JACK WATER WELL COMPLAINT REVIEW

Prepared by:
Alexander Blyth, P.Geol., Ph.D.

Alberta Research Council Inc.
Permit to Practice P03619

Prepared for:

Alberta Environment
10th Floor Oxbridge Place
9820 - 106 Street
Edmonton, Alberta T5K 2J6

July 8, 2008

Contact Information:
Alec Blyth
Alberta Research Council Inc.
3608 – 33 Street NW
Calgary, Alberta T2L 2A6
Phone: 403-210-5345
E-mail: blyth@arc.ab.ca

EXECUTIVE SUMMARY

In the fall of 2005, Petrofund Energy Trust (now Penn West Energy Trust) initiated an investigation into a water well complaint by Mr. Bruce Jack regarding methane gas. In November, 2007, Alberta Research Council (ARC) was contracted by AENV to critically review the scientific and technical data contained in the AENV Jack water well complaint file.

ARC's independent review and evaluation involved the examination of all the data contained in the AENV file and the following additional lines of evidence:

- Review of the local and regional geology and hydrostratigraphy.
- Calculation of hydraulic gradients between the aquifer in the Smoky Group and the oil/gas wells in the Charlie Lake Formation.
- An evaluation of mixing scenarios between shallow biogenic gas and conventional gas.

Alberta Research Council's interim report dated February 21, 2008 found insufficient data to determine whether Mr. Jack's well has been impacted by conventional oil/gas wells in the area and made recommendations for additional sampling.

Alberta Research Council's overall conclusion of the evidence from the review of the AENV and ERCB files and new chemical and isotopic data is that Mr. Jack's well has been impacted by a deeper conventional gas source in the area. There appears to be an approximately 2% component of a deeper gas mixed with shallow biogenic gas (likely from shales). The source of the deeper gas could be from natural faults (well documented in the Peace River Arch area) or may be from nearby energy wells, some of which have evidence of gas migration issues.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 INTRODUCTION

Alberta Research Council (ARC) was contracted by Alberta Environment (AENV) to conduct a review of the technical and scientific data on the subject of a complaint placed by landowner Mr. Jack, located SW-12-078-08 W6M, near Spirit River, Alberta. The complaint was about conventional oil and gas activities undertaken by Penn West and his concerns about the presence of methane gas in his water well. ARC undertook this review to assess whether the evidence suggests that energy resource extraction operations have impacted the water quality on the landowner's property through the migration of hydrocarbons from energy wells to the water well. ARC agreed to work under contract to AENV to independently assess the situation and provide conclusions identifying whether or not the AENV investigation suggests groundwater has been impacted by conventional oil/gas extraction activities in the area.

This report summarizes ARC's independent conclusions based on scientific and technical data surrounding the investigation of the complaint. The review is based primarily on the collected information in AENV's water well complaint file. Available scientific and technical data include gas composition and isotope data from the Jack well, water well construction characteristics, oil and gas well drilling and completion information, and oil and gas well composition and isotope data. In addition, ARC endeavoured to compile, review and assess supplementary information not included within the complaint file. This supplementary information includes an evaluation of the regional geology and hydrogeology, and additional ERCB information on energy wells.

2 REGIONAL GEOLOGIC AND HYDROGEOLOGIC SETTING

2.1 Stratigraphy

The study area is found within the Alberta Basin. A complete review of the geology of the basin is provided in Mossop and Shetsen (1994). A brief overview is given below. The Alberta basin originated in the late Proterozoic by rifting of the North American craton and early sedimentary deposition was dominated by carbonates, evaporates and shale. Uplift of the Rocky Mountains in the early Cretaceous deposited fluvial sandstones and shales into the developing foreland basin. The changing sea levels during the middle to late Cretaceous resulted in deposition of marine shale and coal-bearing fluvial sandstone. A period of compression and uplift in the Tertiary led to the deposition of fluvial sandstone, siltstone and shale. Peat accumulation provided the source material for the coals in the Cretaceous/Tertiary Scollard Formation and the Tertiary Paskapoo Formation. Glaciation during the Quaternary eroded the bedrock and deposited unconsolidated sediments on the bedrock. A stratigraphic column for the Northwestern Plains and Deep Basin is presented in Figure 1. The Peace River Arch Region is well documented to contain numerous structural faults (Cant 1988; O'Connell 1994). Descriptions of the geology from older to younger that are encountered in the area of investigation are as follows:

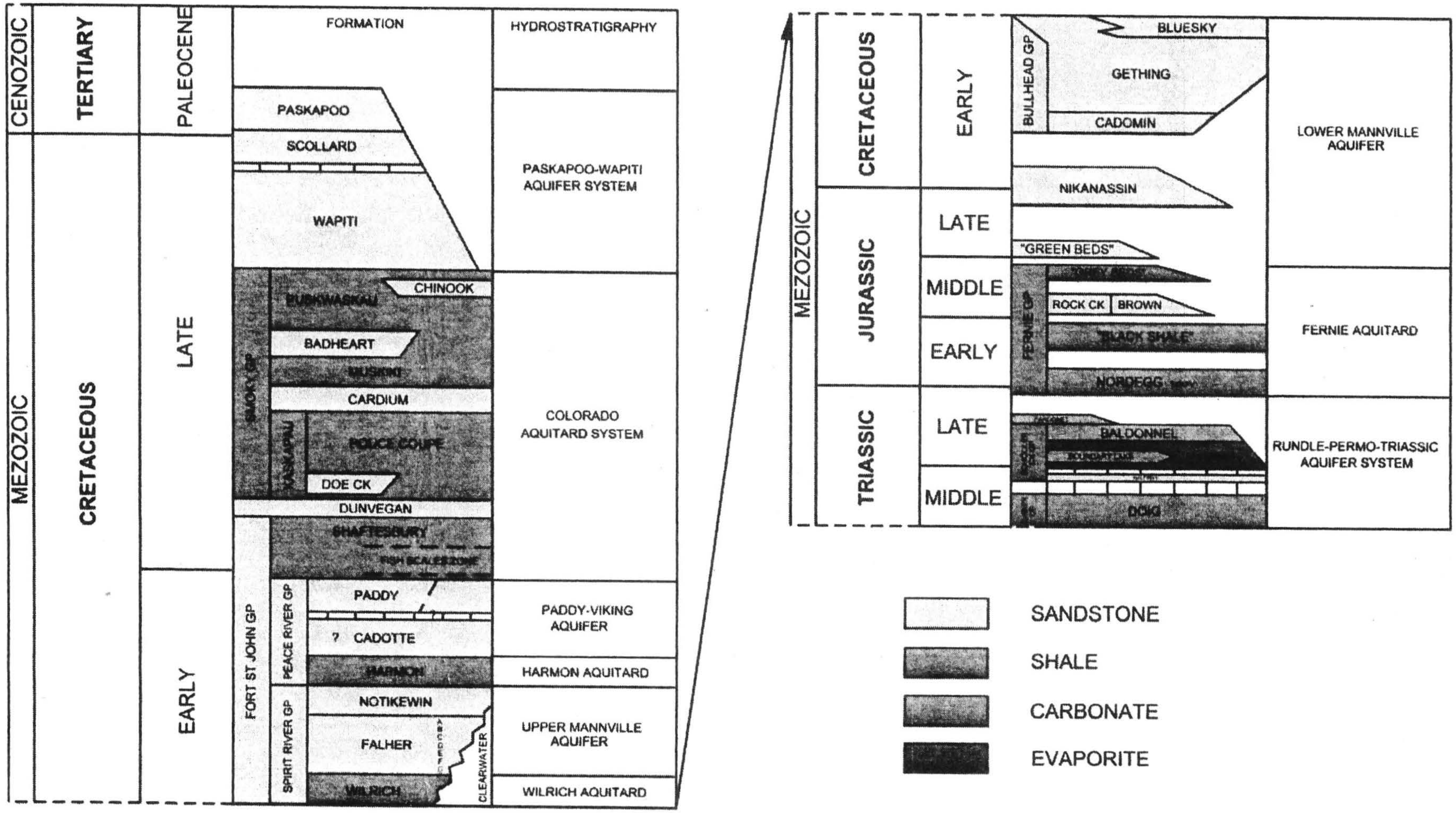


Figure 1 Stratigraphic column for the Northwestern Plains and Deep Basin.

Schooler Creek Group

The Schooler Creek Group, including the Charlie Lake and Baldonnel Formations are Late Triassic aged sediments that were continental shelf deposits on a passive margin. The Charlie lake Formation consists of sandstones, siltstones and anhydrite, deposited in near-shore marine, tidal flat, lagoon and aeolian environments. This formation is the target of all of the area energy wells and produces oil and some gas. The Baldonnel Formation consists of dolostones deposited on the continental slope.

Fernie Group

The Early Jurassic Fernie Group sediments (Nordegg Formation) are continental platform derived limestones and shales. The later formations (Black Shale, Rock Creek and Grey Beds are shales and sandstones are early sediments associated with the foredeep trough caused by the Columbian orogeny. The Nordegg Formation produces oil and gas, and the Rock Creek Formation produces gas.

Nikanassin Formation, Bullhead Group and the Fort St John Group

These Early Cretaceous rocks represent sediments derived from orogenic (mountain building) activity in south-western Alberta. The Nikanassin, Bullhead Group and Fort St John Group (equivalent to the Manville group in central Alberta) are predominantly fine sandstone and siltstone and interbedded sandstone with shale. These rocks contain oil and gas.

Dunvegan Formation

The Late Cretaceous Dunvegan Formation consists of argillaceous siltstone deposited in a fluviodeltaic setting. This formation contains oil and natural gas.

Smoky Group

The Late Cretaceous Smokey Group (equivalent to the Colorado group in central Alberta) is predominantly transgressive marine shale with several regressive events represented by sandstone. Several formations within this group contain oil and/or gas including the Doe Creek Cardium and Chinook Formations. The Jack well is completed in shale and sandstone of the Smoky Group at a depth of about 50 m.

In the area, the Smoky Group is covered by quaternary unconsolidated sediments and till.

2.2 Regional Stress Regime

The stress regime of upper Cretaceous – Tertiary coal-bearing strata in Alberta has a strong correlation to permeability and fracture directions in coal (face cleats). This in turn has a strong control on the direction that "fluids" (both gas and water) tend to migrate in these strata. Rock mechanics theory and field measurements shows that fractures trend in a direction normal to the least compressive stress. Horizontal stress orientations in Alberta have been measured using well breakout analyses (i.e. damage to boreholes caused by stresses acting on the rock)

(Bachu and Michael 2002). Based on breakout analysis the most likely azimuth (orientation) of fractures and face cleats in the coal would be about 055°E of N. Several energy wells (within 1.5 km) line up on the 055° azimuth to the Jack well. These wells, and others, will be examined in section 3 below.

2.3 Hydrostratigraphy and Groundwater Flow and Gradients

Regional flow systems across the Alberta Basin are controlled in part by major recharge areas along the Rocky Mountain front in western Alberta. Regional flow within the basin is northeast towards the basin edge (Hitchon 1969a,b).

In the Spirit River area shallow groundwater flow in the overburden is likely directed northeast towards Howard Creek and the Ksituan River.

Regional groundwater flow in the Smokey Group (where the Jack well is completed) is confined to relatively thin sandstone aquifers (Dunvegan, Cardium and Badheart) within a predominant aquitard system. Flow is directed to the northeast (Hitchon et al. 1990). Hydraulic conductivities of the rock are expected to be low to intermediate and yields from wells in this area are expected to be less than 1 imperial gallons per minute (Hackbarth 1977).

In the deeper (below 800 m) Paddy-Viking aquifer system groundwater flow is directed southeast towards a closed hydraulic head low. The permeability of this aquifer system is low, on the order of a few millidarcy (Hitchon et al. 1990). The Harmon aquitard separates the Paddy-Viking aquifer system from the Upper Mannville Aquifer.

Flow in the Upper Mannville Aquifer (Notikewin and Falher Formations) is directed to the northeast. Again, the permeability of this aquifer system is low, on the order of a few millidarcy (Hitchon et al. 1990). The Wilrich aquitard, the major aquitard in the Peace Rivers area, separates the Upper Mannville Aquifer from the Lower Mannville Aquifer.

Flow in the Lower Mannville Aquifer (Bluesky, Gething, Cadomin and Nikanassin) is directed to the northeast. The permeability of this aquifer system is low, on the order of a few millidarcy (Hitchon et al. 1990). The Fernie aquitard separates the Lower Mannville Aquifer from the Rundle-Permo-Triassic aquifer system. Flow in the Rundle-Permo-Triassic aquifer system is directed to the northeast.

3 ENERGY WELL INFORMATION

A map of the energy wells within an approximate 2 km radius of the Jack well was provided in the May 2007 Matrix Solutions Inc report and has been reproduced here (Figure 2). A summary of the cementing details for these energy wells is presented in Table 1. Several energy wells in the vicinity of the Jack well have surface casing vent flows (SCVF). SCVF are not necessarily an indication of shallow aquifers being impacted. However, there are potential concerns for energy wells with apparently good surface casing but have lower zones that may be leaking. The fresh water aquifers are not necessarily protected. The integrity of the surface casing cement needs to be considered. The cement log details just confirm the cement comes to the surface, but not whether there is a good bond to the formation and casing, or that there is no channelling. As well, there could be potential pathways outside of the borehole. There could be formation damage due to drilling, natural pathways (less likely) or induced pathways (potentially caused by temporarily closing the SCV) that could lead to gas migration to an overlying aquifer.

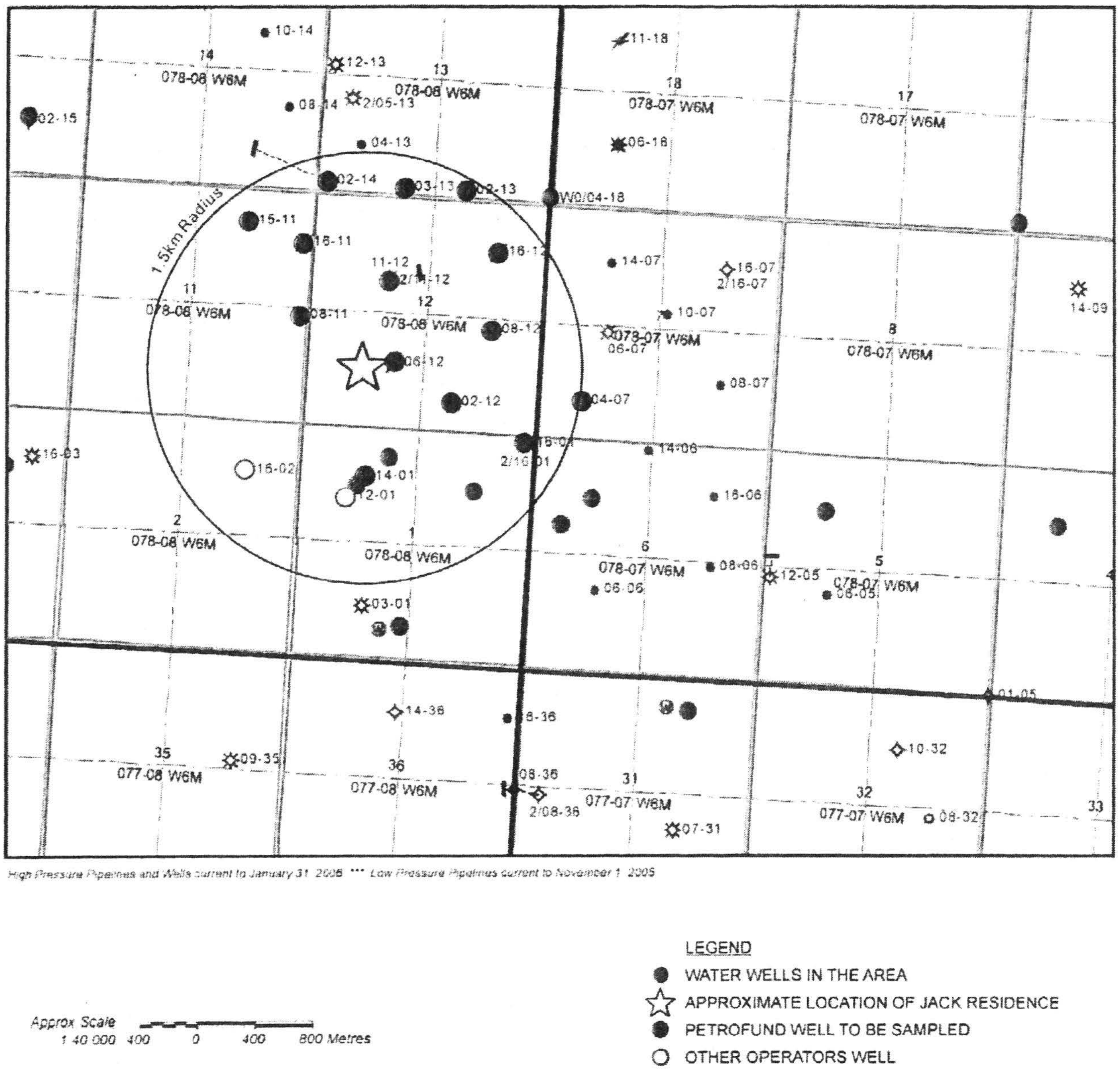


Figure 2 Map location of the Jack residence and surrounding energy wells (from Matrix Solutions 2007).

Several energy wells with SCVF that immediately surround the Jack well are discussed below. The energy well 100/6-12-078-8 W6M is the closest energy well to the Jack water well. The well was originally completed in 1982 as an oil well in the Charlie Lake Formation. In 2003 this well was converted to a water injection well. This well has a surface casing to 298 mKb and had cement returns to the surface. The production casing was cemented in two stages from 1610 to 1163 m Kb and from 1163 mKb to apparently above the bottom of the surface casing. In spite of an apparently acceptable cement job, this well has a surface casing vent flow of 32.1 m^3/day (Lionhead Engineering & Consulting 2006). There is some confusion as to where gas samples were collected from this well. The annulus between the surface casing and the water injection pipe is puckered and filled with inhibited water. The injector pipe should be filled with injection water sourced from 11-18-078-07 W6M. It is not clear from the Maxxam Analytics personnel notes where the "production tubing" sample came from.

An investigation by GChem Ltd (2006) found gas migration from this well. The composition of this gas was indicative of thermogenic gas, with elevated concentrations of methane, ethane and propane (along with butane and pentane above background). Ethane and propane gas concentrations immediately outside the casing were elevated about 2,000 times background values. Isotopic data was not presented by GChem.

The energy well 100/11-12-078-8 W6M was completed in 1980 as a gas well in the Charlie Lake Formation. This well has a surface casing to 252 mKb and had cement returns to the surface. The production casing was cemented from 1628 to 745 m Kb. This well has an uncemented section between 252 and 745 mKb. This well has a surface casing vent flow of 9.8 m^3/day (Lionhead Engineering & Consulting 2006). An investigation by GChem Ltd (2006) found gas migration from this well. The composition of this gas was indicative of thermogenic gas, with elevated concentrations of methane, ethane and propane (along with butane and pentane above background). Ethane and propane gas concentrations immediately outside the casing were elevated about 50 times background values. Isotopic data was not presented. Isotopic data was not presented.

The energy well 102/11-12-078-8 W6M was completed in 2004 as an oil well in the Charlie Lake Formation. This well has a surface casing to 269 mKb and had cement returns to the surface. The production casing was cemented in two stages from 1620 to 810 m Kb and from 810 to the surface casing. In spite of an apparently acceptable cement job, this well has a surface casing vent flow of 1.4 m^3/day (Lionhead Engineering & Consulting 2006). An investigation by GChem Ltd (2006) found gas migration from this well. The composition of this gas was indicative of thermogenic gas, with elevated concentrations of methane, ethane and propane (along with butane and pentane above background). Ethane and propane gas concentrations immediately outside the casing were elevated about 100 times background values. Isotopic data was not presented.

The energy well 100/16-12-078-8 W6M was completed in 1988 as an oil well in the Charlie Lake Formation. In 1998 this well was converted to a water injection well. This well has a surface casing to 224.6 mKb and had cement returns to the surface. The production casing was cemented from 840 to 1572 m Kb. This well has an uncemented section between 252 and 745 mKb. This well has a surface casing vent flow of 41.6 m^3/day (Lionhead Engineering & Consulting 2006).

The energy well 100/14-01-078-8 W6M was completed in 1982 as an oil well in the Charlie Lake Formation. This well has a surface casing to 290 mKb and had cement returns to the surface. The production casing was cemented in two stages from 1680 to 1102.5 m Kb and from 1102.5 to 543 mKb. This well has an uncemented section between 290 and 543 mKb. This well has a surface casing vent flow of 90.5 m^3/day (Lionhead Engineering & Consulting 2006).

Information regarding the jack well and surrounding energy well events is presented as a Gantt (time) chart on Figure 3. Information was collected from the ERCB database, AENV water well data base and information supplied by Mr. Jack through his attorney Mr. Ron Kruhlak. At a meeting on February 25, 2008 Mr. Jack indicated that sediment showed up in his well starting on March 1, 2003. He pumped the well for about 4 weeks and then gas started coming from his well. He associated the sediment in his well with a remedial cement squeeze done on energy well 100/2-14-078-0 W6M located approximately 1400 m from the jack well. The remedial cement squeeze on 100/2-14-078-0 W6M was done on October 11, 2001, 1 year and 5 months before sediment and gas appeared in Mr. Jack's well. The timing of sediment in the jack well roughly corresponds (but actually pre-dates) an acid treatment of the energy well at 100/2-14-078-0 W6M. The closest energy well to the Jack water well is 6-12-078-08 W6M, located approximately 200 m away. This well was completed as an oil well in 1982 and was converted to a water injection well. This well actually started injecting water on November 18, 2003; over seven months after gas appeared in Mr. Jack's water well. It does not appear that gas in Mr. Jack's water well is directly related to conversion of this well to an injector.

Table 1 Summary of ERCB and Lionhead Engineering and Consulting Ltd review of cementing details from energy wells in the vicinity of the Jack well.

Designation	WELL ID	Pool or Zone	Status	Surface Casing Cement			Production Casing Cement (Stage 1)		Production Casing Cement (Stage 2)		Uncemtnted Zones		Cement Bond Log	SCVF
				Top (mKb)	Bottom (mKb)	Returns (m3)	Top (mKb)	Bottom (mKb)	Top (mKb)	Bottom (mKb)	Top (mKb)	Bottom (mKb)		
Jack Well	SW-12-078-08 W6M	Smoky Group	Water well	0	36.58	0	--	--	--	--	--	--	No	--
Energy Well	100/06-05-078-07 W6M	Charlie Lake Fm	Pumping oil	0.0	205.0	Yes	770.0	1638.0	--	--	205.0	770.0	--	Yes
Energy Well	100/12-05-078-07 W6M	Charlie Lake Fm	Flowing gas	0.0	226.8	Yes	Not logged	1633.0	0.0	655.0	?	?	--	Yes
Energy Well	100/06-06-078-07 W4M	Charlie Lake Fm	Pumping oil	0.0	188.0	Yes	<850.0	1746.0	--	--	205.0	<850.0	Yes	Yes
Energy Well	100/08-06-078-07 W6M	Charlie Lake Fm	Pumping oil	0.0	207.0	Yes	?	1624.0	--	--	?	?	--	Yes
Energy Well	100/14-06-078-07 W6M	Charlie Lake Fm	Pumping oil	0.0	206.0	Yes	?	1580.0	--	--	?	?	--	Yes
Energy Well	100/04-07-078-07 W6M	Charlie Lake Fm	Pumping oil	0.0	256.0	3.0	780.0	1576.0	Not logged	780.0	--	--	Yes	No
Energy Well	100/06-07-078-07 W6M	Charlie Lake Fm	Water Injection	0.0	208.5	Yes	<1047.0	1653.0	--	--	208.5	<1047.0	Yes	Yes
Energy Well	100/08-07-078-07 W6M	Charlie Lake Fm	Pumping oil	0.0	236.0	Yes	?	1555.0	--	--	?	?	--	Yes
Energy Well	100/14-07-078-07 W6M	Gething Fm	Flowing Gas	0.0	210.0	Yes	?	1565.0	--	--	?	?	--	Yes
Energy Well	100/14-01-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	290.0	5.0	1102.5	1680.0	534.0	1102.5	290.0	543.0	Yes	Yes
Energy Well	100/16-01-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	283.9	5.0	1183.0	1596.0	1183.0	400.0	283.9	400.0	Yes	No
Energy Well	102/16-01-078-08 W6M	Charlie Lake Fm	Flowing oil	0.0	256.0	4.0	816.0	1555.0	0.0	816.0	--	--	Yes	No
Energy Well	100/08-11-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	222.0	Yes	240.0	1638.0	--	--	222.0	240.0	Yes	No
Energy Well	100/15-11-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	255.0	3.5	800.0	1598.0	Not logged	800.0	--	--	Yes	No
Energy Well	100/16-11-078-08 W6M	Charlie Lake Fm	Water Injection	0.0	223.0	Yes	335.0	1638.0	--	--	223.0	335.0	Yes	Yes
Energy Well	100/02-12-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	255.4	--	808.0	1607.0	Not logged	808.0	--	--	Yes	No
Energy Well	100/06-12-078-08 W6M	Charlie Lake Fm	Water Injection	0.0	298.0	2.0	1163.0	1610.0	Not logged	1163.0	?	?	Yes	Yes
Energy Well	100/08-12-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	204.0	3.0	1097.0	1582.0	Not logged	1097.0	--	--	Yes	No
Energy Well	100/11-12-078-08 W6M	Charlie Lake Fm	Flowing Gas	0.0	252.0	4.0	745.0	1628.0	--	--	252.0	745.0	Yes	Yes
Energy Well	102/11-12-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	269.0	4.0	801.0	1620.0	Not logged	801.0	?	?	Yes	Yes
Energy Well	100/16-12-078-08 W6M	Charlie Lake Fm	Water Injection	0.0	224.6	6.0	1243.0	1571.2	840.0	1103.5	224.6	840.0	Yes	Yes
Energy Well	100/02-13-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	256.0	2.5	795.0	1570.0	125.0	795.0	--	--	Yes	Yes
Energy Well	100/03-13-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	352.0	5.0	1297.0	1576.0	120.0	1297.0	--	--	Yes	No
Energy Well	100/04-13-078-08 W6M	Charlie Lake Fm	Flowing oil	0.0	269.0	4.0	800.0	1582.0	0.0	800.0	--	--	Yes	No
Energy Well	100/02-14-078-08 W6M	Charlie Lake Fm	Pumping oil	0.0	290.0	8.0	390.0	1658.5	0.0	390.0	--	--	Yes	No
Energy Well	100/16-14-078-08 W4M	Charlie Lake Fm	Flowing oil	0.0	259.0	Yes	858.0	1575.0	0.0	858.0	--	--	--	Yes
Energy Well	100/08-23-078-08 W6M	Gething Fm	Flowing gas	0.0	256.0	Yes	860.0	1565.0	0.0	860.0	--	--	--	Yes

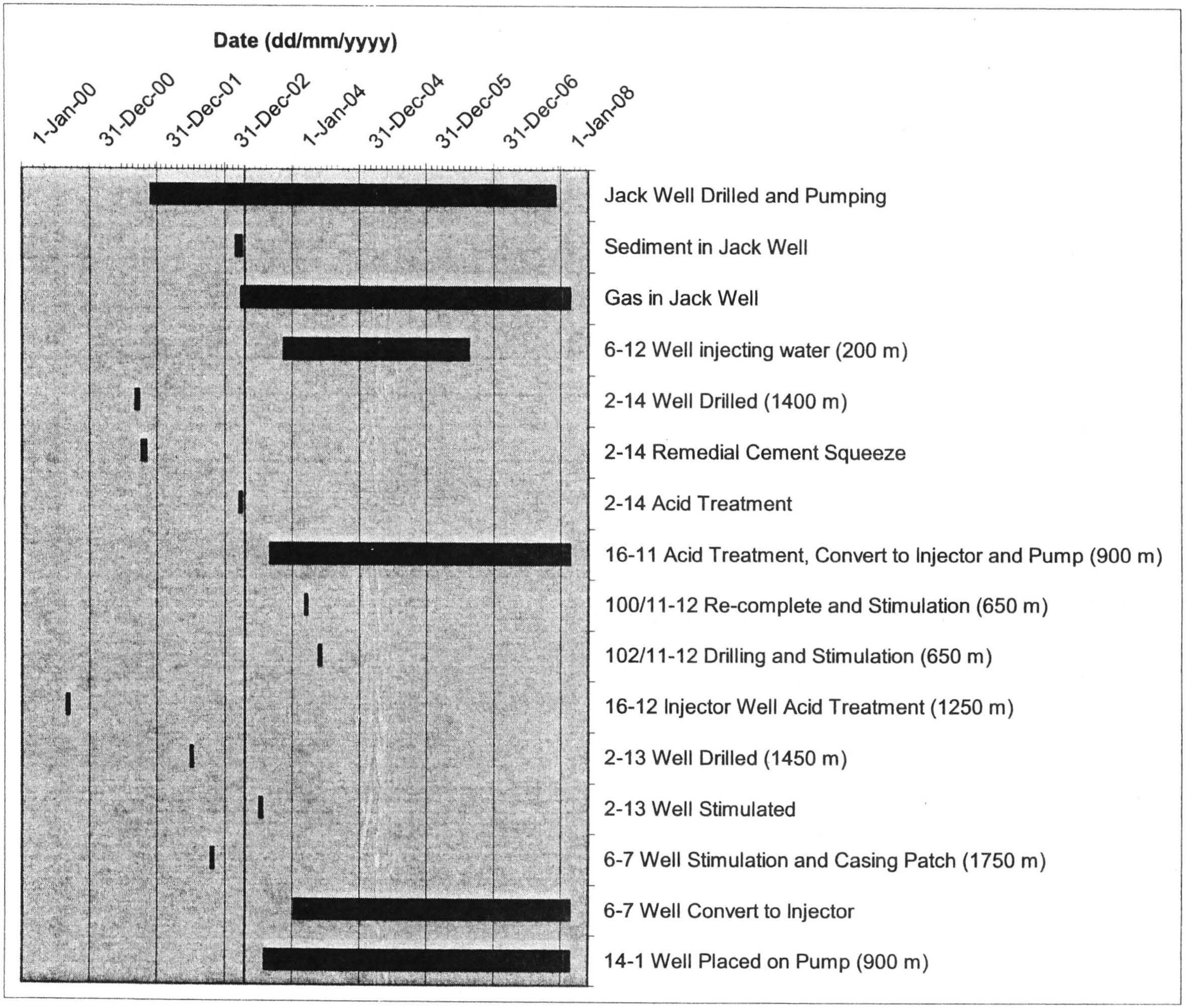


Figure 3 Gantt chart showing timing of events surrounding gas occurrence in the Jack water well.

4 JACK WATER WELL INFORMATION

4.1 Initiation of Well Complaint

In the fall of 2005, Petrofund Energy Trust (now Penn West Energy Trust) initiated an investigation into a water well complaint by Mr. Bruce Jack regarding methane gas.

4.2 Well Design, Construction and Maintenance

A water well drilling report is available, through the AENV Groundwater Information Centre (GIC) (Well ID # 0299882), and is presented in Figure 4. The well was drilled and completed by Du-All Drilling from Valhalla Centre, AB on November 19, 2001. The borehole was drilled and a 141 mm diameter steel casing was inserted to 36.58 m and seated into the bedrock (Figure 5). After reaching competent bedrock and setting the casing, bentonite chips were poured into the annulus between the borehole and the casing. This method of sealing is not preferred, as there is no way to ensure a proper seal the entire length of the annulus. The hole was then drilled further to the total depth of the well which is approximately 60.96 m. A liner was installed from 30.5 to 60.96 m in the well to prevent loose material from the borehole wall entering the well. The liner was perforated by saw from 47.2 to 54.9 m. The casing extends above ground surface. Regular shock chlorination has not been performed on this well.

As part of water and gas sampling of the Jack well performed by AENV and ARC on February 20, 2008, the water well was visually inspected using a submersible video camera. The well construction corresponds to the drilling report in general, except that the screened interval is from 43.1 to 55.8 m for a total screened length of 12.7 m. The slots on the liner appear to be saw cut. Gas was observed entering the well at the top set of saw perforations on the liner (43.0 to 43.3 m). Below this level, no gas bubbles were observed in the water column. The liner was stained black, most likely from bacteria (IRB and SRB). The intake of the pump intake was at 46.75 m and the total available head of water was 20.4 m. The pump is set below the top perforations on the liner. Large free gas bubbles emerging from the the upper slots of the liner would not be entrained in the water pumped from the well. This is why the casing produces a large amount of gas, yet the amount in the water is much less (and the pump does not "gas lock"). The total depth of the well was approximately 54 m. Sediment has most likely filled in the bottom part of the well.

Alberta Environment

Water Well Drilling Report

The data contained in this report is supplied by the Driller. The province disclaims responsibility for its accuracy.

Well I.D.:	1820001
Map Verified:	Not Verified
Date Report Received:	2006/10/06
Measurements:	Imperial

1. Contractor & Well Owner Information

Company Name: DU-ALL DRILLING — Drilling Company Approval No.: 124424

Mailing Address: BOX 10 — City or Town: VALHALLA CENTRE AB CA — Postal Code: T0H 3M0

WellOwner's Name: JACK, BRUCE — Well Location Identifier:

P.O. Box Number: — Mailing Address: — Postal Code:

City: SPIRIT RIVER — Province: AB — Country: CA

2. Well Location

1/4 or LSD	Sec	Twp	Rge	Westof M
SW	12	078	08	6

Location in Quarter
FT from N Boundary
FT from E Boundary

Lot Block Plan

Well Elev: FT — How Obtain: Not Obtain

3. Drilling Information

Type of Work: New Well
Reclaimed Well
Date Reclaimed: — Materials Used: Unknown
Method of Drilling: Rotary
Flowing Well: No — Rate: Gallons
Gas Present: No — Oil Present: No

Proposed well use: Domestic & Stock
Anticipated Water Requirements/day 5000 Gallons

4. Formation Log

Depth from ground level (feet)	Lithology Description
105	Gray Till
141	Gray Medium Grained Shale
150	Brown Sandy Shale
164	Light Gray Shale
181	Dark Gray Shale & Sandstone
200	Dark Gray Shale

5. Well Completion

Date Started(yyyy/mm/dd): 2001/11/19 — Date Completed(yyyy/mm/dd): 2001/11/19
Well Depth: 200 FT — Borehole Diameter: 7.02 Inches
Casing Type: Steel — Liner Type: Plastic
Size OD: 5.562 Inches — Size OD: 4.5 Inches
Wall Thickness: 0.188 Inches — Wall Thickness: 0.144 Inches
Bottom at: 120 FT — Top: 100 FT Bottom: 200 FT
Perforations
from: 155 FT to: 180 FT — Perforations Size: 0.125 Inches x 12 Inches
from: FT to: FT — Inches x Inches
from: FT to: FT — Inches x Inches
Perforated by: Saw
Seal: Driven & Bentonite
from: FT — to: 120 FT
Seal: Shale Trap
from: FT — to: 150 FT
Seal: Other
from: 115 FT — to: FT
Screen Type: Unknown — Screen ID: Inches
from: FT to: FT — Slot Size: Inches
Screen Type: Unknown — Screen ID: Inches
from: FT to: FT — Slot Size: Inches
Screen Installation Method: Unknown
Fittings
Top: Unknown — Bottom: Unknown
Pack: Unknown
Grain Size: — Amount: Unknown
Geophysical Log Taken:
Retained on Files:
Additional Test and/or Pump Data
Chemistries taken By Driller: No
Held: — Documents Held:
Pitless Adapter Type:
Drop Pipe Type:
Length: FT — Diameter: Inches
Comments:
4.181 DARK GRAY SH/SS LAYERS 20 GPM 4.200 DARK GRAY SH LAYERS SEAL TYPE, ALSO K-PACKER

6. Well Yield

Test Date(yyyy/mm/dd): 2001/11/19 — Start Time: 5:05 PM
Test Method: Air
Non pumping static level: 53.4 FT
Rate of water removal: 20 Gallons/Min
Depth of pump intake: 200 FT
Water level at end of pumping: 200 FT
Distance from top of casing to ground level: 24 Inches

Depth To water level (feet)

Drawdown	Elapsed Time Minutes:Sec	Recovery
	1:00	146
	2:00	101
	3:00	86
	4:00	75
	5:00	70
	6:00	66
	7:00	63
	8:00	60.5
	9:00	58.1
	10:00	56.9
	12:00	56
	14:00	55.3
	16:00	55
	20:00	54.2
	25:00	53.8
	30:00	53.6
	35:00	53.5
	120:00	53.4

Total Drawdown: 146.6 FT
If water removal was less than 2 hr duration, reason why:
Recommended pumping rate: 15 Gallons/Min
Recommended pump intake: 175 FT
Type Pump Installed
Pump Type:
Pump Model:
H.P.:
Any further pumptest information? No

7. Contractor Certification

Driller's Name: ALFRED STEINKE
Certification No.: 40861A
This well was constructed in accordance with the Water Well regulation of the Alberta Environmental Protection & Enhancement Act. All information in this report is true.
Signature — Yr Mo Day

Report 1 **Pump Test 1** page1

Figure 4 Water well drilling report for the Jack well.

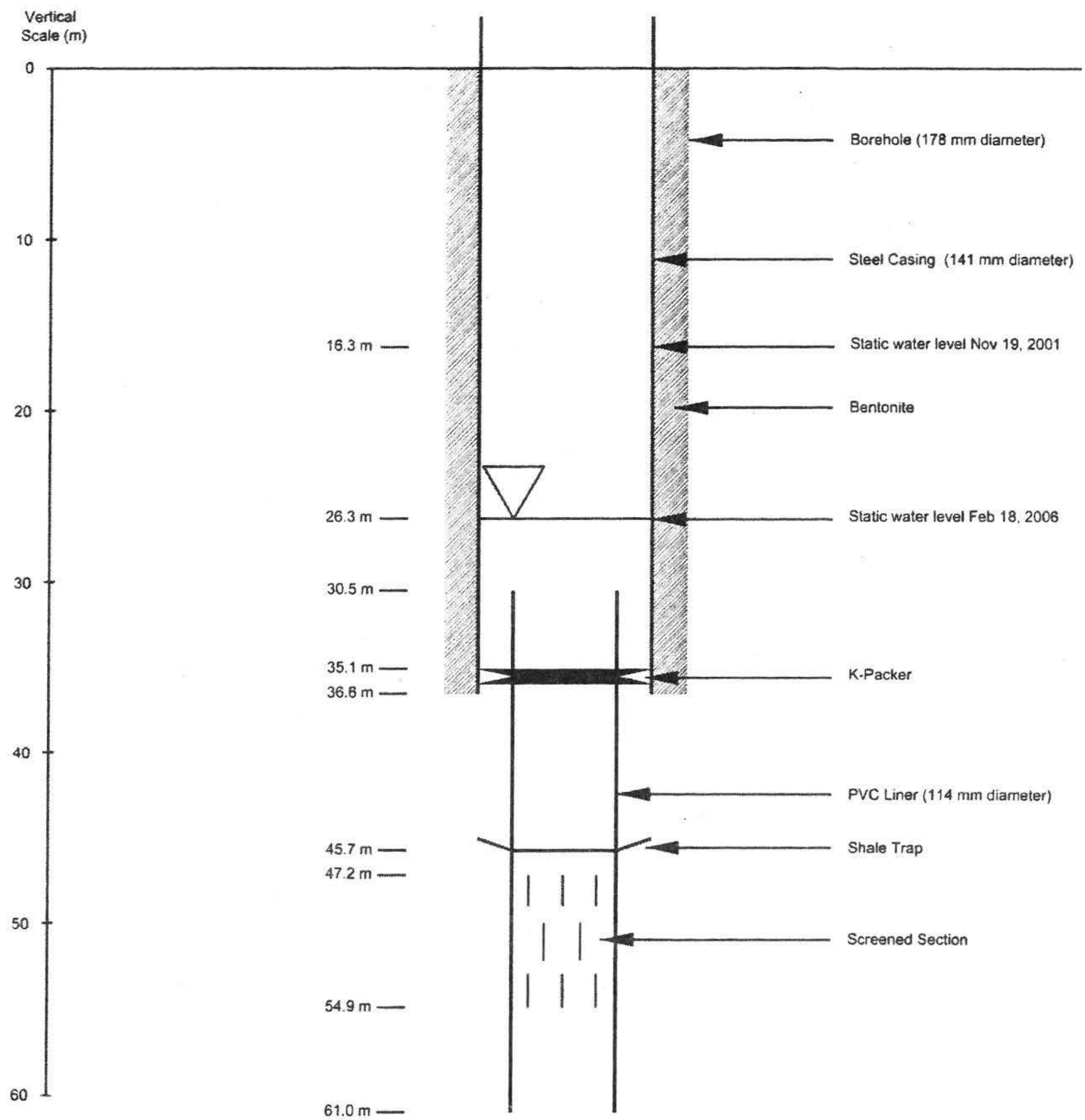


Figure 5 Completion details of the Jack water well.

4.3 Stratigraphy

There is a clear lithology log that indicates that this well is completed in shale and sandstone. The Jack well in the Smoky River Group (Figure 1), with the groundwater bearing zone at a depth of about 50 m (703 MASL).

4.4 Hydrogeology

4.4.1 General Groundwater flow directions

Local and very shallow groundwater flow is likely controlled by topography and flow directions are likely from the Jack well site to Howard Creek and the Ksituan River to the northeast. In the Jack well, the deeper confined groundwater flow within the Smoky Group bedrock is part of the regional groundwater flow system flow directed to the northeast (Hitchon et al 1990).

4.4.2 Vertical Hydraulic Gradient

An estimation was made of the vertical hydraulic gradient between the water bearing zone of the Jack well and that of nearest energy well with pressure data (100/08-12-078-08 W6M about 900 m to the northwest) using the following:

Depth of aquifer in Jack well = 703 MASL.
Depth of Charlie Lake zone well 100/08-12-078-08W6M = -758 MASL.
The head of water in the Jack well = 737 MASL.
A shut-in pressure of 11788 KPa was measured in the Charlie Lake Formation of well 100/08-12-078-08W6M (equivalent to 1204 m of water). Therefore the equivalent head of water in the energy well = 446 MASL assuming density of 1000 kg/m^3 (fresh water).

The vertical gradient is estimated from = $\Delta h/\Delta l$ = (737-446)/(703-(-758) = 0.2. This suggests a downward vertical gradient. If these zones become connected, groundwater would flow down into the energy well. The rate of flow however, is going to be controlled by the hydraulic conductivity along the flow path. For example, if a fracture connects an energy well to an overlying aquifer, the amount of groundwater produced could be significant, but will be controlled by the fracture aperture.

4.4.3 Hydraulic Conductivity

One pumping recovery test was performed on the Jack Well when it was drilled on November 19, 2001. While only recovery data is available and the pumping interval length is not known, an attempt was made to estimate the hydraulic conductivity of the aquifer. The aquifer test data was analysed by ARC for this report using AQTESOLV, Version 3.50 Professional, Aquifer Test Design and Analysis Computer Software (1996-2003 HydroSOLVE Inc.). This software provides analytical solutions for evaluating parameters in confined, unconfined, leaky, or fractured aquifer systems, and allows evaluation of the aquifer test data by visual curve matching to select the most appropriate interpretation to represent aquifer conditions at the site. The raw data and graphical solutions are included in Appendix A.

The Theis (1935) confined aquifer solution was used to solve the recovery portion of the pumping test. An apparent transmissivity of 1.05×10^{-3} m^2/min to 9.79×10^{-3} m^2/min (1.5 to 14.1 m^2/day) was calculated, depending on which part of the recovery curve was analysed. Since no pumping information prior to the recovery test was available, the data was also analysed assuming a slug test was performed (a large slug of water was instantaneously removed from the well and the well was allowed to recover). The Bower and Rice (1976) confined aquifer slug test solution resulted in an apparent hydraulic conductivity of $3.3x10^{-4}$ m/min (equivalent to a transmissivity of 2.5 m^2/day). This value suggests that the aquifer has higher transmissivity than is normally found in sandstone.

On February 18, 2008 (9:24 am) a pumping and recovery test was performed on the Jack well by AENV and ARC. A pressure transducer was installed in the well to record water levels. The existing pump was used to pump the well at 13 IGPM for 154 minutes and then the well was allowed to recover for 113 minutes. A graph of time versus drawdown is presented in Appendix A. The water levels recorded during the pumping portion of the test show variability due to irregular gas production from the well. During gas surging, the density of the water column above the transducer is reduced and the apparent water level is reduced. From the time versus drawdown graph an accurate water level can be seen when gas surging is not occurring. Following the short term pumping and recovery test, the pump was restarted and a long term pumping test was performed starting February 18, 2008 at 2:00 pm.

The Theis (1935) confined aquifer solution was used to solve both the pumping test and the recovery test. An apparent transmissivity of $1.65x10^{-3}$ m^2/min to $3.28x10^{-3}$ m^2/min (2.4 to 4.7 m^2/day) was calculated. Again, this value suggests that the aquifer has higher transmissivity than is normally found in sandstone. The shape of the recovery curve suggests the water in this well is coming from a fracture or fracture zone. This would explain the higher than expected transmissivity.

A safe pumping rate can be estimated using a Q20 calculation (Farvolden 1959). This equation estimates the drawdown in a well after 20 years of pumping to determine the sustainable yield of the well. The calculated Q20 for the Jack well is about 3 IGPM. This driller recommended pumping rate (15 IGPM), and the actual pumping rate (13 IGPM) is much higher than the rate calculated by the Q20 equation and will lead to aquifer depletion.

The water static water level in the well has declined by 10 m over about a 4 year period. This is likely an indication of over-pumping. This large drop in water level (pressure) is expected to decrease the solubility of methane in the water and cause an increase in the amount of methane coming out of the water. This is similar to the case where pressure is decreased in a carbonated drink (by opening the top) and CO_2 bubbles out of solution. This solubility decrease could explain an increase in the amount of methane coming out of the water.

4.5 Water and Gas Chemistry

This section presents the results of ARC's compilation, review and assessment of chemistry data from the well complaint file including data from the Jack well and surrounding energy wells. An analysis of this new chemistry data is organized into major ion chemistry, gas chemistry and isotope geochemistry.

4.5.1 Major Ions, Metals and Bacterial Chemistry

No historical major ion chemistry is available for the Jack well. In addition, no chemistry from surrounding water wells from a similar depth is available from the AENV Groundwater Information System. On February 20, 2008 AENV and ARC sampled the Jack well. The results are presented in Table 2 (and Appendix B) and compared to maximum allowable concentration and aesthetic objectives set by the Guideline for Canadian Drinking water Quality (Health Canada 2007). The water from the Jack well exceeds the maximum allowable concentration for fluoride. This is common for bedrock wells in Alberta. The pH, total dissolved solids (TDS) and sodium levels in the Jack well exceed aesthetic limits.

Table 2 Routine, metals and bacteria for the jack well.

		CDWQG (2007)	
Parameter	Jack Well Value	MAC	AO
pH (units)	**8.83**		6.5-8.5
EC (µS/cm)	2060		
TDS-calculated (mg/L)	**1270**		≤ 500
Tot Alk as CaCO3 (mg/L)	968		
Sodium (mg/L)	**547**		≤ 200
Potassium (mg/L)	1.7		
Calcium (mg/L)	1.87		
Magnesium (mg/L)	0.793		
Iron (mg/L)	0.005		≤ 0.3
Iron (tot) (mg/L)	0.0129		
Manganese (mg/L)	0.00050		≤ 0.05
Chloride (mg/L)	127		≤ 250
Fluoride (mg/L)	**1.76**	1.5	
Sulphate (mg/L)	7		≤ 500
Carbonate (mg/L)	58		
Bicarbonate (mg/L)	1060		
NO2 as N (mg/L)	nd		
NO2+NO3 as N (mg/L)	0.018		
Aluminum (mg/L)	nd		0.1
Antimony (mg/L)	0.000009	0.006	
Arsenic (mg/L)	0.00128	0.010	
Barium (mg/L)	0.8710	1	
Beryllium (mg/L)	nd		
Bismuth (mg/L)	nd		
Boron (mg/L)	1.400	5	
Chromium (mg/L)	0.0058		
Cobalt (mg/L)	0.00002		
Copper (mg/L)	0.0013		≤ 1.0
Cadmium (mg/L)	0.000015	0.005	
Lead (mg/L)	0.005	0.01	
Lithium (mg/L)	0.037800		
Mercury (mg/L)	0.00020	0.001	
Molybdenum (mg/L)	0.006630		
Nickel (mg/L)	0.00011		
Phosphorus (mg/L)	0.571		
Selenium (mg/L)	0.0025	0.01	
Silicon (mg/L)	0.0049		
Silver (mg/L)	nd		
Strontium (mg/L)	0.184000		
Sulphur (mg/L)	0.0032		
Thallium (mg/L)	0.000009		
Thorium (mg/L)	0.00005		
Tin (mg/L)	nd		
Titanium (mg/L)	0.00229		
Uranium (mg/L)	0.000003	0.02	
Vanadium (mg/L)	0.00140		
Zinc (mg/L)	0.0009		≤ 5.0
Cations	24		
Anions	23.2		
Balance	1.04		
Tot Coliforms (MPN/100mL)	0	0	
Fecal Coliforms (MPN/100mL)	0	0	
Slime Bacteria (cfu/mL)	350000		
S Reducing Bacteria (cfu/mL)	5000		
Hetrotrophic Bacteria (cfu/mL)	7000000		
Iron Reducing Bacteria (cfu/mL)	140000		

4.5.2 Dissolved Organic Chemistry

On February 20, 2008 AENV and ARC sampled the Jack well for USEPA volatile priority pollutants and extractable priority pollutants. No volatile or extractable organic components were detected in the water samples (Appendix B).

A dissolved gas analysis was also done on the Jack well to determine dissolved concentrations of C1 to C4 and atmospheric gases. The dissolved C1 to C4 analysis (DG_C1C4) show methane (31,600 µg/L), ethane (205 µg/L), propane (2.02 µg/L) and isobutene (0.13 µg/L) are present. These numbers are normalized for the standard headspace analysis in a 40 mL glass vial method.

4.5.3 Atmospheric Elements and Hydrocarbon Gas Chemistry

Several historical free gas analyses are available for the Jack well (Table 3). The samples appear to be free from atmospheric contamination (based on low oxygen and nitrogen values). The gas samples contain 915,200 to 973,300 ppm methane and <100 to 1200 ppm ethane. The propane, butane and higher gases were below the detection limit. The laboratory method detection limit for hydrocarbon gases was poor (100 ppm) and better analyses would be preferred.

On February 22, 2008 AENV and ARC sampled free gas from both gas separated from the pumped water and from the casing of Mr. Jack's water well. Results are presented in Table 3 and in Appendix B.

The C1 to C4 analysis (G_C1C4) of the **gas separated from the water** show methane (848,000 ppm), ethane (1910 ppm), and propane (14.5 ppm) were present. No butane was detected. A volatile organic carbon (voc) analysis of the exsolved gas shows the presence of propane, butane, pentane, heptane and hexane compounds, in the tens of parts per billion ranges, which are indicative of conventional natural gas in the sample.

The C1 to C4 analysis (G_C1C4) of the **casing vent gas** show methane (818,000 ppm), ethane (1830 ppm), and propane (18 ppm) were present. No butane was detected. A volatile organic carbon (voc) analysis of the casing vent gas shows the presence of propane, butane, pentane, heptane and hexane compounds, in the tens of parts per billion ranges, which are indicative of conventional natural gas in the sample. Higher order gas concentrations are lower than in the gas separated from the water, most likely due to mixing with air in the casing.

In addition to the Jack well, 66 analyses from 27 nearby energy wells have gas chemistry. Methane concentrations are similar to those measured in the Jack well while ethane, propane, butane and higher order hydrocarbons are 1 to 2 orders of magnitude higher than the detection limit.

Table 3 Summary of Chemical Analyses for the Jack Water Well and surrounding energy wells.

LSD	Pool or Zone	Depth Interval (m)	Status	Sample Location	Lab	Consultant	Owner	Sampling Date (d-m-y)	Nitrogen (%)	Carbon Dioxide (ppm)	Methane (ppm)	Ethane (ppm)	Propane (ppm)	I-Butane (ppm)	N-Butane (ppm)	I-C5 (ppm)	N-C5 (ppm)	C6 (ppm)	C7+ (ppm)	δ13C CO2 (‰)	δ13C Methane (‰)	δ13C Ethane (‰)	δ13C Propane (‰)	δ13C I-Butane (‰)	δ13C N-Butane (‰)
SW-12-078-08 W6M	Smoky Group	47.2 - 54.9	Water well, active		AGAT	Matrix	Bruce Jack	07/02/2005	2.31	1800	973300	1200	<100	<100	<100	<100	<100	100	300						
"	"	"	"	Headspace	GCHEM	GCHEM	"	12/05/2006			843548	782.5	2.2	0.11	0.01	0.34	0.07								
"	"	"	"	Headspace	GCHEM	GCHEM	"	19/5/2006			790343	773.3	2.5	0.18	0.34	2.81	0.47								
"	"	"	"	Headspace	GCHEM	GCHEM	"	19/5/2006			933130	929.5	3.6	0.33	0.58	0.55	0.34								
"	"	"	"	Well, after purge	Maxxam	Matrix	"	19/10/2006	6.23	1200	933200	<100	7	<100	<100	<100	<100	<100	<100	-34.47	-65.90	-30.74			
"	"	"	"	Duplicate	Maxxam	Matrix	"	19/10/2006	7.08	1100	922300	<100	<100	<100	<100	<100	<100	<100	<100	-33.87	-64.97	-30.53			
"	"	"	"	Well, pump on	Maxxam	Matrix	"	19/10/2006	7.72	760	915200	<100	<100	<100	<100	<100	<100	<100	<100	-25.10	-65.80	-30.36			
"	"	"	"	Well, pump on	Zymax	Matrix	"	19/10/2006												-0.30	-69.30	-32.20			
"	"	"	"	Duplicate	Maxxam	Matrix	"	19/10/2006	6.97	730	925100	<100	<100	<100	<100	<100	<100	<100	<100	-34.66	-65.57	-30.24			
"	"	"	"	Well	ARC, Veg/UofA	ARC/AENV	"	20/2/2008	2.85	1410	848000.0	1910.0	14.1	0.0	0.0					-37.59	-65.48	-29.76	-23.05		
"	"	"	"	Duplicate	UofVictoria	ARC/AENV	"	20/2/2008													-65.8	-30.0	-24.6		
"	"	"	"	Casing vent gas	ARC, Veg/UofA	ARC/AENV	"	20/2/2008	4.84	1160	818000.0	1830.0	18.0	0.478	0.045	0.015	0.001	0.000	0.172		-65.44	-29.35	-22.79		
"	"	"	"	Duplicate	UofVictoria	ARC/AENV	"	20/2/2008													-65.7	-29.6	-24.2		
06-05-078-07 W6M	Charlie Lake Fm	1580.0-1581.5	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.55	8500	894300	52300	24800	4100	5500	1500	1100	800	1300						
12-05-078-07 W6M	Charlie Lake Fm	1547.0-1556.0	Flowing gas	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	10.54	6300	874600	8900	1600	700	400	200	200	400	900						
06-06-078-07 W4M	Charlie Lake Fm	1618.0-1635.0	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.45	6200	873200	67700	31300	5000	6700	1800	1300	800	900						
08-06-078-07 W6M	Charlie Lake Fm	1592.0-1600.0	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	4.80	1200	841500	62800	27500	4900	6600	1900	1300	1100	2400						
14-06-078-07 W6M	Charlie Lake Fm	1555.0-1558.0	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.22	1400	893600	63000	23700	4200	5900	1800	1400	1000	1100						
04-07-078-07 W6M	Charlie Lake Fm	1553.5 - 1556.5	Pumping oil	Production Casing	Maxxam	Lionhead	Trico	20/09/2006	3.64	3400	791600	94700	39600	6200	11400	2600	2400	1600	1500		-45.51	-35.26	-32.48		-32.98
"	"	"	"	Production Casing	Maxxam	Maxxam	Trico	17/10/2006	2.25	4200	822400	86600	36000	5200	9500	2200	2300	2100	3500		-45.55	-35.09	-32.34	-33.00	-31.65
06-07-078-07 W6M	Charlie Lake Fm	1543.0-1545.0	Water injection	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.22	1800	858800	73500	39500	6900	9700	2800	2100	1400	1000						
08-07-078-08 W6M	Charlie Lake Fm	1534.0 - 1537.0	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	1.30	4800	853300	71100	36600	6600	8700	2300	1600	1000	800						
14-07-078-08 W6M	Gething Fm	1332.0-1335.0	Flowing Gas	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	6.02	2300	832200	50200	28900	6500	9300	2900	2200	1700	1500						
14-01-078-08 W6M	Charlie Lake Fm	1592.0 - 1594.5	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	3.00	5500	834700	67400	37000	6100	9700	2800	1900	1200	800						
"	"	"	"	SCV	Maxxam	Lionhead	Northstar	22/09/2006	2.88	730	837700	69800	34200	5900	9400	2500	1800	1100	740		-51.31	-31.05	-27.92	-28.09	
"	"	"	"	SCV	Maxxam	Maxxam	Northstar	17/10/2006	4.59	700	819300	67500	35000	5900	9200	2400	1600	1100	600		-49.96	-30.94	-27.65	-28.71	-27.87
"	"	"	"	Production Casing	Maxxam	Lionhead	Northstar	22/09/2006	3.64	470	773400	89700	48000	9900	17600	5800	6300	3900	1500		-45.05	-35.40	-32.94	-33.02	-32.50
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	2.99	400	839000	80900	32400	4600	6900	1200	1100	400	<100		-45.62	-35.33	-31.99	-32.89	-31.51
16-01-078-08 W6M	Charlie Lake Fm	1563.2 - 1566.5	Pumping oil	Production Casing	Maxxam	Lionhead	Northstar	20/09/2006	2.73	370	713100	131000	76200	11700	19500	4000	3500	2700	3800		-44.76	-35.19	-33.03	-32.25	-32.15
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	18/10/2006	2.13	400	716700	132700	79100	12500	21400	4400	3900	2400	2200		-45.06	-35.39	-32.93	-33.51	-32.05
16-01-078-08 W6M	Charlie Lake Fm	1507.8 - 1510.8	Flowing oil	Production Casing	Maxxam	Lionhead	Trico	22/09/2006	3.27	50	956300	2500	8	30	6	<100	<100	<100	<100	-18.13	-46.79	-28.72	-23.11	-30.05	-36.71
"	"	"	"	Production Casing	Maxxam	Maxxam	Trico	18/10/2006	0.86	22900	841900	78500	30000	2700	7800	1300	2200	1300	600	-17.68	-46.10	-35.02	-31.72	-31.09	-29.77
08-11-078-08 W6M	Charlie Lake Fm	1569.0 - 1575.0	Pumping oil	Production Casing	Maxxam	Lionhead	Northstar	22/09/2006	4.80	540	828100	68700	27100	5300	9400	1800	1400	440	200		-44.84	-34.63	-32.61	-31.95	-30.01
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	2.76	600	858700	68800	25200	4600	8000	1500	1200	300	<100		-44.91	-34.53	-31.73	-33.05	-31.89
15-11-078-08 W6M	Charlie Lake Fm	1563.5 - 1565.5	Pumping oil	Production Casing	Maxxam	Lionhead	UEI	11/10/2006	3.94	680	699400	113100	61000	12700	23100	7400	8700	80	13300		-45.54	-35.32	-32.11	-32.33	-31.04
"	"	"	"	Production Casing	Maxxam	Maxxam	UEI	17/10/2006	2.20	500	740500	118700	62400	12000	20700	5600	6200	4700	2900		-45.40	-35.23	-32.06	-32.74	-31.24
16-11-078-08 W6M	Charlie Lake Fm	1557.0 - 1562.5	Water injection	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	3.21	3800	843600	62600	35500	5700	8800	3000	2000	1200	900						
"	"	"	"	SCV	Maxxam	Lionhead	Northstar	22/09/2006	4.27	540	823600	63700	33200	5400	8100	2700	1900	1600	5300		-50.15	-31.16	-27.56	-28.91	-27.79
"	"	"	"	SCV	Maxxam	Maxxam	Northstar	17/10/2006	1.90	600	855400	65600	34400	5600	8600	2900	2100	1500	1100		-50.34	-31.21	-27.70	-29.42	-28.33
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	33.72	700	220000	68400	79400	17800	32100	12400	9900	9400	19500		-46.79	-35.00	-34.71	-31.64	-30.31
02-12-078-08 W6M	Charlie Lake Fm	1564.8 - 1566.2	Pumping oil	Production Casing	Maxxam	Lionhead	UEI	20/09/2006	2.95	440	815100	84800	37900	5800	9900	2500	2700	1000	4100		-45.52	-34.89	-34.16	-34.77	-32.72
"	"	"	"	Production Casing	Maxxam	Maxxam	UEI	18/10/2006	2.75	500	820900	87100	38400	5500	8800	2100	2200	1900	2200		-45.46	-35.27	-32.15	-32.92	-31.53
"	"	"	"	Production Casing	Zymax	Matrix	UEI	18/10/2006												-9.90	-45.40	-35.60	-31.80	-32.50	
"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			81318	1070	296.8	48.07	71.18	27.71	13.18								
"	"	"	"	Soil gas, 1.1 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			4218	134.3	131.2	71.37	145.1	115.9	61.55								
"	"	"	"	"	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			3162	152.3	137	61.56	117.8	125.5	111.6								
"	"	"	"	Soil Gas, 2.5 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			40090	361.4	86.13	32.57	27.99	17.65	4.92								
"	"	"	"	Soil Gas, Background	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			43.97	3.38	1.47	0.43	0.69	1.91	0.31								
"	"	"	"	"	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			9.95	0.52	0.59	0.31	0.79	1.15	1.11								
06-12-078-08 W6M	Charlie Lake Fm	1570.0 - 1572.0	Water injection	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.18	2400	863300	71400	38200	6300	9500	2900	2000	1200	700						
"	"	"	"	SCV	Maxxam	Lionhead	Northstar	22/09/2005	5.05	670	808900	69200	35600	5900	9300	2900	2000	1100	540		-52.63	-33.01	-29.26	-30.07	-29.71
"	"	"	"	SCV	Maxxam	Maxxam	Northstar	17/10/2006	1.53	800	852000	70900	36400	5900	9200	3000	2100	1400	800		-49.95	-31.36	-28.04	-28.95	-28.33
"	"	"	"	SCV	Zymax	Matrix	Northstar	17/10/2006												-24.00	-51.50	-31.00	-27.00	-28.50	
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	35.93	100	229100	56300	85100	19100	36800	15500	13100	11700	14700		-65.30	-36.09	-32.91	-31.69	-28.79
"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			812821	721138	34673	5767	9048	2980	1349								
"	"	"	"	Soil gas, 1.1 m	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			902585	7901	1175	135.7	81.38	32.19	7.44								
"	"	"	"	"	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			881436	7380	1215	135.4	81.96	30.19	10.8								
"	"	"	"	Soil Gas, 2.5 m	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			575403	5131	803.1	103.8	64.01	0.08	7.25								
"	"	"	"	Background	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			18.92	1.98	0.62	3.03	0.02	1.11	0.08								
08-12-078-08 W6M	Charlie Lake Fm	1556.0 - 1557.5	Pumping oil	Production Casing	Maxxam	Lionhead	Northstar	22/09/2005	2.32	430	665100	131700	84100	16900	33000	10300	10500	90	480		-44.94	-35.42	-33.33	-33.67	-32.40
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	19/10/2006	2.07	400	723200	140700	78300	11000	18300	2200	1500	500	100		-45.05	-35.55	-32.88	-33.28	-31.37
11-12-078-08 W6M	Charlie Lake Fm	1557.5 - 1601.5	Flowing Gas	SCV	AGAT	Matrix	Petrofund Energy Trust	23/09/2005	1.21	27200	859400	55200	29100	4700	7000	2200	1400	700	400						
"	"	"	"	SCV	Maxxam	Lionhead	Northstar	20/09/2006	0.09	60	873700	70900	35800	3300	8800	2700	1800	1000	920		-50.04	-30.86	-28.13	-28.00	
"	"	"	"	SCV	Maxxam	Maxxam	Northstar	17/10/2006	1.57	<100	853700	69300	36100	5900	9000	2900	2000	1400	1600		-50.15	-31.21	-27.67	-28.94	-28.34
"	"	"	"	Production Casing	Maxxam	Lionhead	Northstar	20/09/2006	36.35	90	336200	87200	83600	19900	40600	11700	11100	90	4200		-46.87	-35.53	-32.69	-33.56	-31.60
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	34.74	<100	349100	89200	91100	19800	39900	11100	10400	5600	3500		-47.21	-36.06	-32.93	-28.63	-33.22
"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			837484	72010	34694	5776	8826	2919	1280								
"	"	"	"	Soil gas, 1.1 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			6342	508.2	280.35	39.05	50.11	33.5	23.65								
"	"	"	"	"	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			16377	662.2	371.17	45.07	51.75	35.07	12.59								
"	"	"	"	Soil Gas, 2.5 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			4127	282.5	151.65	21.9	33.12	17.07	11.95								
"	"	"	"	Soil Gas, 2.5 m	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			79314	237.2	889.15	67.69	99.24	37.89	18.72								
"	"	"	"	Background	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			95.85	10.18	7.82	1.95	3.18	3.42	1.34								
"	"	"	"	Background	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			84.73	6.74	7.17	1.89	3.45	3.37	1.38								
"	"	"	"	Soil Gas, Background	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			2.4	0.07	0.13	0.04	0.01	0.53	1.55								
11-12-078-08 W6M	Charlie Lake Fm	1586.4 - 1588.4	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.09	400	876300	67000	34700	5800	8400	2600	1800	1000	900						
"	"	"	"	SCV	Maxxam	Lionhead	UEI	20/09/2006	17.01	140	687600	53400	26600	4200	6400	1900	1300	780	930		-49.68	-30.78	-28.40	-28.87	-28.50
"	"	"	"	SCV	Maxxam	Maxxam	UEI	17/10/2006	20.81	<100	646800	49400	24600	4000	6300	1900	1400	800	300		-51.21	-31.60	-27.47	-28.57	-27.61
"	"	"	"	SCV Duplicate	Maxxam	Maxxam	UEI	17/10/2006													-51.16	-31.42	-28.12	-29.31	-28.47
"	"	"	"	Production Casing	Maxxam	Lionhead	UEI	20/09/2006	3.12	170	561900	179700	121100	21400	38800	9300	9100	90	7300		-45.55	-35.04	-32.75	-32.57	-32.18
"	"	"	"	Production Casing	Maxxam	Maxxam	UEI	17/10/2006	1.69	<100	582800	192900	121300	19200	32900	8900	8100	7900	5600		-45.89	-35.09	-33.09	-33.32	-31.98
"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			662312	48344	22196	3476	5038	1432	553.1								
"	"	"	"	Soil gas, 1.1 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			13840	967.4	540.2	98.88	150.6	73.22	29.9								
"	"	"	"	Soil gas, 2.5 m	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			13912	417.9	169.5	23.17	34.92	27.63	9.73								
"	"	"	"	Background	GCHEM	GCHEM	Pertofund Energy Trust	11/05/2006			84.73	6.74	7.17	1.89	3.45	3.37	1.38								
16-12-078-08 W6M	Charlie Lake Fm	1538.0 - 1540.3	Water injection	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	0.14	700	877500	62300	35500	6200	9400	2800	1900	1200	800						
"	"	"	"	SCV	Maxxam	Lionhead	Northstar	20/09/2006	2.65	100	847900	64100	34300	5800	8900	2500	1600	1000	500		-51.26	-31.08	-27.61	-27.99	-27.92
"	"	"	"	SCV	Maxxam	Maxxam	Northstar	17/10/2006	1.72	<100	876600	55400	29000	5100	8300	2700	1900	1100	600		-52.01	-31.31	-27.72	-28.98	-27.76
"	"	"	"	Production Casing	Maxxam	Lionhead	Northstar	20/09/2006	26.83	270	93500	3500	2500	1400	2700	1100	830	940	1200		-45.38	-33.06	-31.65	-30.06	-31.83
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	13.53	<100	72600	3000	2000	1700	3300	1900	1500	1500	1200		-44.74	-32.37	-32.18	-29.27	-29.68
"	"	"	"	Prod Casing Duplicate	Maxxam	Maxxam	Northstar	17/10/2006												-15.19	-43.24	-32.49	-31.23	-28.44	-27.92
02-13-078-08 W6M	Charlie Lake Fm	1536.0 - 1542.0	Pumping oil	SCV	AGAT	Matrix	Pertofund Energy Trust	18/01/2005	0.57	700	878200	66600	34400	5100	6400	1400	800	300	200						
"	"	"	"	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	8.44	2600	786000	61800	35800	6500	9600	2700	1800	1000	400						
"	"	"	"	SCV	Maxxam	Lionhead	Trico	22/09/2005	12.35	190	742800	53700	28800	5200	7700	2000	1400	850	340		-51.85	-31.12	-27.99	-29.84	-28.51
"	"	"	"	Production Casing	Maxxam	Lionhead	Trico	22/09/2005	3.29	420	759000	103600	51400	9300	18000	5300	5300	40	4100		-45.07	-35.06	-32.47	-32.79	-31.35
"	"	"	"	Production Casing	Maxxam	Maxxam	Trico	17/10/2006	2.98	300	815800	92500	38600	5400	9100	2000	1700	800	800		-45.34	-35.68	-32.70	-33.10	-31.59
03-13-078-08 W6M	Charlie Lake Fm	1543.0 - 1546.0	Pumping oil	Production Casing	Maxxam	Lionhead	Northstar	22/09/2005	6.86	390	752500	91900	42200	7000	12600	3100	3000	30	5200		-45.28	-35.62	-33.14	-32.57	-31.86
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	3.28	400	765100	99500	49100	8600	16100	6500	12000	2600	1800		-45.24	-35.29	-32.23	-33.80	-31.93
04-13-078-08 W6M	Charlie Lake Fm	1544.7 - 1547.0	Flowing oil	Production Casing	Maxxam	Lionhead	UEI	22/09/2005	2.45	80	788800	109400	47500	7100	11700	2200	1800	680	500		-45.41	-35.88	-32.63	-32.67	-30.90
02-14-078-08 W6M	Charlie Lake Fm	directional	Pumping oil	Production Casing	Maxxam	Lionhead	Northstar	22/09/2005	4.46	510	745700	106800	51300	9600	16400	4300	4400	40	3100		-45.44	-35.02	-32.39	-32.80	-31.57
"	"	"	"	Production Casing	Maxxam	Maxxam	Northstar	17/10/2006	1.82	500	756300	113600	59800	10600	17500	5100	6100	5100	4500		-45.43	-35.51	-32.83	-31.81	-31.81
"	"	"	"	SCV	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			10.37	0.583	3.1	0.06	0.16	0.15	0.07								
"	"	"	"	Soil gas, 1.1 m	GCHEM	GCHEM	Pertofund Energy Trust	12/05/2006			238302	1952	270.4	29.48	17.45	6.88	1.66								
"	"	"	"	"	GCHEM	GCHEM	Pertofund Energy Trust	19/05/2006			104217	778.2	106	21.04	7.91	5.12	1.59								
16-14-078-08 W4M	Charlie Lake Fm	1541.0-1544.0	Flowing oil	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	1.25	800	902800	50500	19300	3000	5200	2000	1600	1000	800						
08-23-078-08 W6M	Gething Fm	1293.0-1297.5	Flowing gas	SCV	AGAT	Matrix	Pertofund Energy Trust	23/09/2005	2.17	7500	907700	37800	12700	2200	3900	1700	1400	1000	2300						

4.5.4 Stable Carbon Isotope Chemistry on Hydrocarbon Gas

Stable carbon isotopes sometimes can be used to help in the identification of the origin of gas in water wells. Five carbon isotope analyses on hydrocarbon gas were available for the Jack well (Table 3). New analysis from the gas separated from the water and from the casing (AENV and ARC sampling on February 18, 2008) are also available. In addition to the Jack well, 27 nearby energy wells have carbon isotope analyses on the hydrocarbon gases. Analyses are from production casings and from surface casing vent flows (where present). The analytical techniques used for gas isotope results the Jack well sample and the energy wells are not known.

A histogram of the carbon isotope values of methane from the Jack water well and the surrounding conventional oil/gas wells is presented in Figure 6. Jack well has methane isotope signatures that fall within the range of -60 to -80, typical of biogenic methane (Schoell 1980; Whiticar et al. 1986; Rice 1993). The methane values for the conventional gas wells and the water injection wells have been coded for production casing samples and surface casing vent (SCV) samples. The conventional gas well isotope signatures are much less depleted than the Jack well signatures and are typical for conventional gas. The surface casing vent flow samples have methane isotope signatures that fall between those of the Jack well and production casing indicating a shallower source for the gas.

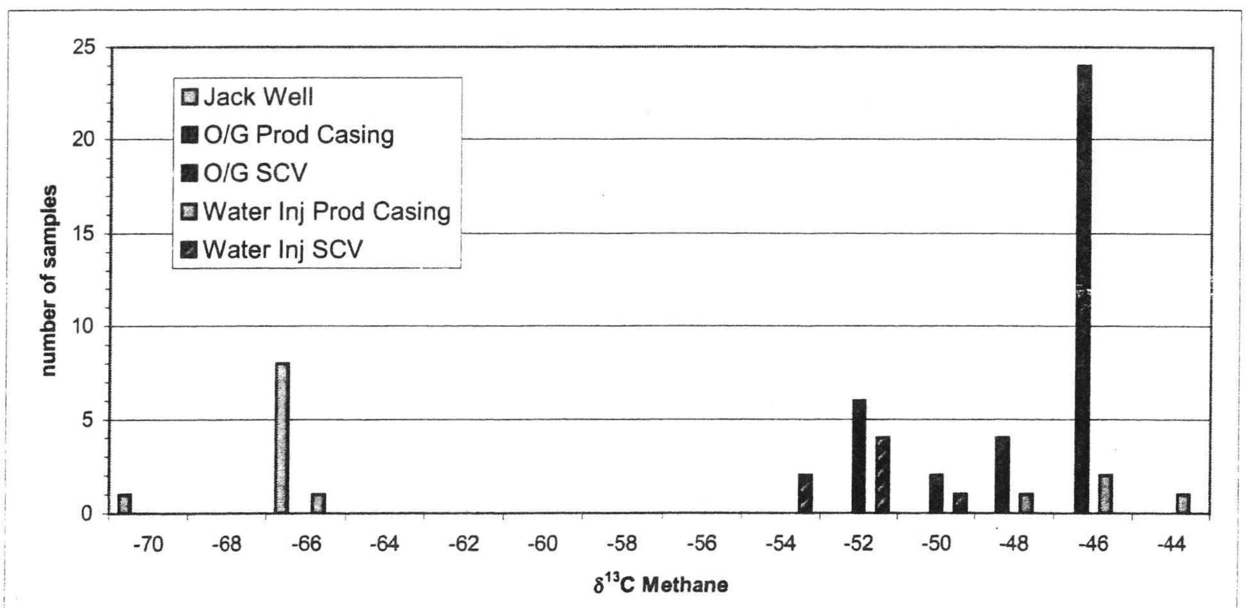


Figure 6 Histogram of the carbon isotope values of methane in the Jack energy wells.

A histogram of the carbon isotope values of ethane from the Jack well and conventional oil/gas is presented in Figure 7. The Jack well has an ethane isotope signature that is similar to the ethane signature of the surface casing vent flow samples. This could indicate a possible component of conventional gas is in the Jack well. The ethane isotope signatures of the SCVFs are heavier than the signature of the production casing samples. This is because the isotope signature of the ethane does not correlate directly to depth (i.e. heavier as you go deeper), but is also related to geologic seals (low permeability rocks) and different geological history of gas generation, migration and alteration (Muehlenbachs et al. 2000).

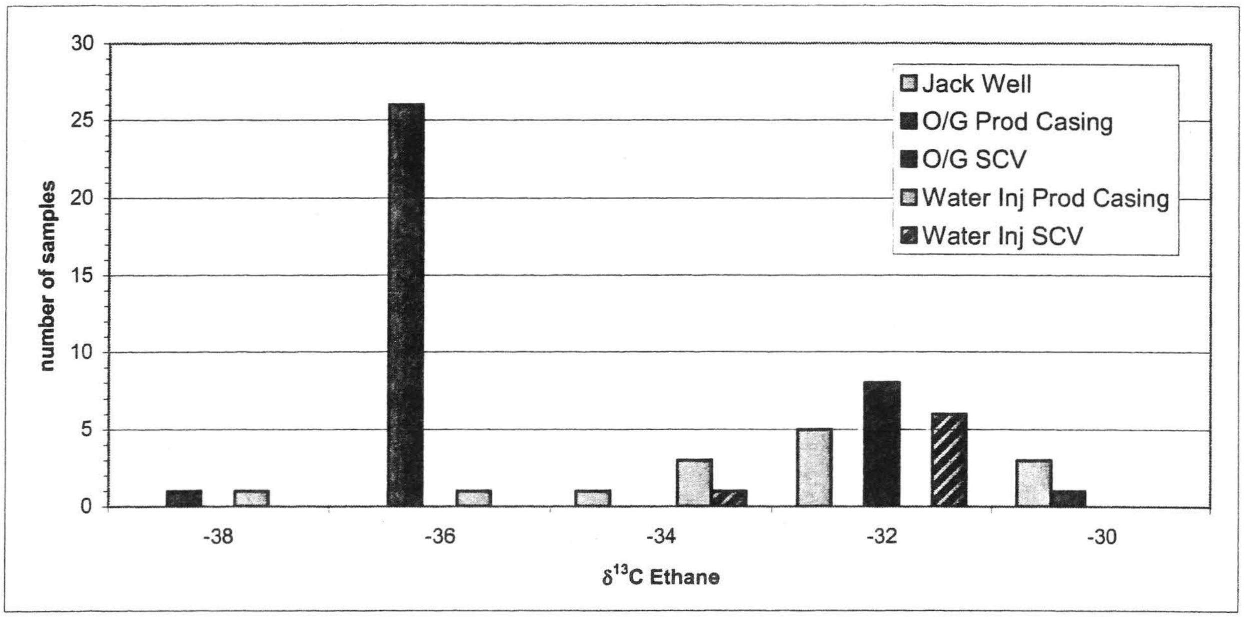


Figure 7 Histogram of the carbon isotope values of ethane in the Jack and energy wells.

A plot of the methane concentration versus the methane carbon isotope signature ($\delta^{13}C_{\text{Methane}}$) is presented on Figure 8. Below the line at -60 ‰ typically represents a biogenic (bacterial) origin for methane (Schoell 1980 and 1983; Whiticar et al 1986; Rice 1993). The conventional oil/gas wells have a $\delta^{13}C_{\text{Methane}}$ values that are less depleted (less negative) than the typical range of biogenic methane. These values represent a thermogenic origin. One of the water injection wells has a methane isotope value from the production casing that appears biogenic in origin. Most of the injection water is sourced from recycled produced water but at least one Cadotte source water well is in the area (personal communication with Brenda Austin, ERCB).

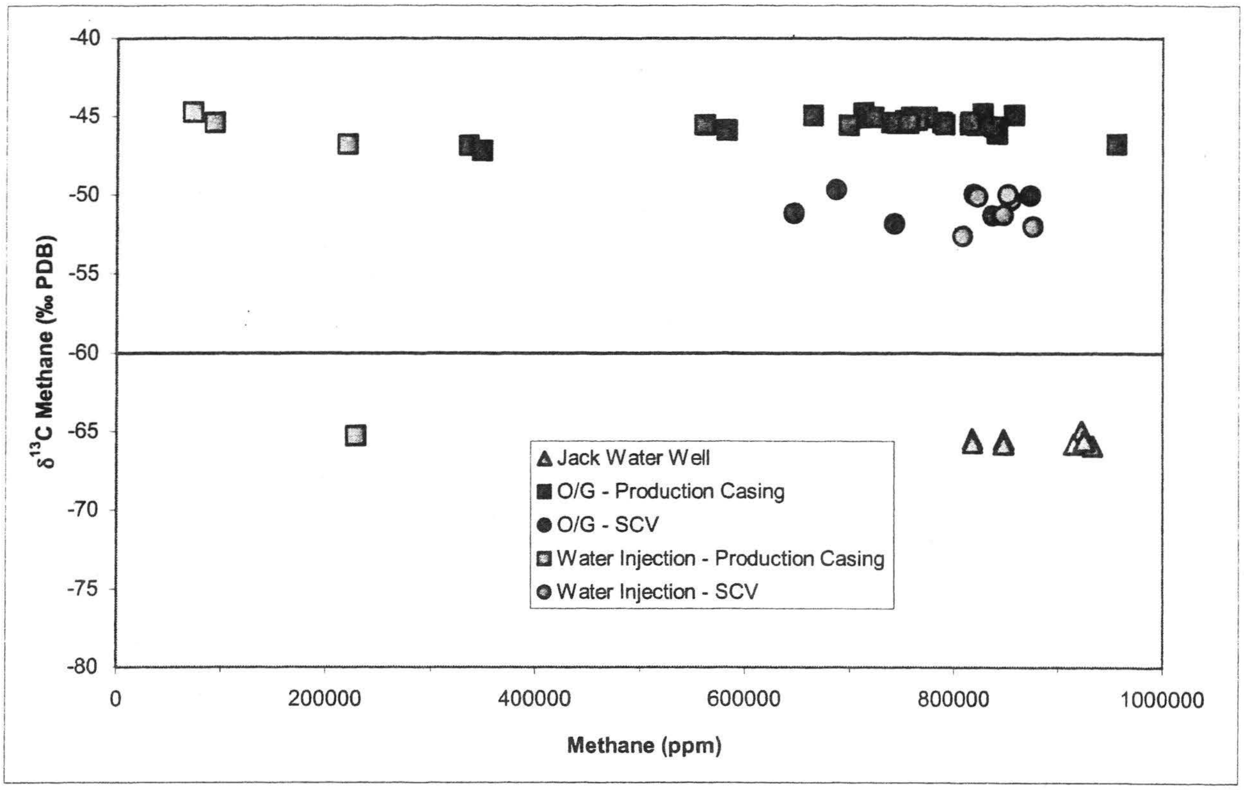


Figure 8 Methane concentration versus $\delta^{13}C$ of methane.

A plot of the ethane concentration versus the ethane carbon isotope signature ($\delta^{13}C_{Ethane}$) is presented on Figure 9. Most of the analyses from the Jack water well have ethane concentrations below the lab detection limit (which was high at 100 ppm). One sample had 1200 ppm. New sampling performed by AENV and ARC (February 20, 2008) found ethane concentrations in the gas separated from the water of 1910 ppm and casing gas concentrations of 1830 ppm. The carbon isotopic analyses of ethane are fairly consistent between labs except for the October 19, 2006 sample sent to Zymax. The ethane isotope signature from the Jack well is slightly more enriched than the production or SCVF gases of the energy wells sampled. This could indicate an even deeper gas source or that the ethane in Mr. Jack's well has been partially oxidized. Ethane concentrations in the Jack well are about 35 times less than that observed in the conventional oil/gas wells suggesting a different source for the ethane or only a small proportion of mixing (discussed later).

Propane isotope analyses were also performed on the jack well by two different laboratories (U of Alberta and U of Victoria). Both laboratories had very reproducible results (standard deviation on the order of 0.3) but the results were different by 1.8 and 1.6 per mill for the casing vent and exsolved gas respectively. One of the labs has the wrong result, or both do. This demonstrates the two types of error in any analysis. *Precision* or statistical errors reflect random fluctuation in the analytical procedure and can be calculated by repeated analysis of the same sample. *Accuracy* errors are systematic deviations due to faulty procedures or interferences during analysis and can be measured by analyzing reference samples and by inter-laboratory comparisons (Appelo and Postma 1999). This demonstrates that propane concentrations (14 to 18 ppm) are below the resolving power of the isotopic technique.

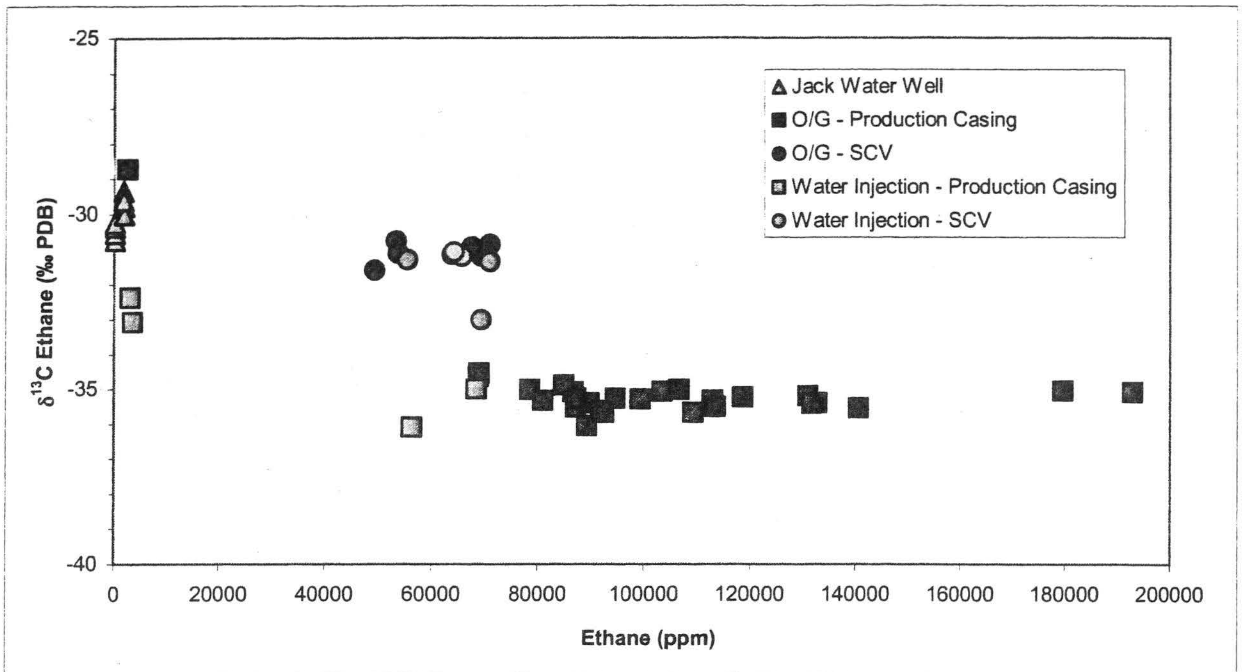


Figure 9 Ethane concentration versus $\delta^{13}C$ of ethane.

A plot of the methane carbon isotope signature ($\delta^{13}C_{Methane}$) versus the ethane carbon isotope signature ($\delta^{13}C_{Ethane}$) is presented on Figure 10. Three distinct groups of analysis occur on this graph; the production casing gas, the surface casing vent flow gas and the Jack water well gas. Each has a distinct methane and ethane isotope range indicating a different gas source. Again, the ethane isotope signature of the Jack well is similar to the ethane signature of the surface casing vent gases.

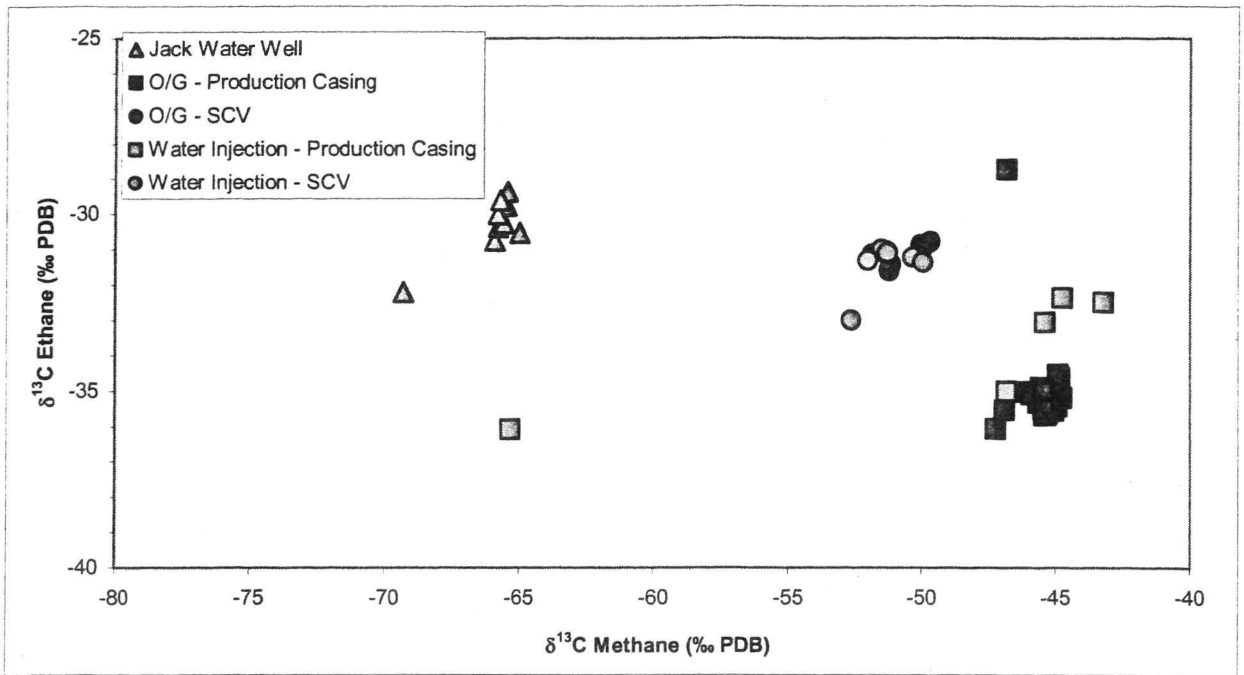


Figure 10 $\delta^{13}C$ Methane versus $\delta^{13}C$ Ethane.

Both the hydrocarbon gas composition and the isotopic signatures of gases can be modified by mixing between different sources of gases (such as biogenic methane with thermogenic methane). These hypothetical mixing curves can be calculated using the equations of Jenden et al. (1993) shown on Figure 11. The y-axis of this plot is the ratio of methane to all other hydrocarbon gases. For this mixing calculation two different end member gases were considered: a biogenic gas and a conventional gas, representative of the surface casing vent gas.

The mixing scenario (mixing curve) was a biogenic gas ([Methane=999,999 ppm], $\delta^{13}C_{methane}$=-65.5 ‰) mixed with a typical SCV gas from the area ([Methane=838,000 ppm], $\delta^{13}C_{methane}$=-50.7 ‰). The tick marks on the curves represent mixtures of conventional gas with the gas from water well, ranging from 0% to 100% in 5% intervals. The Jack well mixing curve shows a possible 2% mix of the conventional gas member with a biogenic end-member.

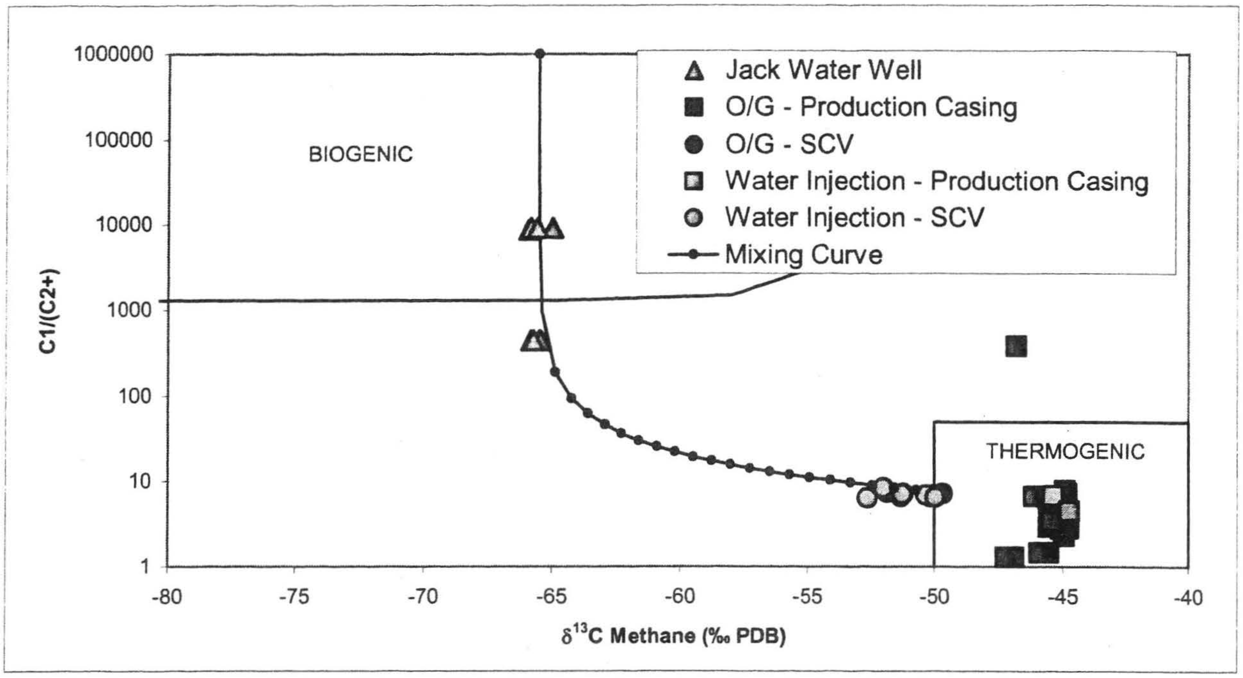


Figure 11 Mixing plot of δ^{13}C of methane versus the methane/C2+ ratio. Data for the bacterial and thermogenic fields are from Faber and Stahl 1984.

A similar plot can be constructed for ethane (Figure 12). The first mixing scenario (curve 1) was a biogenic gas with an ethane isotope signature chosen to fall through the Jack well ethane isotope signature ([Ethane=1 ppm], $\delta^{13}C_{methane}$=-30.8 ‰) mixed with a typical SCV gas from the area ([Ethane=105,300 ppm], $\delta^{13}C_{methane}$=-31.1 ‰). Again, the Jack well mixing curve shows a possible 0.01% mix of the conventional gas member with a biogenic end-member. This is a very small portion of thermogenic gas. A second mixing scenario (curve 2) was a biogenic gas with an ethane isotope signature more typical of water wells ([Ethane=1 ppm], $\delta^{13}C_{ethane}$=-45.0 ‰) mixed with a typical SCV gas from the area ([Ethane=105,300 ppm], $\delta^{13}C_{methane}$=-31.1 ‰). Again, the Jack well mixing curve shows a maximum possible 2% mix of the conventional gas member with a biogenic end-member.

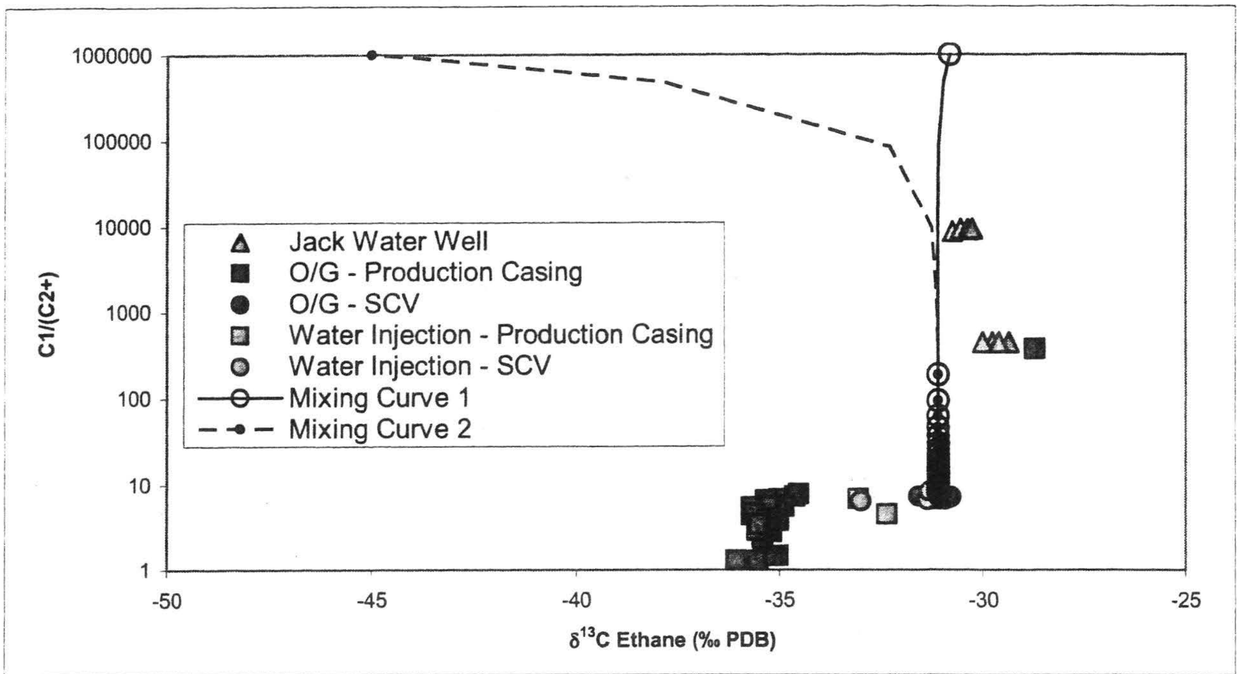


Figure 12 Mixing plot of $\delta^{13}C$ of ethane versus the methane/C2+ ratio.

5 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Alberta Research Council's review of the AENV Jack complaint file and ERCB data, and independent review of additional data and aspects of the complaint, provides the following conclusions:

- The Jack water well is completed in shale and sandstone of the Smoky Group.
- The Jack well appears to be producing water from a fracture or fracture zone. Other water wells drilled in nearby sections have apparently not hit this water zone and well yields are very low. A new water well drilled near the existing well would likely hit the same fracture (and would probably also have gas in it) or would be of very poor yield.
- A local stress analysis indicates the most likely azimuth (orientation) of fractures would be about 055° (Bachu and Michael 2002). Several energy wells (within 2 km) line up on the 055° azimuth to the Jack well.
- Several energy Wells in the vicinity (within 1.5 km) of the Jack well have surface casing vent flows. While SCVF are not necessarily an indication of shallow aquifers being impacted, there are potential concerns that energy wells with apparently good surface casing may have lower zones that may be leaking.
- An estimate of downward vertical gradient between the Jack well (Smoky Group) and the Charlie Lake formation is 0.2. This represents a downward vertical gradient. If these two zones become connected, water would flow downwards towards the deeper zone well rather than up into the Jack water well.

- The Jack well has been over-pumped and the aquifer is being mined. The existing pump rate is over 4 times the safe yield for this well. Static water levels have declined by 10 m over a 4 year period. This decline in water levels is expected to decrease the solubility of methane in the water and cause an increase in the amount of methane coming out of the water.
- The Jack well has hydrocarbon gas concentration indicative of a small conventional natural gas component (2%) mixed with shallow biogenic methane (likely from shales). This conventional natural gas may be from energy wells in the area but the Peach River Arch region has well documented occurrences of numerous structural faults that could be conduction deeper fluids.
- The Jack well has a $\delta^{13}C$ methane value that is typical of shallow, biogenic methane. The production casing samples from energy wells have $\delta^{13}C$ methane values that are less depleted and are typical of thermogenic gas. The SCV gas has $\delta^{13}C$ methane values that are intermediate between the Jack well and the production casing gas, but is still thermogenic in origin. The SCV gases appear to be from a shallower formation than the well completion depth.
- The ethane carbon isotope values for the Jack well are similar (but slightly more enriched) to the ethane signatures of the surface casing vent flows.
- The propane carbon isotope signature of the Jack well is more enriched than any of the surrounding energy wells sampled. Concentrations of propane are low and an inter laboratory comparison indicate the concentration is below the resolving power of the isotopic technique.
- The energy well 100/6-12-078-8 W6M is the closest energy well to the Jack water well. In spite of an apparently acceptable cement job, this well has a surface casing vent flow of 32.1 m^3/day. This well was found to have a gas migration issue (GChem 2006) with ethane and propane gas concentrations immediately outside the casing were elevated about 2,000 times background values. The water injection status of this well does not appear to have any bearing on gas in the jack well. Gas appeared in the Jack well several month prior to commencement of water injection and continued long after water injection ceased.
- The hydrocarbon gas composition and isotopic values can be modified by mixing between different sources of gases. Mixing scenarios indicate a biogenic end-member gas mixed with 2% of a thermogenic gas with a composition similar to the SCVF gas could produce results similar to the Jack well.

ARC makes the following recommendations:

- Several energy wells in the vicinity of the Jack well have been shown to have gas migration issues. Gas compositions indicate a thermal origin for the gas but isotopic data was not available. This data needs to be collected or released and reviewed if it exists.
- The energy well 100/6-12-078-8 W6M needs to have cement integrity investigated to identify the source of the SCVF and gas migration.

- A shut-in interference test can be performed to test the connection between the Jack water well and the 100/6-12-078-8 W6M energy well. Water levels and gas flow rates should be monitored in the Jack well while pressure build-up is monitored in the energy well.

Overall Conclusion

Alberta Research Council's overall conclusion of the evidence from the review of the AENV and ERCB files is that Mr. Jack's water well has an approximately 2% component of conventional natural gas mixed with shallow biogenic gas (likely from shales). The source of this gas may be a leaking energy well, but natural migration along documented faults in the area could be occurring.

6 CLOSURE

This report details a thorough review of the AENV well complaint file for Mr. Jack regarding conventional gas activities undertaken in the area and the presence of methane gas in the Jack water well.

This work was carried out in accordance with accepted hydrogeological practices.

Respectfully submitted,
Alberta Research Council
Permit to Practice P03619

Alexander R. Blyth, Ph.D., P. Geol.
Research Hydrogeologist

7 REFERENCES

Appelo, C.A.J. and Postma, D., 1999. Geochemistry, groundwater and pollution. A.A. Balkema, Rotterdam, Netherlands, 536 p.

Bouwer, H. and R.C. Rice, 1976. A slug test method for determining hydraulic conductivity of unconfined aquifers with completely or partially penetrating wells, Water Resources Research, vol. 12, no. 3, pp. 423-428.

Cant, D.J., 1988. Regional structure and development of the peace River Arch, Alberta; a Paleozoic failed-rift system?. Bulletin of Canadian Petroleum Geology, v. 36, p. 284-295.

Faber, E. and Stahl, W., 1984. Geochemical surface exploration for hydrocarbons in North Sea. The American Association of Petroleum Geologists Bulletin, Vol. 68, No. 3, p. 363-386.\

Farvolden, R.N., 1959. Groundwater supply in Alberta. Alberta Research Council, unpublished report.

GChem Ltd., 2006. Update of Results: Natural gas contents in surface casing vents & soils at Petrofund Energy Trust (PTF) and water at Mr. Bruce Jack water well (BJWW), 078-08W6 June 21st 2006. Letter report to Petrofund Energy Trust.

Hackbarth, D., 1977. Hydrogeology of the Grande Prairie area, Alberta. Alberta Research Council report 76-4.

Health Canada, 2007. Guidelines for Canadian Drinking Water Quality – Summary Table.

Hitchon, B., 1969a, Fluid flow in the Western Canada Sedimentary Basin: 1. Effect of topography. Water Resources Research, vol. 5, no. 1, pp. 186-195.

Hitchon, B., 1969b, Fluid flow in the Western Canada Sedimentary Basin: 2. Effect of geology. Water Resources Research, vol. 5, no. 2, pp. 460-469.

Hitchon, B., Bachu, S. and Underschultz, J.R., 1990. Regional subsurface hydrogeology, Peace River Arch area, Alberta and British Columbia. Bulletin of Canadian Petroleum Geology, Vol. 38A, pp. 196-217.

Jenden, P.D., Drazan, D.J. and Kaplan, I.R., 1993. Mixing of thermogenic natural gases in Northern Appalachian basin. The American Association of Petroleum Geologists Bulletin, V. 77, no. 6, pp. 980-998.

Lionhead Engineering and Consulting Ltd., 2006. Spirit River water well investigation for PennWest Petroleum Ltd. Consulting report for PennWest Petroleum Ltd, November 2006.

Matrix Solutions Inc., 2007. Resident water well testing isotope analysis study SW 12-078-08 W6M. Consulting report prepared for Penn West Energy Trust, May 2007.

Mossop, G.D. and Shetsen, I. (compilers) 1994. Geological atlas of the Western Canada Sedimentary Basin. Calgary, Canadian Society of Petroleum Geologists and Alberta Research Council, 510 p.

Muehlenbachs, K., Szatkowski, B., and Miller, R., 2000. Carbon isotope ratios in natural gas: A detailed depth profile in the Grande Prairie Region of Alberta. GeoCanada 2000: the Millennium Geoscience Summit Conference Proceedings CD, May 29-June 2, 2000, Calgary, Alberta.

O'Connell, S.C., 1994. Geological history of the peace River Arch: in Geological atlas of the Western Canada Sedimentary Basin. Calgary, Canadian Society of Petroleum Geologists and Alberta Research Council, Special Report 4, p. 431-438.

Rice, D.D., 1993. Composition and origins of coalbed gas. In: B.E. Law and D.D. Rice (eds.), Hydrocarbons from coal: AAPG Studies in Geology 38, p. 159-184.

Schoell, M., 1980. The hydrogen and carbon isotopic composition of methane from natural gases of various origins. Geochimica et Cosmochimica Acta, Vol. 44, p. 649-661.

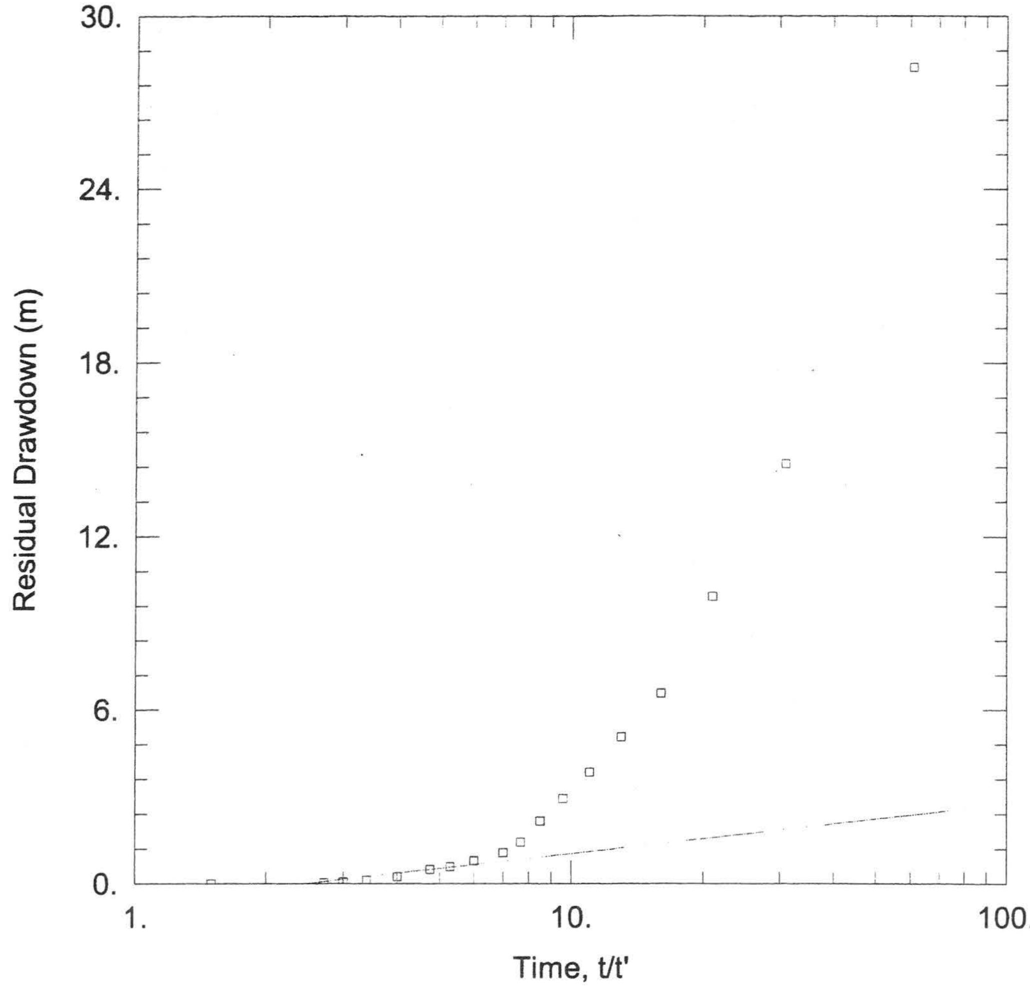
Schoell, M., 1983. Genetic characterization of natural gases. American Association of Petroleum Geologists Bulletin, Vol. 67, No. 12, p. 2225-2238.

Theis, C.V., 1935. The relation between the lowering of the piezometric surface and the rate and duration of discharge of a well using groundwater storage, Am. Geophys. Union Trans., vol. 16, pp. 519-524.

Whiticar, M.J., Faber, E. and Schoell, M., 1986. Biogenic methane formation in marine and freshwater environments: CO_2 reduction vs. acetate fermentation – Isotopic evidence. Geochimica et Cosmochimica Acta, Vol. 50, p. 693-709.

APPENDIX A

PUMPING TEST GRAPHICAL SOLUTION



WELL TEST ANALYSIS

Data Set:
Date: 02/08/08 Time: 12:10:49

PROJECT INFORMATION

Company: Alberta Research Council
Client: AENV
Project: 8789018
Test Well: Jack Well
Test Date: Nov 19, 2001

AQUIFER DATA

Saturated Thickness: 5.18 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Jack Well	0	0

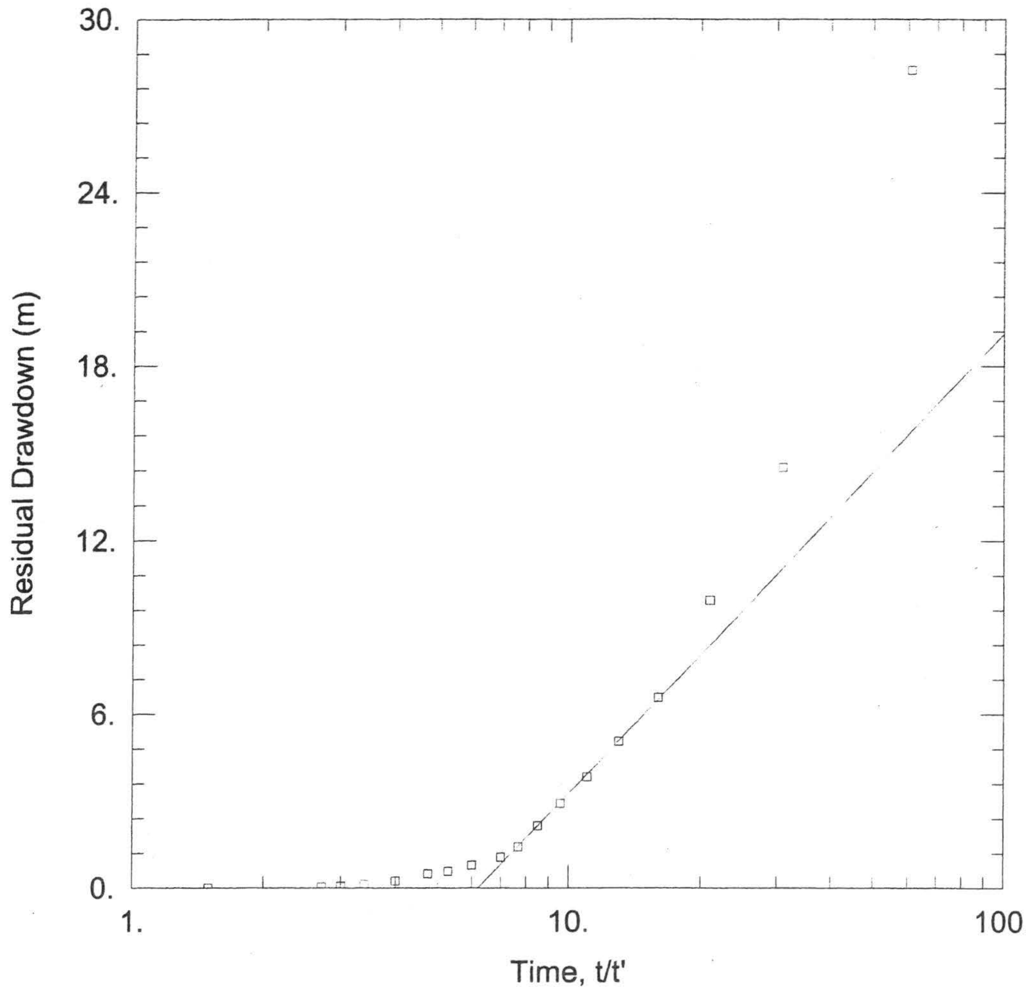
Observation Wells

Well Name	X (m)	Y (m)
▫ Jack Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.009791 m^2/min S/S' = 2.451



WELL TEST ANALYSIS

Data Set: O:\hg\PROJECTS\2007-2008\Jack Well Complaint\Report\JackRecovery.aqt
Date: 02/12/08 Time: 15:15:40

PROJECT INFORMATION

Company: Alberta Research Council
Client: AENV
Project: 8789018
Test Well: Jack Well
Test Date: Nov 19, 2001

AQUIFER DATA

Saturated Thickness: 5.18 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Jack Well	0	0

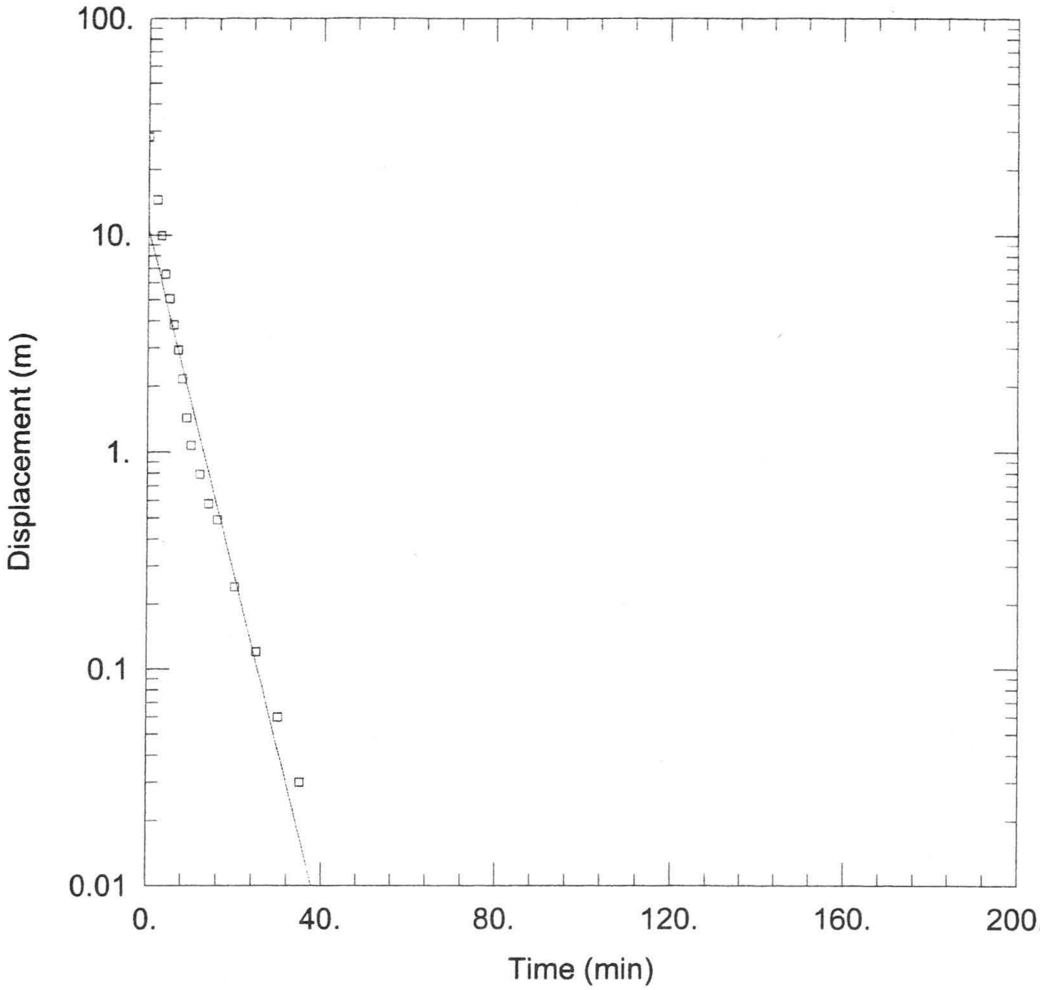
Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)

T = 0.001052 m^2/min S/S' = 6.209



WELL TEST ANALYSIS

Data Set:
Date: 02/14/08 Time: 09:46:46

PROJECT INFORMATION

Company: Alberta Research Council
Client: AENV
Project: 8789018
Test Well: Jack Well
Test Date: Nov 19, 2001

AQUIFER DATA

Saturated Thickness: 5.18 m Anisotropy Ratio (Kz/Kr): 1.

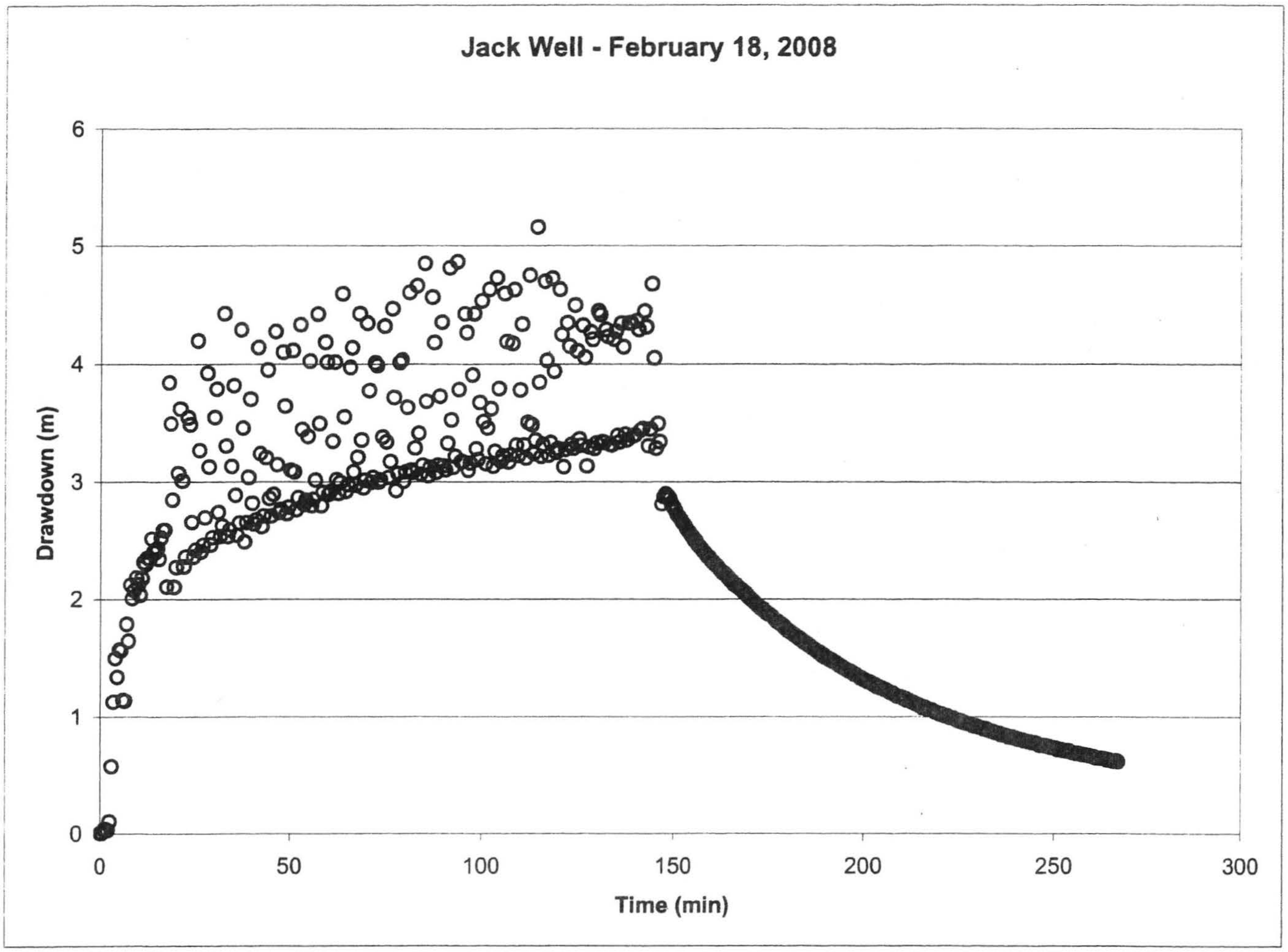
WELL DATA (New Well)

Initial Displacement: 28.22 m
Total Well Penetration Depth: 38.63 m
Casing Radius: 0.076 m
Static Water Column Height: 44.68 m
Screen Length: 7.7 m
Well Radius: 0.057 m

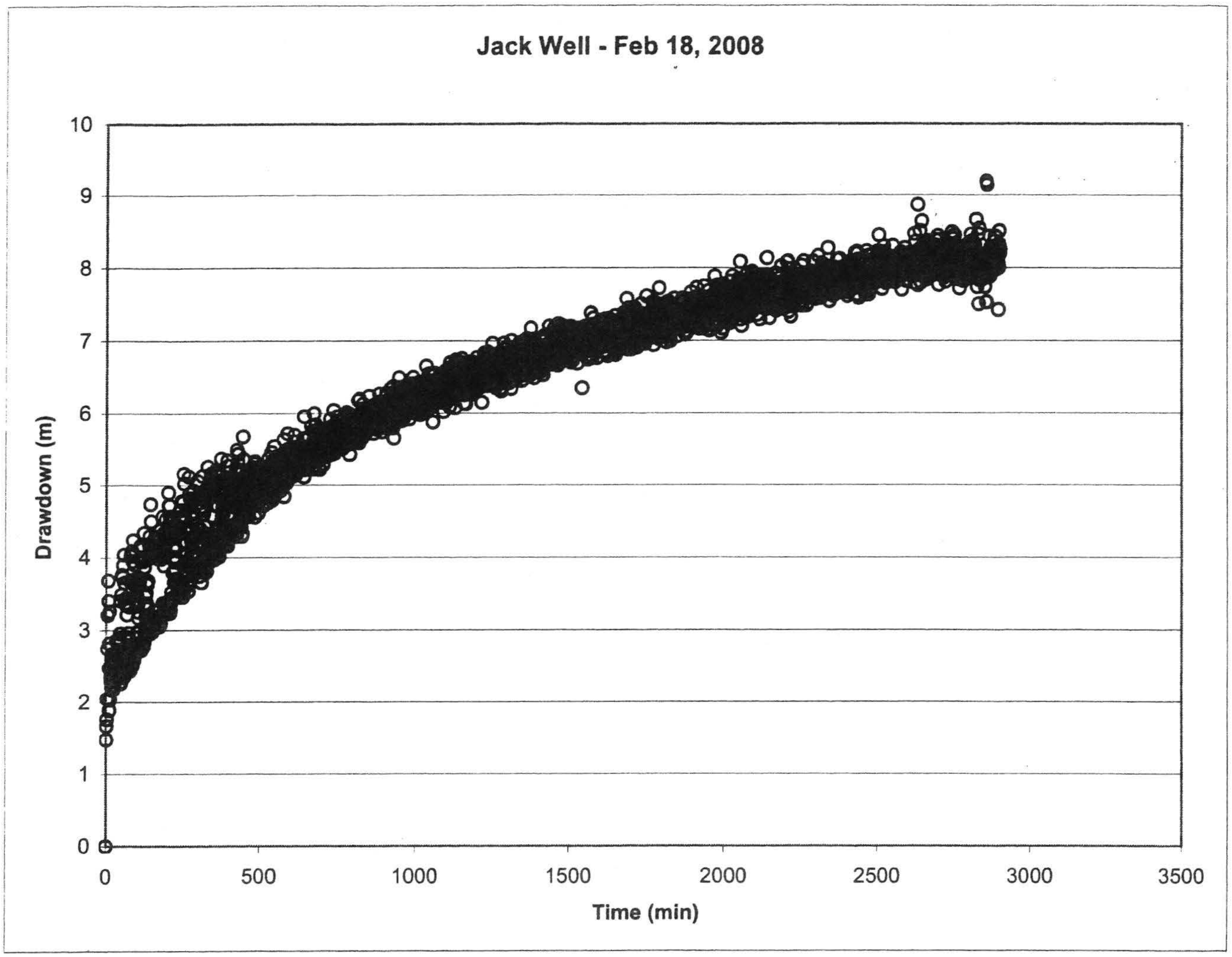
SOLUTION

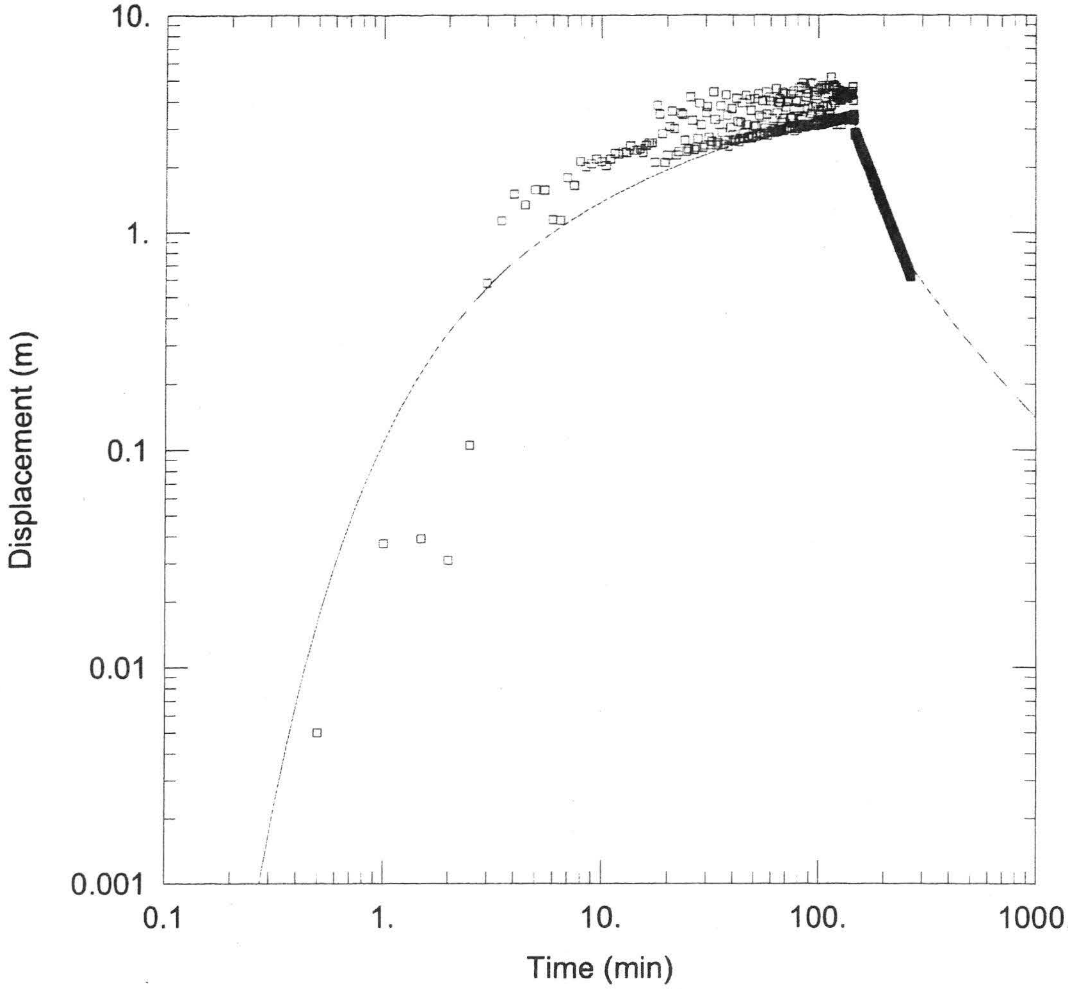
Aquifer Model: Confined
Solution Method: Bouwer-Rice

K = 0.0003318 m/min
y0 = 10.67 m



Jack Well - February 18, 2008
Drawdown (m)
0
1
2
3
4
5
6
0
50
100
150
200
250
300
Time (min)


Jack Well - Feb 18, 2008
Drawdown (m)
Time (min)
0
1
2
3
4
5
6
7
8
9
10
0
500
1000
1500
2000
2500
3000
3500



WELL TEST ANALYSIS

Data Set: O:\hg\PROJECTS\2007-2008\Jack Well Complaint\Report\JackFeb 18_08.aqt
Date: 02/22/08 Time: 14:30:08

PROJECT INFORMATION

Company: Alberta Research Council
Client: AENV
Project: 8789018
Test Well: Jack Well
Test Date: February 18, 2008

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Jack Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined

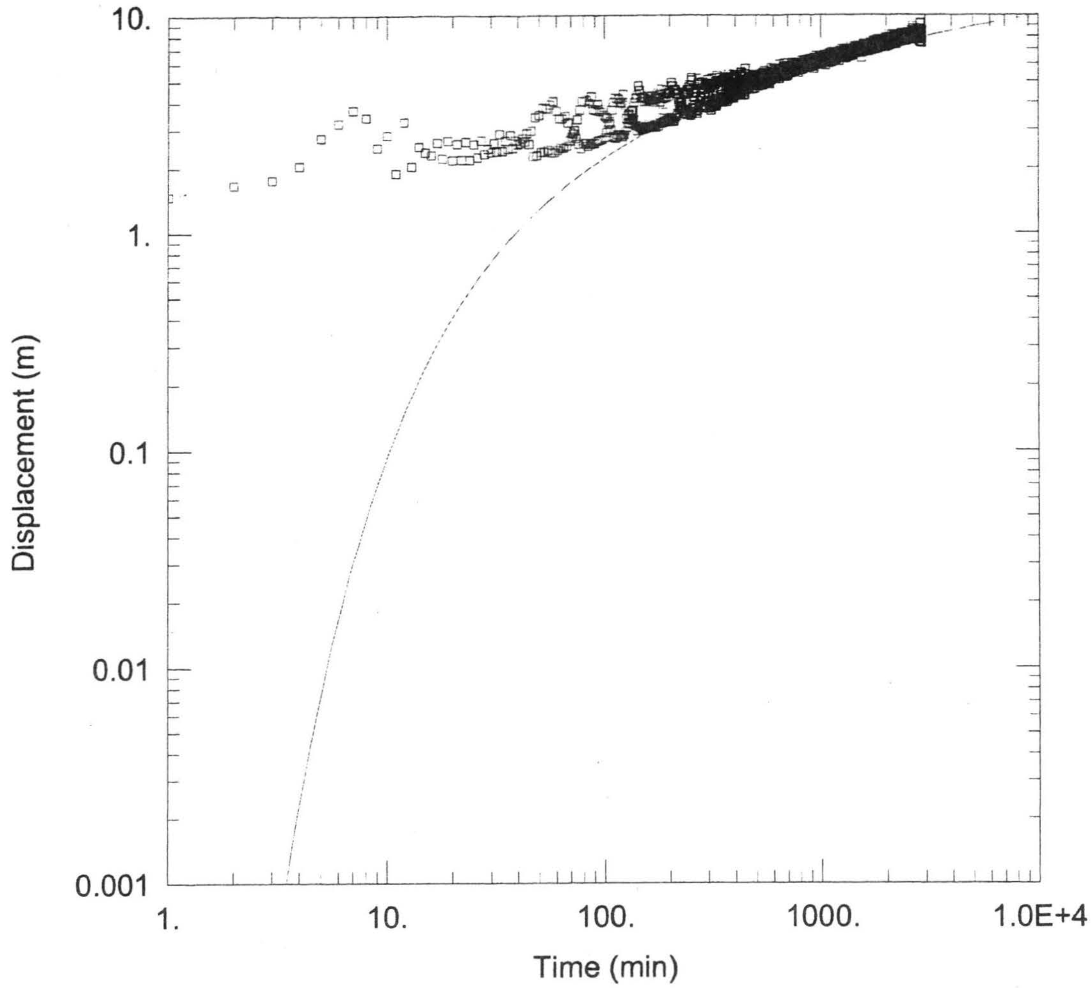
Solution Method: Theis

T = 0.003279 m^2/min

Kz/Kr = 1.

S = 5.552

b = 5.18 m



WELL TEST ANALYSIS

Data Set: O:\hg\PROJECTS\2007-2008\Jack Well Complaint\Report\JackFeb 18_08 long.aqt
Date: 02/22/08 Time: 15:39:12

PROJECT INFORMATION

Company: Alberta Research Council
Client: AENV
Project: 8789018
Test Well: Jack Well
Test Date: February 18, 2008

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
Jack Well	0	0

Observation Wells

Well Name	X (m)	Y (m)
□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined

Solution Method: Theis

$T = 0.001647\ m^2/min$

$S = 39.68$

Kz/Kr = 1.

b = 5.18 m

APPENDIX B
ANALYTICAL RESULTS

ALBERTA RESEARCH COUNCIL
PO Bag 4000
Vegreville, Alberta
Canada T9C 1T4
(780) 632 8211

ENVIRONMENTAL MANAGEMENT

CERTIFICATION ON ANALYTICAL RESULTS

MONDAY MARCH 31st, 2008

ARC SAMPLE NUMBER
0800430

SOURCE
GROUND WATER PUMP
JACK WELL 8789018

TYPE AND DESCRIPTION

RESULTS TO

DON JONES
ALBERTA RESEARCH COUNCIL, 3608-33 STREET NW
CALGARY, ALBERTA
T2L 2A6

SAMPLED BY

DATE SAMPLED
20-FEB-2008 13:40

DATE RECEIVED
21-FEB-2008

	PARAMETER	ANALYTICAL RESULTS	UNCERTAINTY		UNITS	MRV	MDL	ENVIRODAT VMV CODE	TEST ID
**	PH	8.83	±	0.07	units	N/A	N/A	10301L	PH
	CONDUCTIVITY	2060.	±	3.3	uS/cm	0.1	2.0	02041L	CON
	TDS(CALCULATED)	1270.			mg/L	0.1	0.1	100536	CLTDS
	T-HARDNESS	7.93			mgCaCO3/L	0.01	0.25	10602L	TH
	POTASSIUM	1.7	±	0.1	mg/L	0.1	0.1	102086	KKF
	SODIUM	547.	±	6.8	mg/L	0.5	1.5	102085	NAF
**	(NO2+NO3)-N	0.018*	±	0.005	mg/L	0.005	0.020	07105L	N23
**	NO2-N	<0.001			mg/L	0.001	0.016	07205L	NO2
**	FLUORIDE	1.76	±	0.03	mg/L	0.01	0.04	09107L	F
**	SULFATE	7.	±	3.	mg/L	3.	6.	16306L	SO4
	SILICA	5.5	±	0.7	mg/L	0.1	0.1	102616	SIF
	CHLORIDE	127.	±	2.1	mg/L	0.3	0.6	102087	CLF
*	P-ALKALINITY	48.2	±	0.3	mgCaCO3/L	1.0	4.0	10151L	PALK
	T-ALKALINITY	968.	±	0.6	mgCaCO3/L	1.0	4.0	10101L	TALK
	BICARBONATE	1060.			mg/L	1.	5.	06201L	HCO3
	CARBONATE	58.			mg/L	1.	5.	06301L	CO3
	CALCIUM	1.87			mg/L	0.004	0.100	103969	043E0
	MAGNESIUM	0.7930			mg/L	0.0001	0.0005	103979	025E0
	IRON	12.9			ug/L	2.00	4.00	103975	057E1
	CATIONS	24.0			meq/L	N/A	N/A	00120E	CAT
	ANIONS	23.2			meq/L	N/A	N/A	00125E	AN
	BALANCE	1.04				N/A	N/A		BAL
	TKN DISS	1.19	±	0.05	mg/L	0.01	0.11	07017L	TKND
**	PHOSPHOR DISS	0.207	±	0.006	mg/L	0.001	0.002	103464	TDP

"<" denotes value less than minimum reported value (MRV)
*denotes reported value less than method detection limit but higher than MRV
**recommended holding time exceeded
***MDL under development

NO_2 = NITRITE
NO_3 = NITRATE
TDS = TOTAL DISSOLVED SOLIDS

COMMENTS

CERTIFIED BY **Diana Spasiuk**
Senior Technologist
FOR YOGESH KUMAR
ENVIRONMENTAL MANAGEMENT
CONTACT : DIANA SPASIUK 632-8445

ALBERTA RESEARCH COUNCIL
PO Bag 4000
Vegreville, Alberta
Canada T9C 1T4
(780) 632 8211

ENVIRONMENTAL MANAGEMENT

CERTIFICATION ON ANALYTICAL RESULTS

MONDAY MARCH 31st, 2008

ARC SAMPLE NUMBER
0800430

ICPMS ANALYTICAL RESULTS*

PARAMETER (DISSOLVED)	ENVIRODAT VMV CODE	MEAN CONCENTRATION		STANDARD ERROR	UNITS	REMARKS	DETECTION LIMIT
ALUMINUM	103927	0.981	±	0.029	ug/L		1.
ANTIMONY	103951	0.0091	±	0.0007	ug/L		0.001
ARSENIC	103928	1.28	±	0.047	ug/L		0.04
BARIUM	103930	871.	±	4.8	ug/L		0.1
BERYLLIUM	103931	<0.003	±	0.0001	ug/L		0.01
BISMUTH	103932	0.0032	±	0.0003	ug/L		0.01
BORON	103929	1400.	±	19.	ug/L		8.
CALCIUM	103933	1.87	±	0.012	mg/L		0.1
CHLORINE	103935	121.	±	0.71	mg/L	Reference value	0.3
CHROMIUM	103937	5.80	±	0.15	ug/L		0.3
COBALT	103936	0.0189	±	0.0008	ug/L		0.01
COPPER	103938	1.33	±	0.023	ug/L		0.1
Cd DISSOLVED	103934	0.0150	±	0.0008	ug/L		0.006
IRON	103939	4.60	±	0.61	ug/L	Reference value	4.
LEAD	103949	0.0103	±	0.0006	ug/L		0.006
LITHIUM	103942	37.8	±	0.47	ug/L		0.2
MAGNESIUM	103943	0.7680	±	0.0047	mg/L		0.0005
MANGANESE	103944	0.482	±	0.0063	ug/L		0.03
MERCURY	103940	0.198	±	0.0052	ug/L	Reference value	0.05
MOLYBDENUM	103945	6.63	±	0.063	ug/L		0.008
NICKEL	103947	0.107	±	0.0089	ug/L		0.06
PHOSPHORUS	103948	571.	±	10.	ug/L		5.
POTASSIUM	103941	1360.	±	12.	ug/L	Reference value	5.
SELENIUM	103952	2.47	±	0.14	ug/L		0.3
SILICON	103953	4.86	±	0.058	mg/L		0.8
SILVER DISSOLVED	103926	<0.0005	±	0.0002	ug/L		0.005
SODIUM	103946	513000.	±	5769.	ug/L		60.
STRONTIUM	103955	184.	±	2.5	ug/L		0.008
SULPHUR	103950	3.17	±	0.21	mg/L	Reference value	0.6
THALLIUM	103958	0.0088	±	0.0016	ug/L		0.003
THORIUM	103956	0.0528	±	0.0052	ug/L		0.03
TIN	103954	<0.03	±	0.0011	ug/L		0.07
TITANIUM	103957	2.29	±	0.057	ug/L		0.07
URANIUM	103959	0.0033	±	0.0002	ug/L		0.003
VANADIUM	103960	1.40	±	0.038	ug/L		0.05
ZINC	103961	0.874	±	0.023	ug/L		0.2

* RESULTS BASED ON 5 READINGS PER MEASUREMENT

COMMENTS

CERTIFIED BY **Diana Spasiuk**
Senior Technologist
FOR YOGESH KUMAR
ENVIRONMENTAL MANAGEMENT
CONTACT : DIANA SPASIUK 632-8445

These results relate only to the items tested