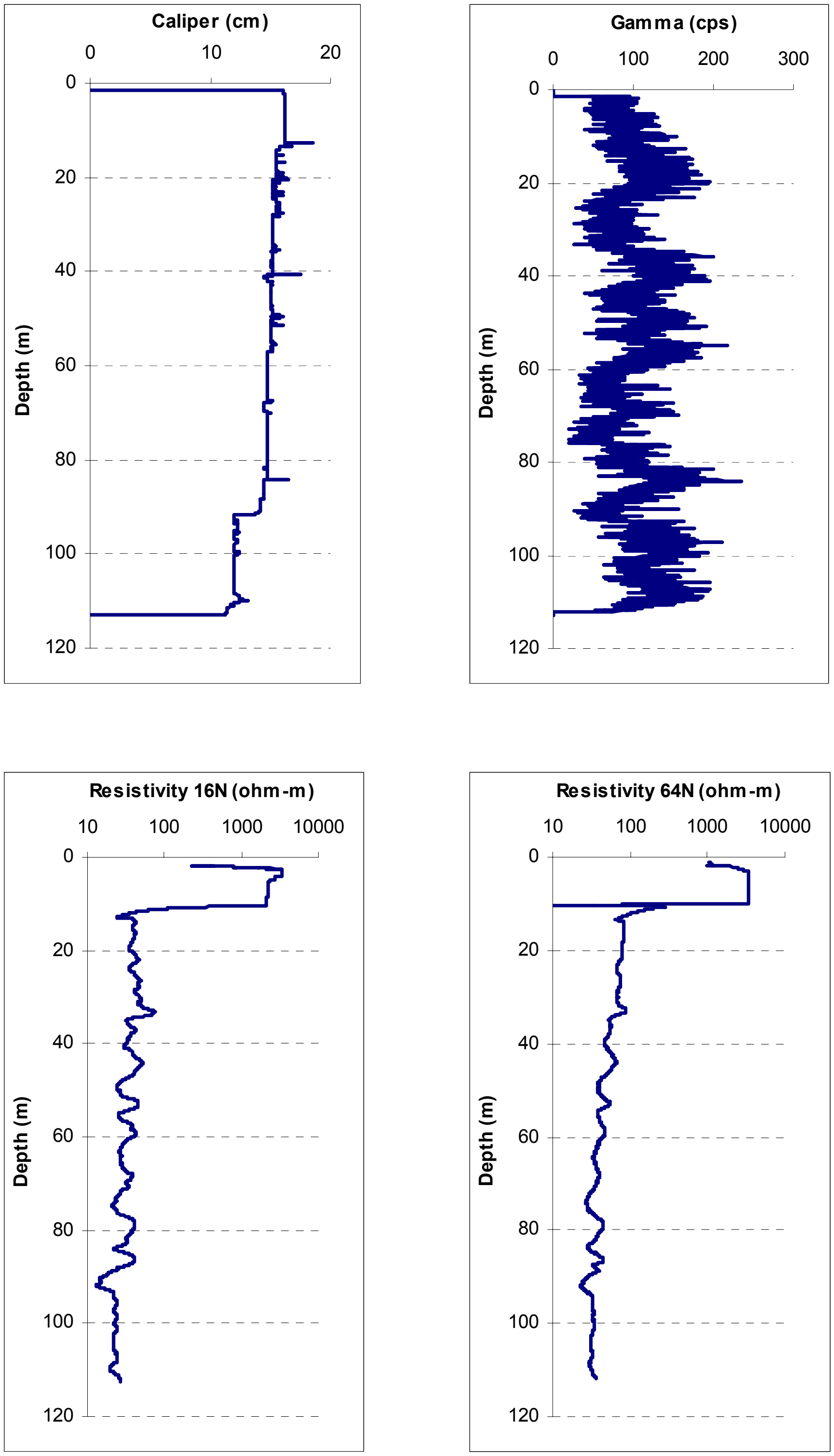


Figure E-12: Geophysics logs as a function of depth, Petitcodiac, NB

Port Elgin, New Brunswick

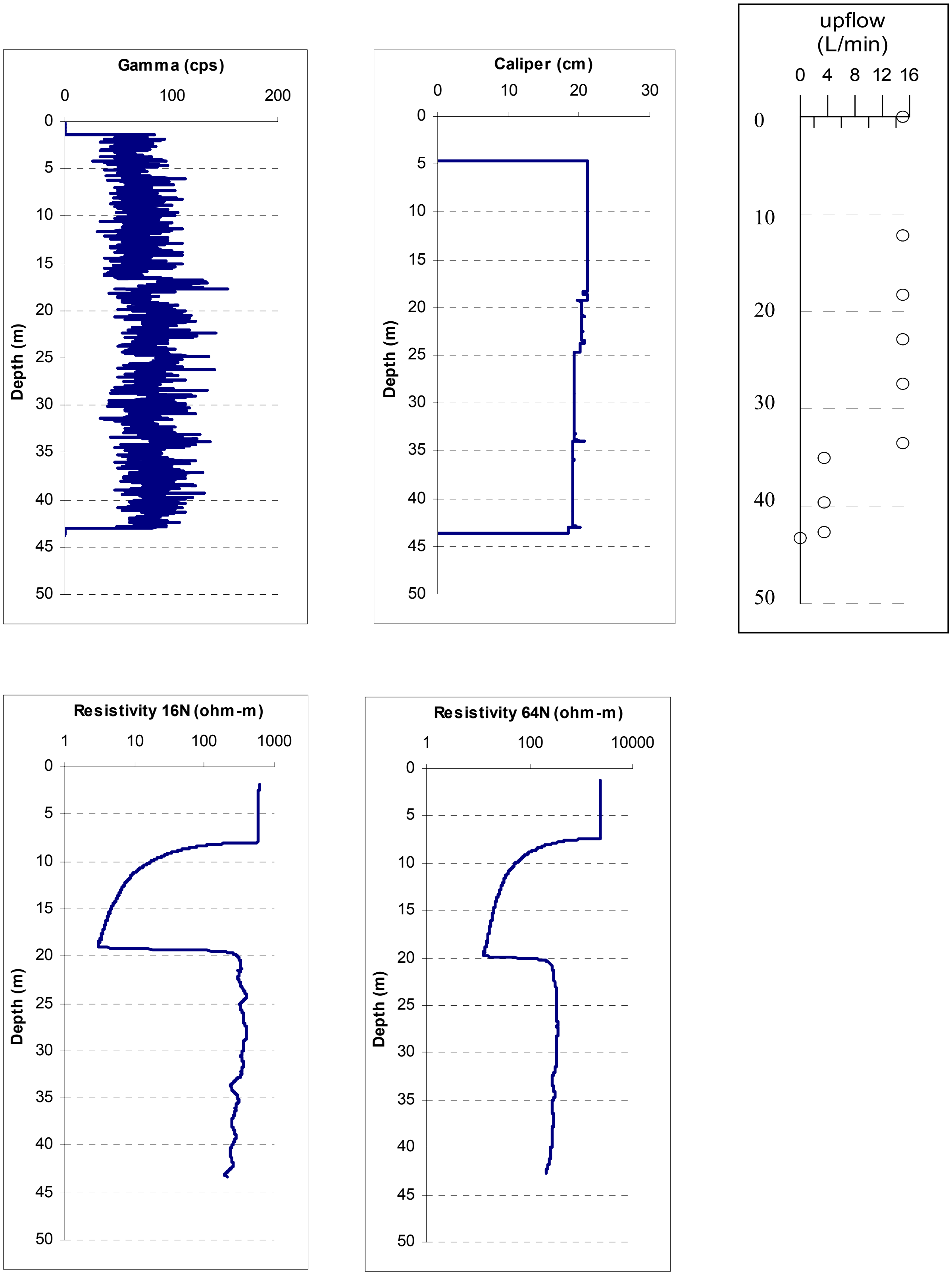


Figure E-13: Geophysics logs as a function of depth, Port Elgin, NB

Sackville #4, New Brunswick

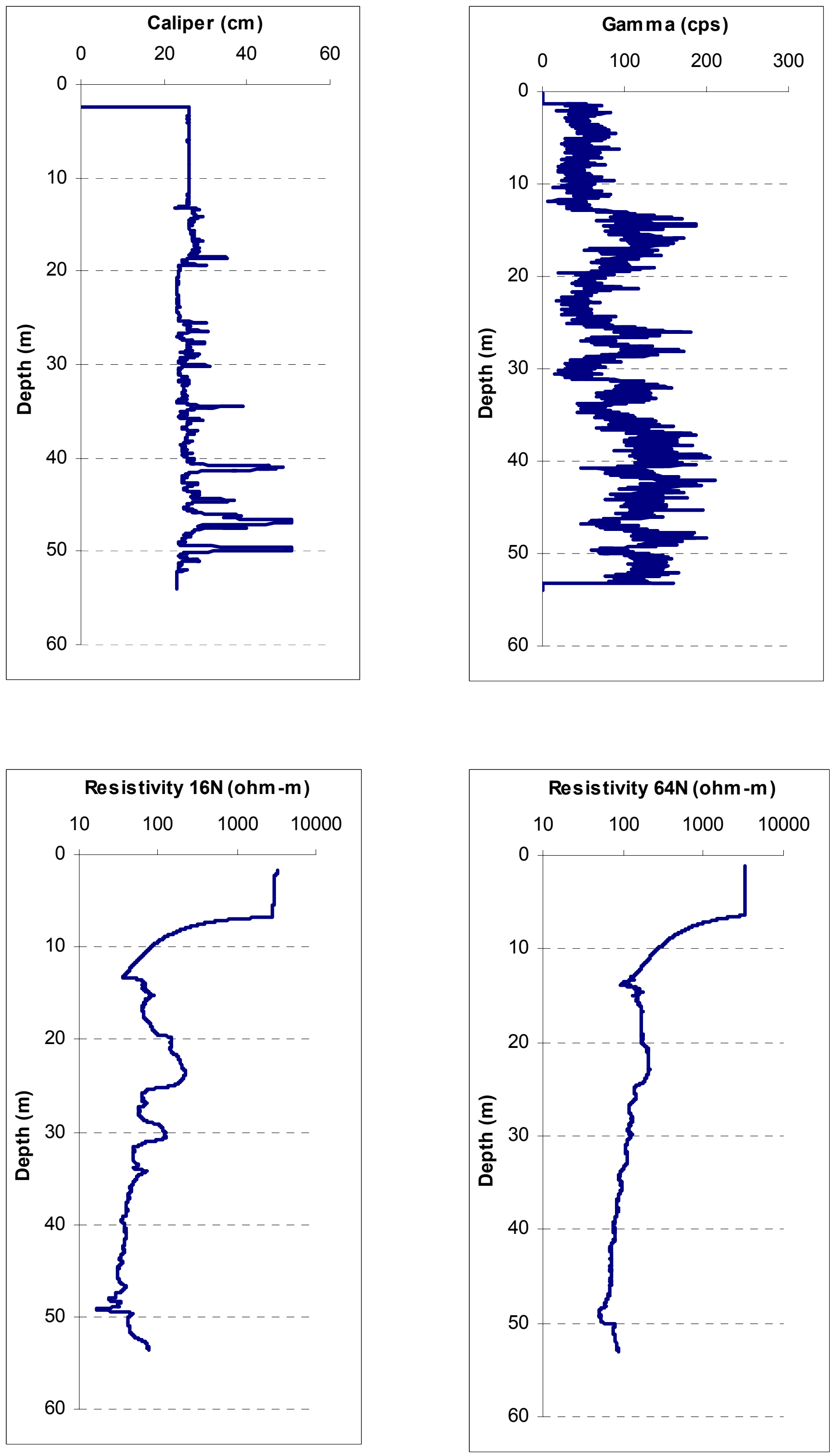


Figure E-14: Geophysics logs as a function of depth, Sackville #4, NB

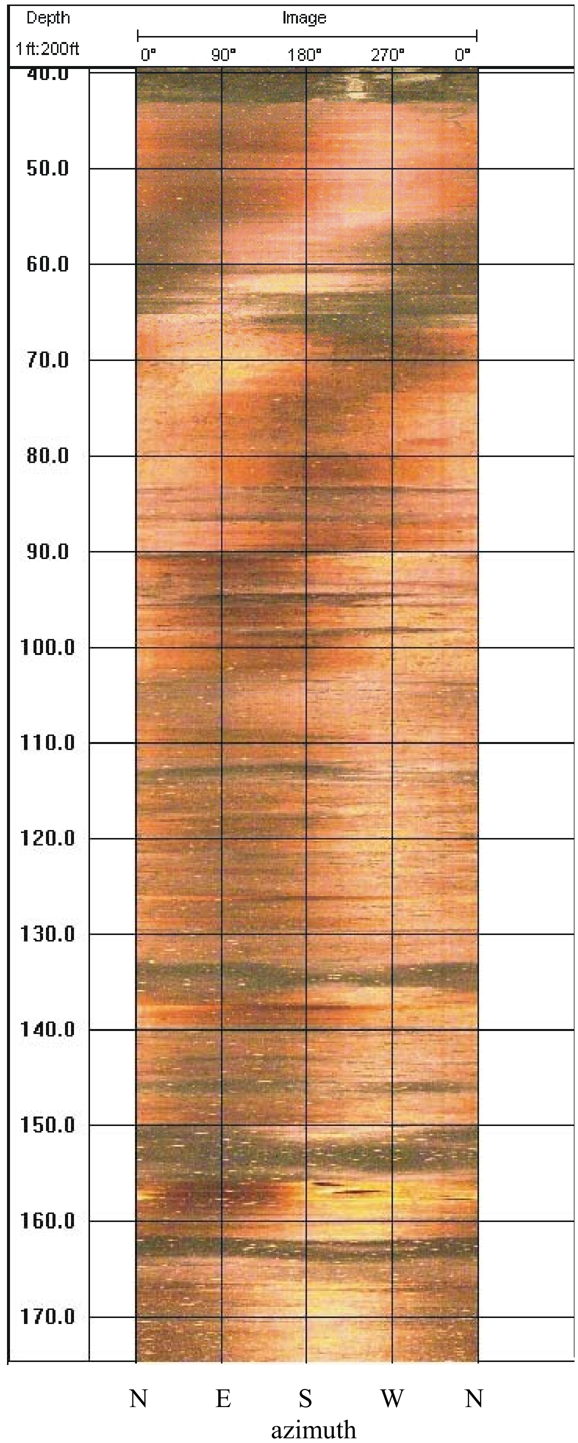


Figure E-15: Optical televiewer, Sackville #4, NB

Sackville #7, New Brunswick

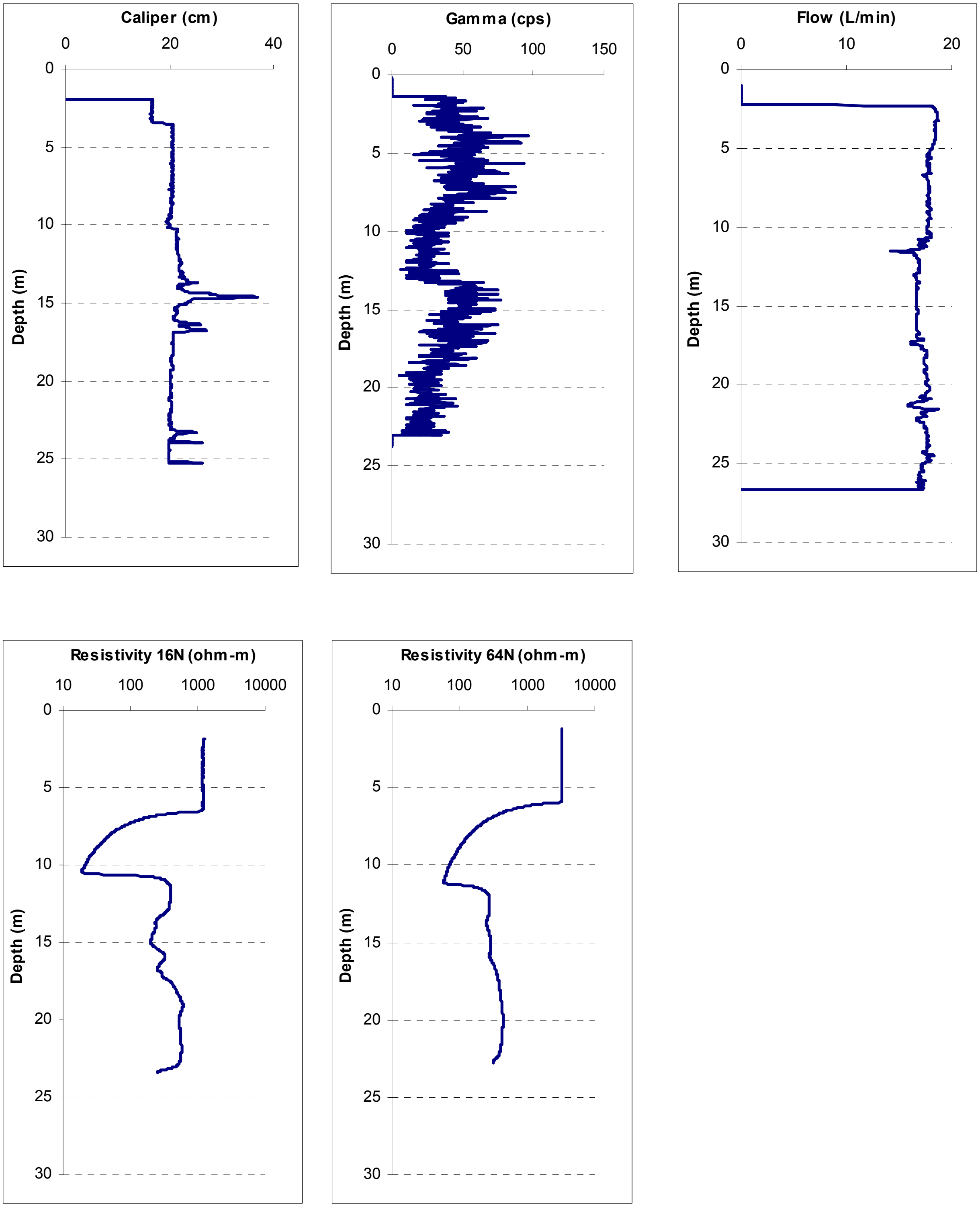


Figure E-15: Geophysics logs as a function of depth, Sackville #7, NB

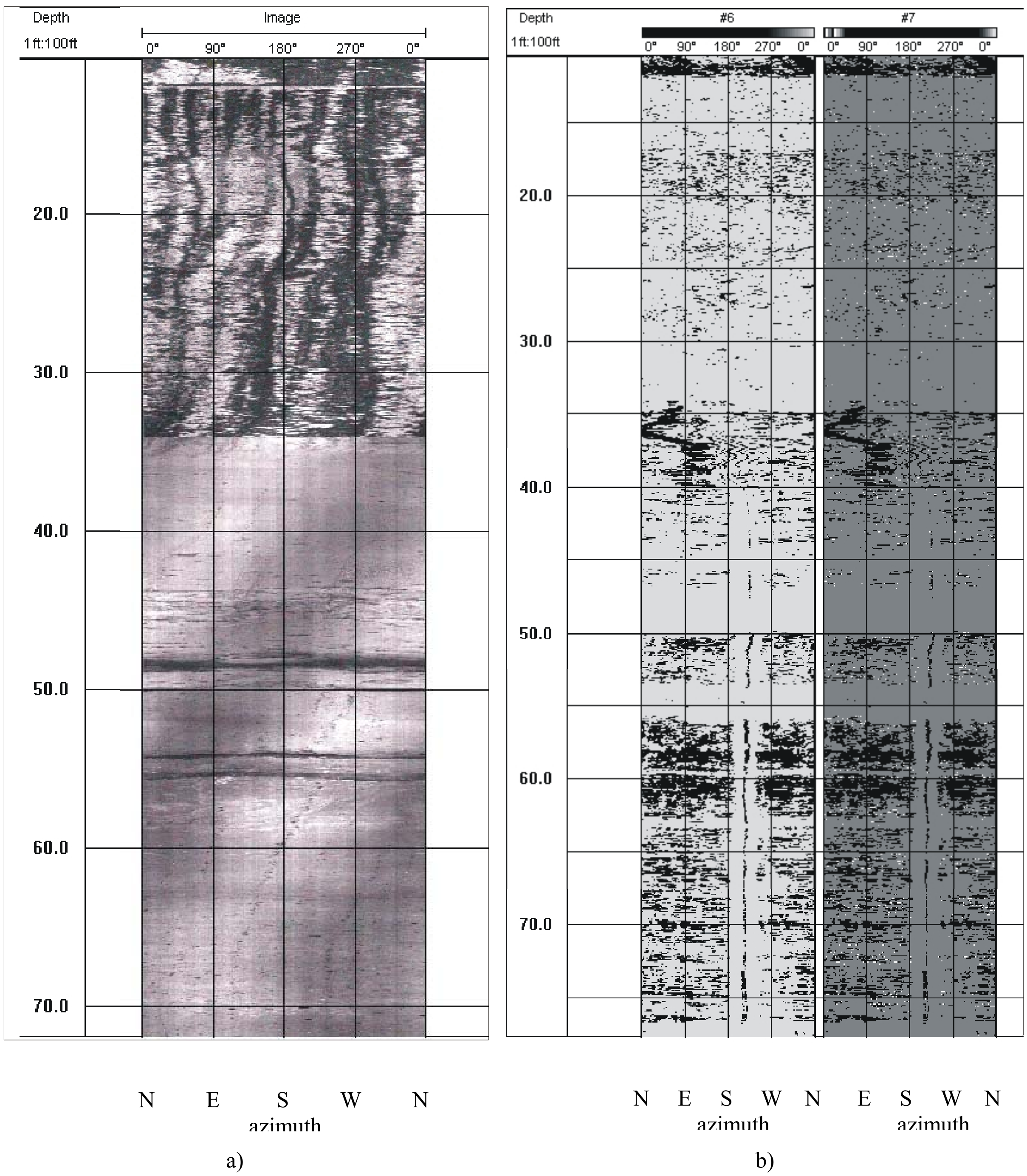


Figure E-16: a) Optical televiewer and b) acoustic televiewer, Sackville #7, NB

Shediac, New Brunswick

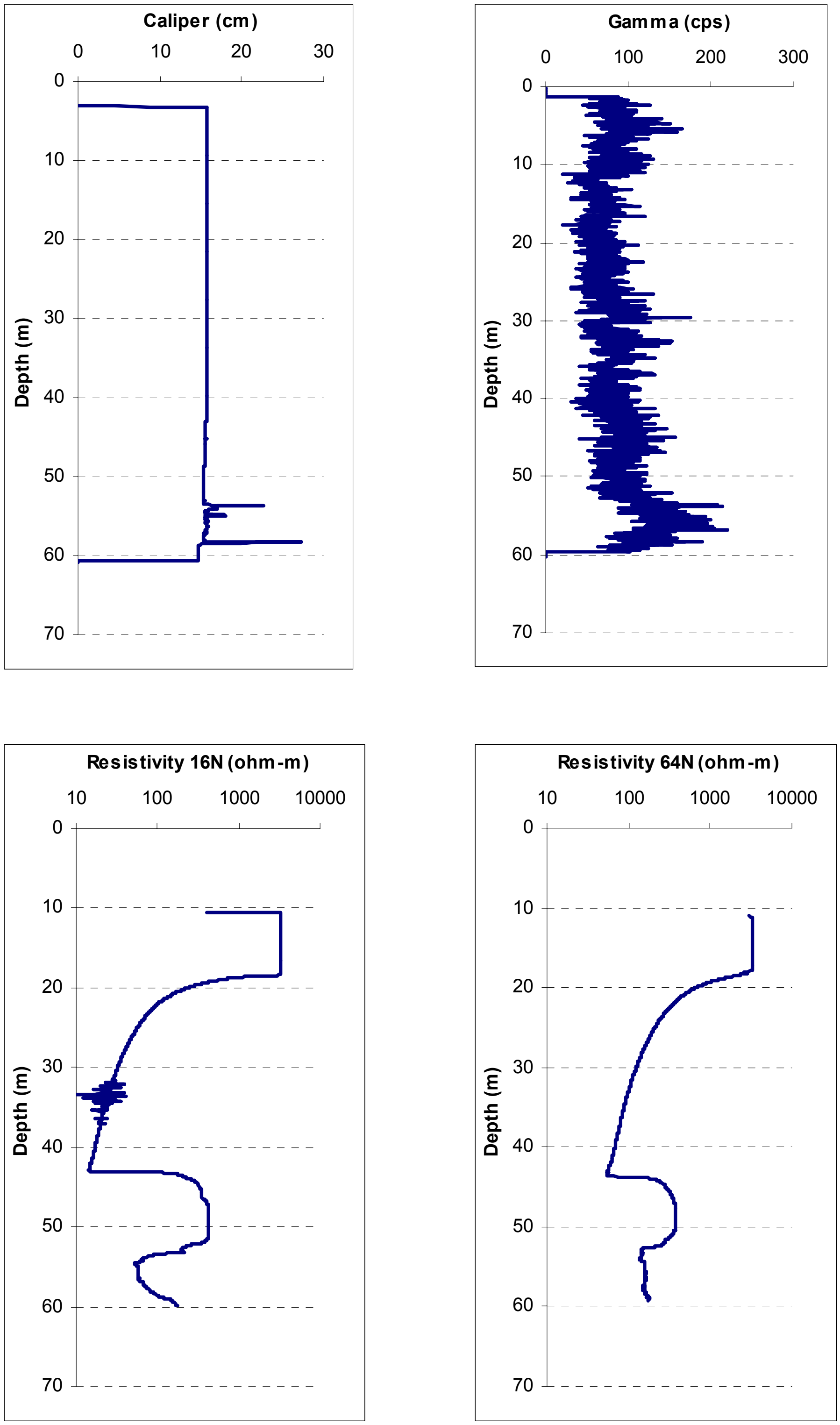
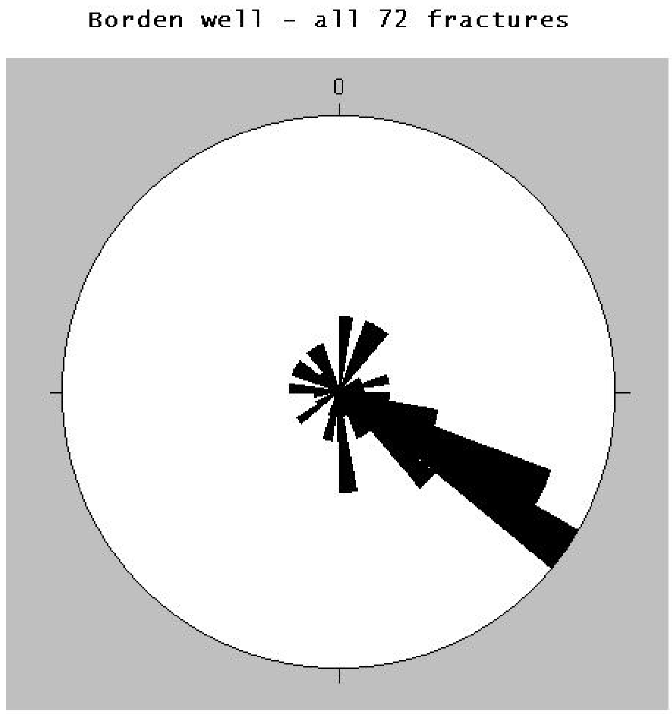


Figure E-17: Geophysics logs as a function of depth, Shediac, NB

Fracture orientation

Borden, Prince Edward Island



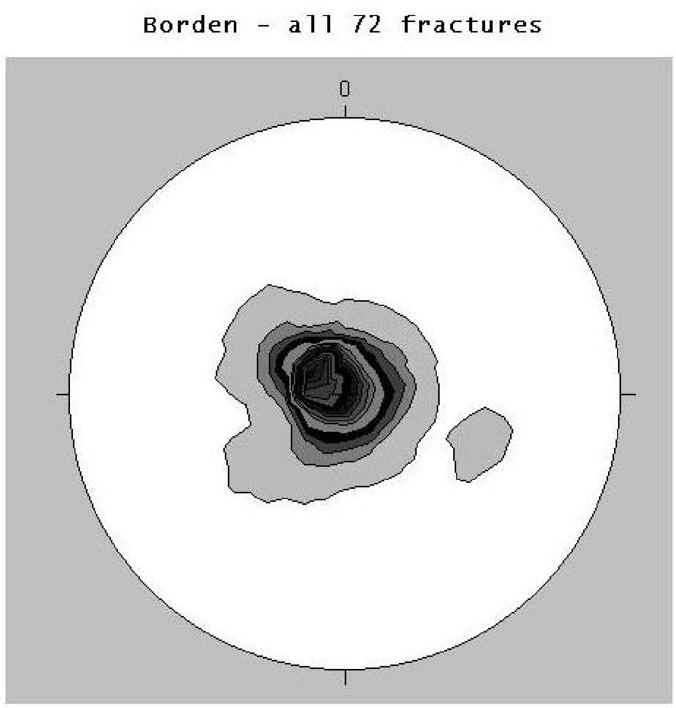


Figure E-18: Rosette diagrams (all fractures), Borden, PEI

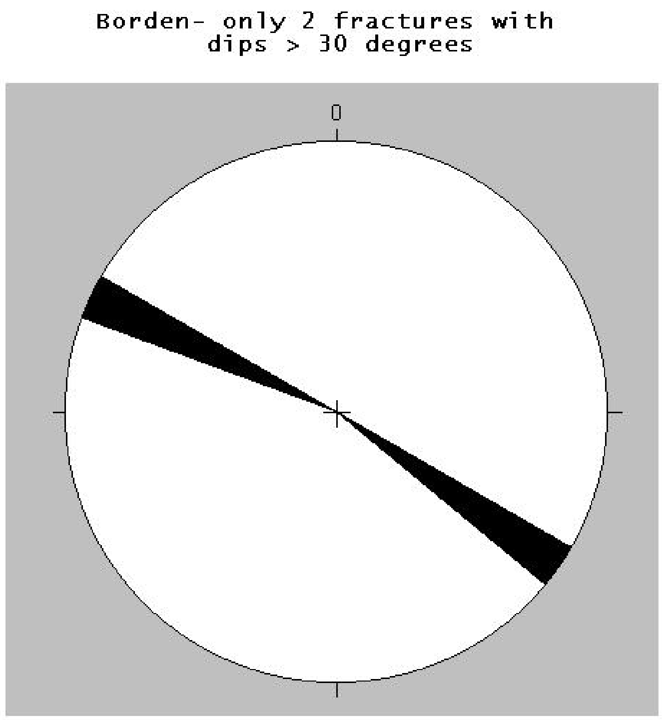
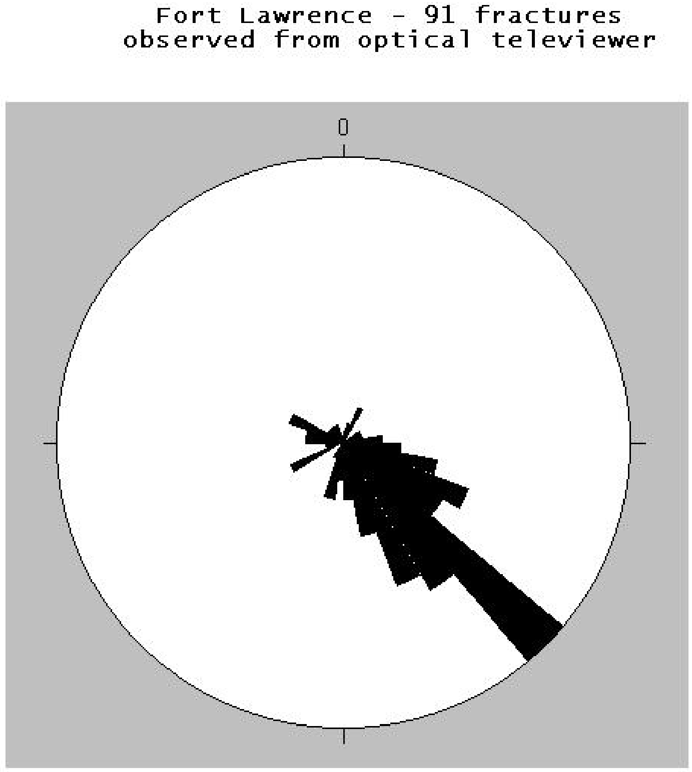


Figure E-19: Rosette diagram (two fractures with dips > 30^o), Borden, PEI

Fort Lawrence, Nova Scotia



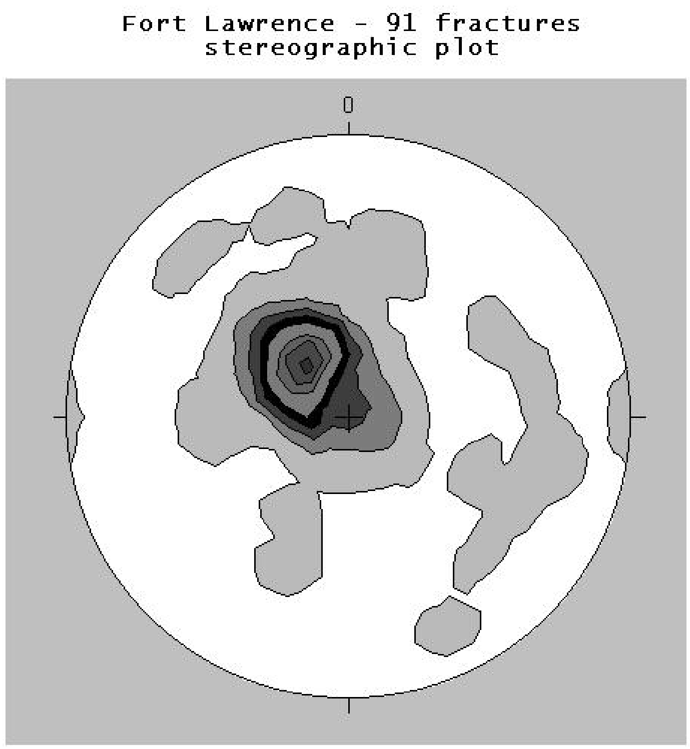
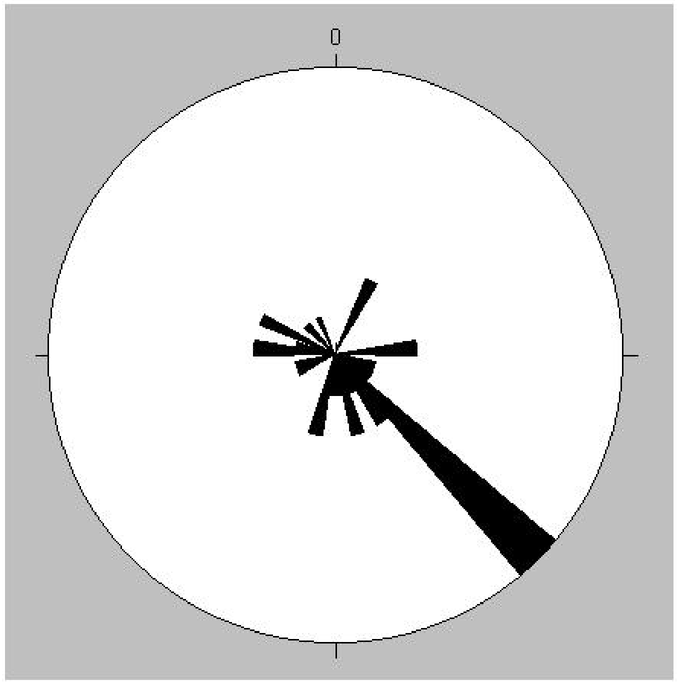


Figure E-20: Rosette diagrams (91 fractures), Fort Lawrence, NS

Fort Lawrence - 32 fractures
with dips > 30 degrees



Fort lawrence - 32 fractures
with dips > 30 degrees
- stereographic plot -

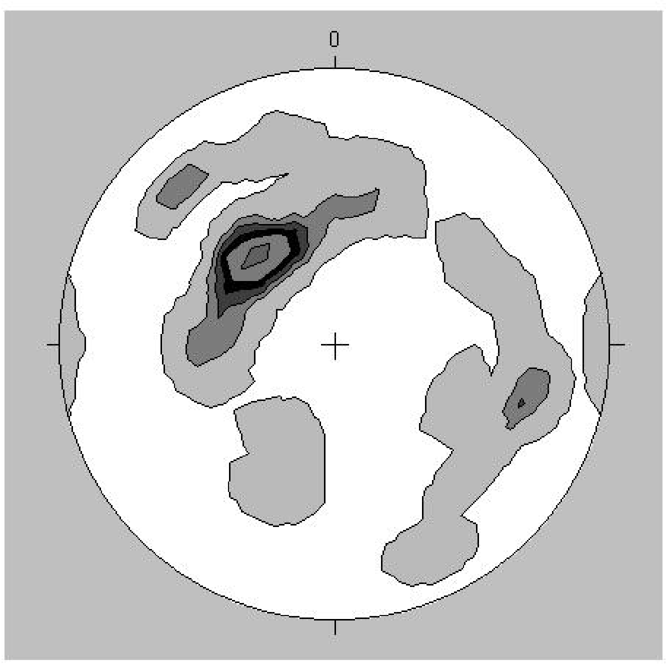
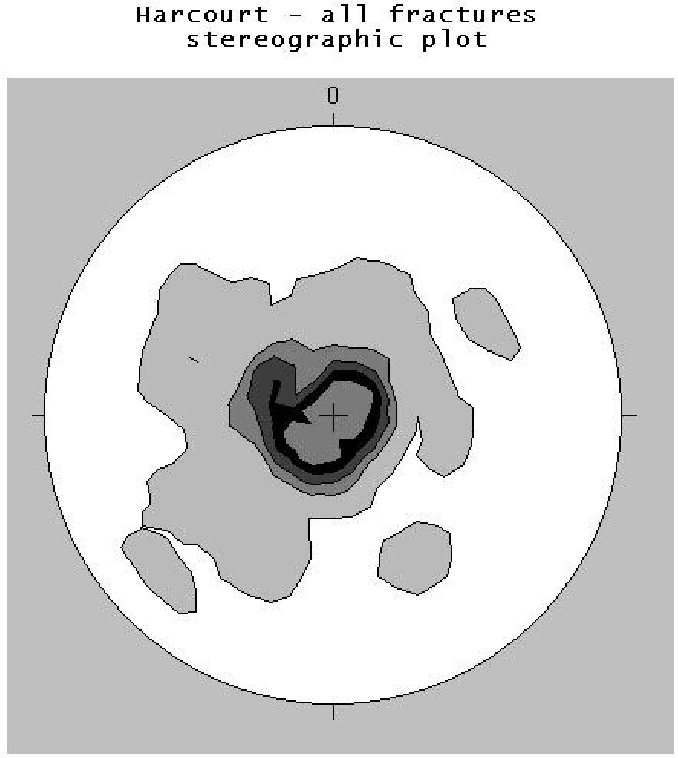


Figure E-21: Rosette diagrams (32 fractures with dips > 30°), Fort Lawrence, NS

Harcourt, New Brunswick



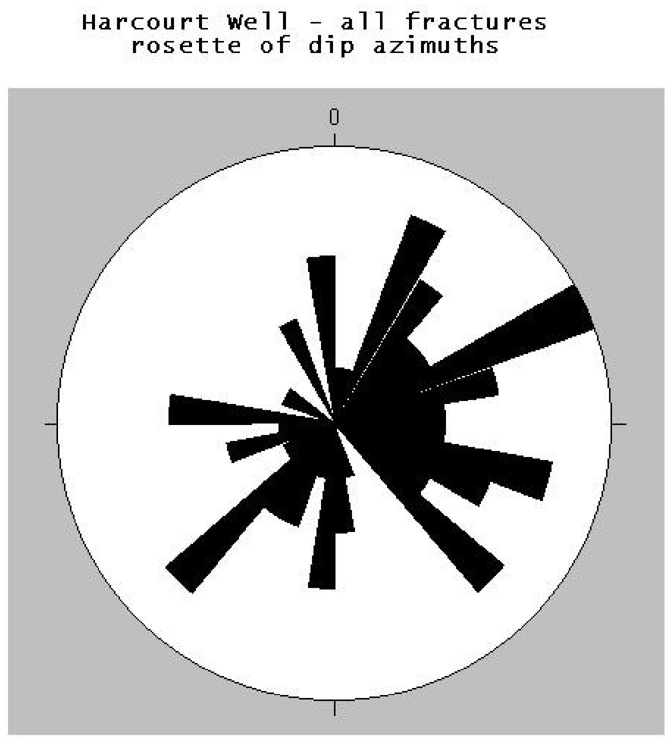
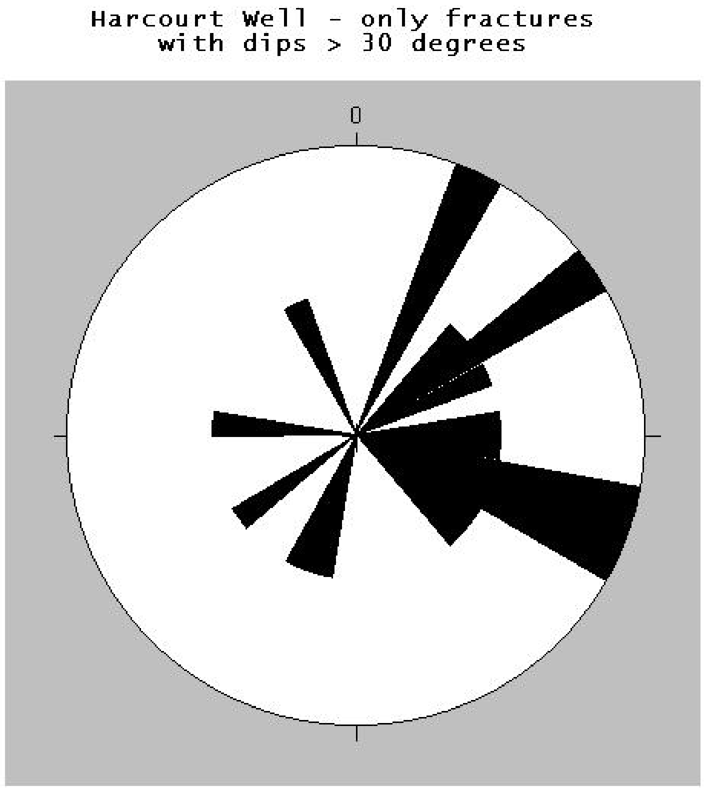


Figure E-22: Rosette diagrams (all fractures), Harcourt, NB



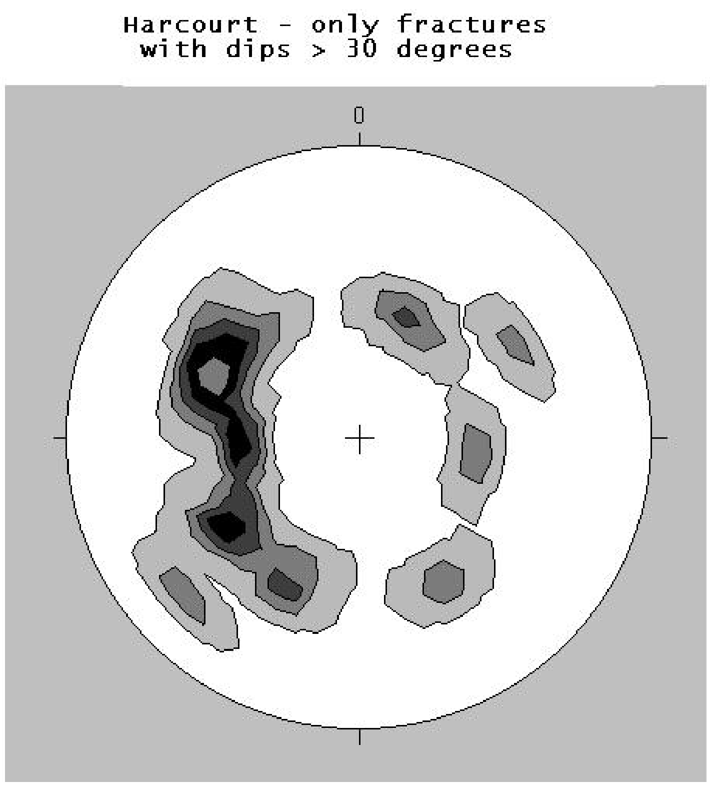
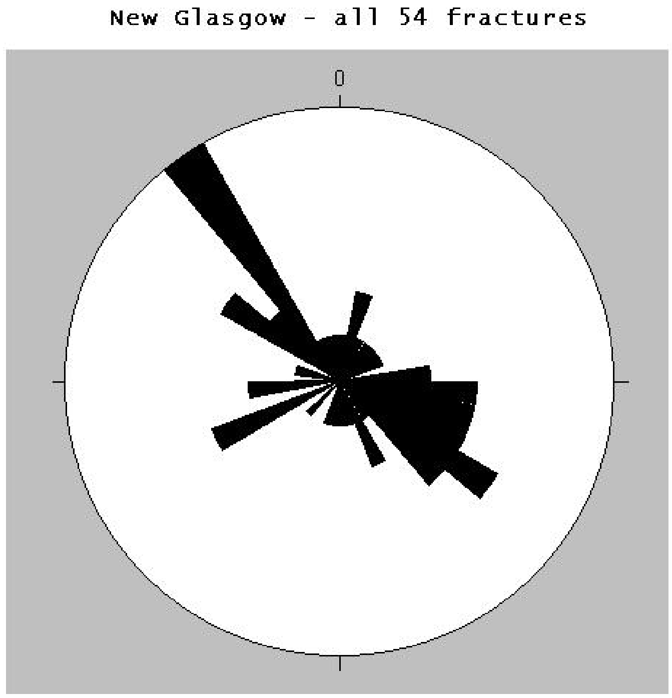


Figure E-23: Rosette diagrams (fractures with dips > 30°), Harcourt, NB

New Glasgow, Prince Edward Island



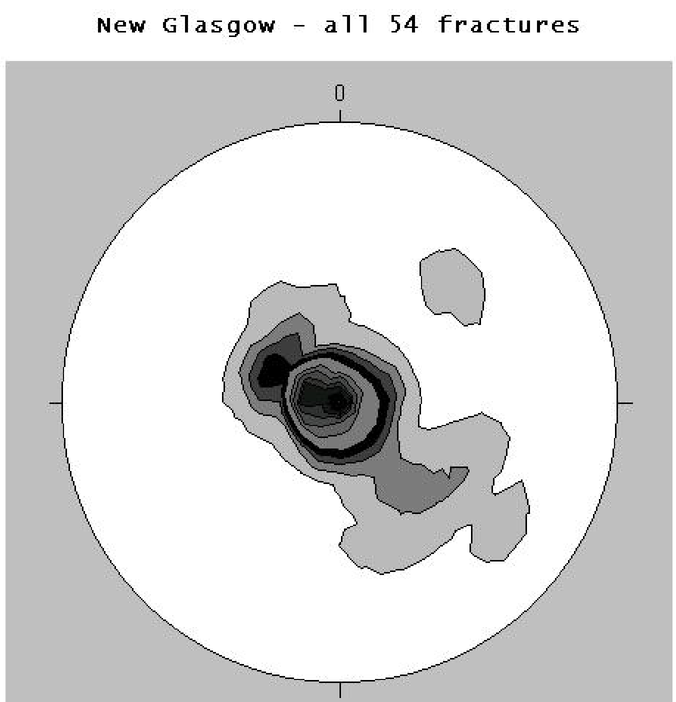


Figure E-24: Rosette diagrams (all fractures), New Glasgow, PEI

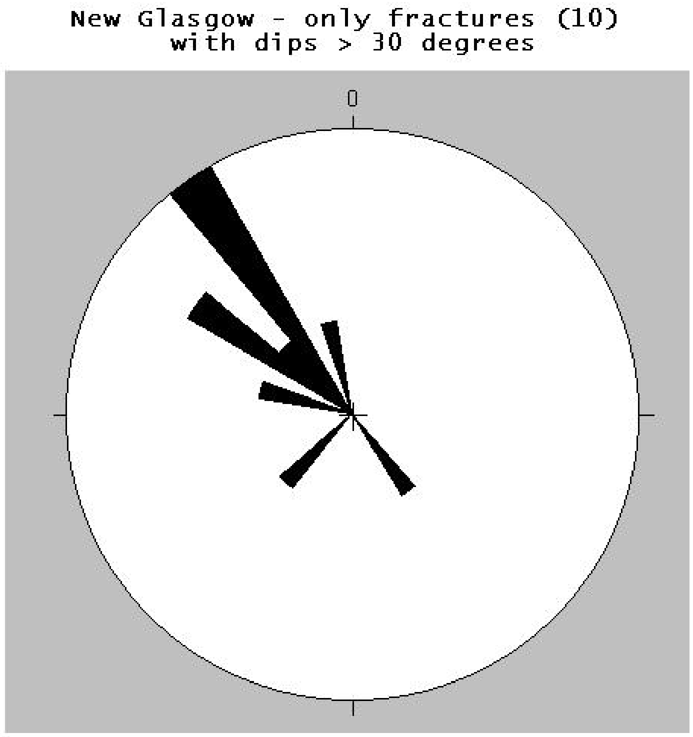
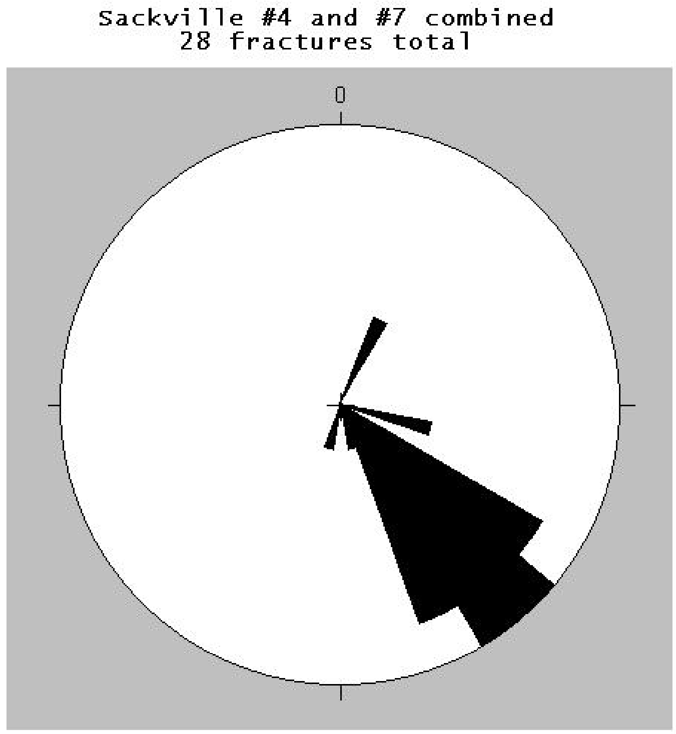


Figure E-25: Rosette diagram (10 fractures with dips > 30^o), New Glasgow, PEI

Sackville, New Brunswick



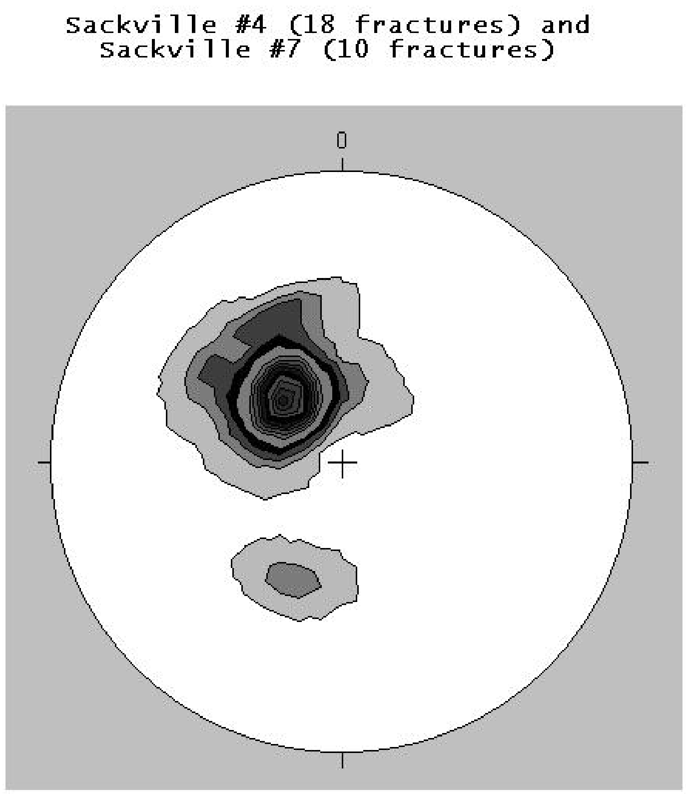


Figure E-26: Rosette diagrams (all fractures), Sackville, NB

Shediac, New Brunswick

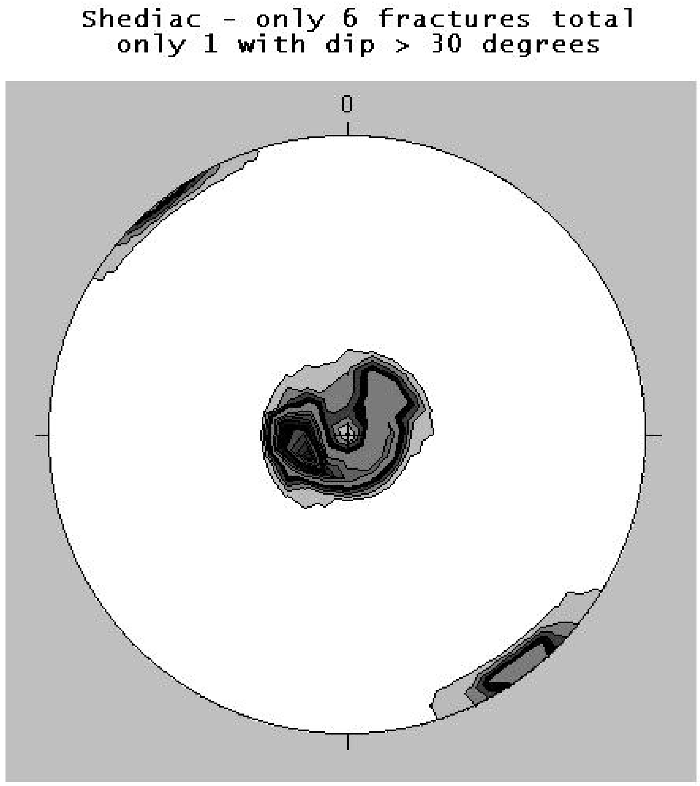


Figure E-27: Rosette diagram (all fractures), Shediac, NB