

**Alberta
Innovates
Technology
Futures**

JACK WATER WELL INVESTIGATION

Follow-Up Water and Gas
Testing

Final Report

Prepared For:

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August 17, 2011

1.0 INTRODUCTION

In February 2011 Alberta Innovates Technology Futures (AITF) prepared a report for the Energy Resources Conservation Board (ERCB) assessing if the source of the gas in the Jack water well could be related to energy industry activities. An objective of this study was to evaluate the effects of remedial cementing conducted at an energy well located at 100/06-12-078-08W6M on the Jack water well. The results were inconclusive and AITF made a few recommendations for subsequent testing. Here we provide the results of:

- A pumping test conducted on the Jack water well, with pumping rates sufficient to reach the same water level as a test conducted on September 26, 2009.
- Resampling gas and water from the Jack water well.

2.0 OBJECTIVES

Pumping tests were conducted on the Jack water well before (September 26, 2009) and after (January 29, 2010, February 27, 2010 and May 22, 2010) the remedial cementing occurred on the energy well at 100/06-12-078-08W6M to see if there was a change in the amount and composition of gas in the water well. The post-remedial cementing pumping tests did not draw water levels down in the water well to the same elevation as the pre-remedial cementing pumping tests making direct comparison of the results difficult. The objective of the new pumping test was to draw the water level down to at least the same elevation as when degassing occurring during the test conducted on September 26, 2009, which was 30.54 m below top of casing (TOC).

The results of gas concentration and isotopic analyses on gases collected from the Jack water well from the last post-remedial work sampling visit conducted in May 2010 gave inconclusive results. While $\delta^{13}\text{C}$ of methane decreased slightly in the well, concentrations of ethane and propane increased. Together these results suggested a more complicated system than can be explained by a simple two-source biogenic/thermogenic mixing model. The objective of the repeat sampling was to see whether these trends are continuing and to conduct a laboratory intercomparison to determine whether the results reported from different laboratories can be compared directly. A water sample from the Jack water well was also submitted for routine parameters and various isotopic tracers to monitor any changes in water quality since the last testing in 2008, and to provide more information about the source and history of water in the well.

3.0 METHODS

3.1 Pumping Test

AITF personnel visited the Jack property between February 3rd and 6th, 2011 to perform a pumping test and resample the water well. Prior to starting the pumping test the depth to static water was 25.12 m below TOC of the well. The post-remedial cementing pumping tests conducted in January, February and May 2010 used the Jack's water pump, but were unable to reach the same level of drawdown as the pre-remedial cementing pumping test conducted in September 2009, possibly due to increases in static water level that had occurred over this period. A stronger pump was used in the February 4, 2011 pumping test to try to draw the

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water levels down further. AITF's pump was installed in the Jack water well at 18:15 on February 3, 2011 and a pressure transducer was placed in the well. A Calscan Hawk 9500 gas and water flow meter were attached to the Jack well to measure continuous gas flow from the casing and water flow from the discharge line, and a low flow gas meter was used periodically throughout the pumping test to try to detect gas when samples were taken.

The pump was initially started at 10:12 am on February 4, 2011 but the maximum pumping rate was measured at only 7.15 lgpm. To try to increase the pumping rate the water flow meter was removed and the pump was restarted at 12:28 pm. The pump was stopped at 13:51 to remove the gas separator from the outflow in an attempt to raise the flow rate and the pump was restarted immediately and the flow rate was measured at 11.83 lgpm. The pumping test continued until the water levels were drawn down more than 30.54 m below the TOC. The recovery portion of the pumping test started at 16:22 (February 5, 2011) when the pump was stopped and continuous water levels were measured until 11:16 am on February 6, 2011

Table 1: Summary of Pumping Test Timing

Activity	Time
Pump started	12:28 February 4, 2011
Recovery (pump stopped)	16:22 February 5, 2011
End of recovery monitoring	11:16 February 6, 2011

3.2 Gas and Water Sampling

Three gas samples were taken off a gas separator connected to the discharge line of the pump during the pumping test, and submitted for composition and isotopic analyses (Table 2). All gas samples were collected in FlexFoil gas bags. Three samples were taken during the duration of the pumping test to get an idea of the temporal variability of the concentrations and isotopic composition of the gas as the water levels in the Jack water well were drawn down. The compositional analyses were conducted at AITF in Vegreville and included atmospheric gases and hydrocarbon fractions (C1 through C4). The samples taken at 13:30 and 22:15 on February 4, 2011 were submitted to AITF Victoria. At 13:00 on February 5, 2011 three samples were taken in sequence off of the gas separator and submitted for isotopic analyses of C1 through C4 (methane, ethane, propane and butane) at three different isotopic laboratories: AITF Victoria, the University of Alberta, and the University of Calgary.

Table 2: Summary of gas samples taken during the February 4, 2011 pumping test.

	AITF Veg. Gas conc.	AITF Vic. Gas isotope	U of A Gas isotope	U of C Gas isotope
February 4, 13:30	x	x		
February 4, 22:15	x	x		
February 5 13:00	x	x	x	x
Standard		x	x	x

A gas of known concentrations was also submitted to all three laboratories for isotope analyses to evaluate the comparability of results using a more isotopically enriched sample with C2+ components. A methane isotopic standard was not used because, the methane isotopic standards available did not have any C2+ components. The standard used in this interlaboratory comparison had the following known gas concentrations: hydrogen=1%; butane=1%; propane=1%; ethane=3%; CO₂=5%; N₂=5%; and methane= 84%.

Water samples for routine, trace, Extractable Priority Pollutants (EPP), and Volatile Priority Pollutants (VPP) were submitted to the AITF laboratory in Vegreville. Analysis of $\delta^{18}\text{O}$, $\delta^2\text{H}$, and $\delta^{13}\text{C}_{\text{DIC}}$ were performed at AITF in Victoria. The sample for $\delta^{34}\text{S}$ analysis was submitted to the University of Calgary and the ^3H sample was submitted to Isotope Tracer Technologies (Waterloo). The water sample taken for bacterial analyses had to be at the laboratory within 24 hours of sampling, so this water sample was taken after the end of the pump test on February 6, 2011 and submitted to Alberta Environment.

4.0 RESULTS

4.1 Water Levels

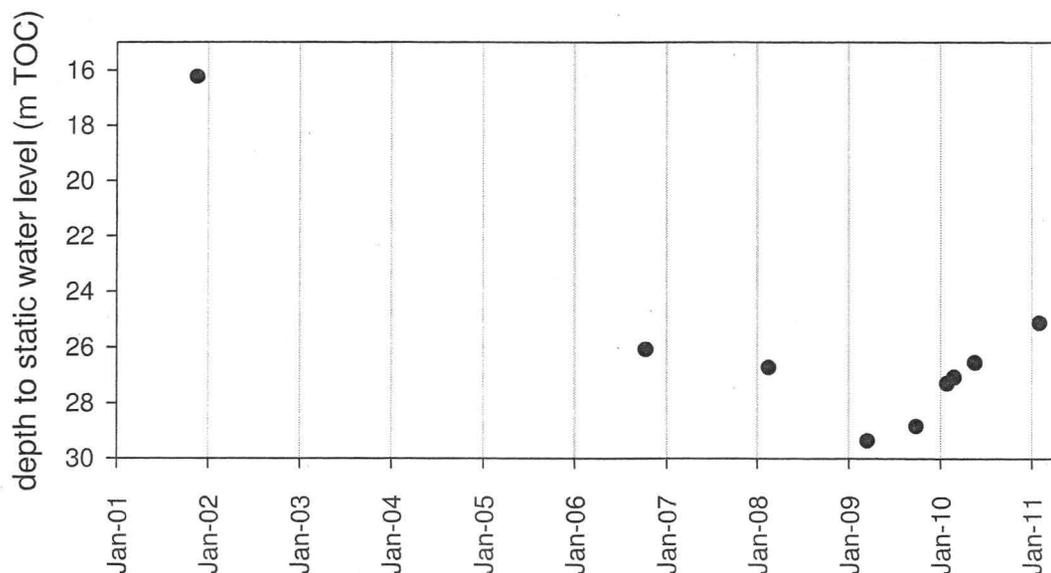


Figure 1: All of the manual water level data available for the Jack Water Well.

Before the pumping test started (February 3, 2011) the static water level in the Jack water well was 25.12 m below TOC. Adding this measurement to the water level history available for the Jack water well (Figure 1) (assembled using measurements reported in the original drillers report, a water level reported in the Matrix 2006 report, and measurements made by AITF during site visits made between 2008 and 2010) shows that the increasing trend in water levels that started in late 2008 or early 2009 has continued at a fairly constant rate. The cause for this trend of increasing water levels is not clear, and it is unfortunate that there are no other water level records in the area available for comparison. A water level logger was installed in the Jack water well on September 28, 2009 and left in until May 20, 2010 to try to see if there were any changes in water level before and after remedial cementing of the energy well at 100/06-12-078-08W6M, however the water level logger malfunctioned and no reliable estimates of water levels could be recovered from the record (for more detail see Appendix E).

4.2 Pumping Test

Gas flow measurements prior to starting the pumping test did not detect any measureable gas flow from the Jack water well under non-pumping conditions. Gas discharge was also not detected by the gas flow meter during the duration of the pumping test even when water levels

in the water well were drawn down below 30.54 m (Figure 2, bottom panel). The lack of degassing is also evident in the smooth water level profile. Once the water levels were drawn down below 30.54 m during the September 26, 2009 pumping test the well started degassing (Figure 2, top panel), shown by the fluctuations in water level that started when degassing began. Note that during the September 26, 2009 pumping test the gas flow meter wasn't working during the initial phase of the test, but the gas was observed discharging from the water well and pressure head measured with the transducer became variable (by about 1 m) after this time, due to eruption of the gas from the casing and changes in the density of water above the transducer.

The pumping test data was analyzed using AQTESOLV, Version 3.50 Professional, Aquifer Test Design and Analysis Computer Software (1996-2003 HydroSOLVE Inc.). This software provides analytical solutions for evaluating hydraulic 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 Theis (1935) confined aquifer solution was used to solve both the pumping test and the recovery test for the pumping test performed on February 4, 2011 and the graphical solutions are included in Appendix A. The pumping test started on May 22, 2010 was interrupted by a power failure, but was restarted and eventually completed. The qualitative observations made during this test and water level summary were presented in the previous report (AITF, 2011). For completeness, transmissivity ranges and graphical solutions, previously omitted from the last summary report, are now included in Table 3 and added to Appendix A. The pre- and post-remedial cementing pumping test analyses were conducted using the Theis (1935) confined aquifer solution to maintain consistency with early pumping test analyses since the primary goal was to identify significant changes in hydraulic properties of the aquifer over time. The confined aquifer solution is likely sufficient for change detection, however, if a more accurate estimate of aquifer properties is required, a more comprehensive fractured aquifer solution may be warranted in the future.

Table 3: Summary of transmissivity ranges

	Date	Transmissivity (m ² /min)
Pre-remedial cementing of 100/06-12-078-08 W6M	November 19, 2001	1.05 x 10 ⁻³ to 9.79 x 10 ⁻³
	February 18, 2009	1.65 x 10 ⁻³ to 3.28 x 10 ⁻³
	September 26, 2009	1.46 x 10 ⁻³ to 2.73 x 10 ⁻³
Post-remedial cementing of 100/06-12-078-08 W6M	January 29, 2010	2.91 x 10 ⁻³ to 3.32 x 10 ⁻³
	February 27, 2010	4.21 x 10 ⁻³ to 4.70 x 10 ⁻³
	May 23, 2010	2.44 x 10 ⁻³ to 2.84 x 10 ⁻³
	February 4, 2011	2.90 x 10 ⁻³ to 3.13 x 10 ⁻³

The post-remedial cementing transmissivity estimates are within the range estimated from the original recovery test performed in 2001 and the pre-remedial cementing tests from 2009 (Table 3). As was noted in previous reports (ARC, 2008; AITF, 2011) the transmissivity estimates are generally higher than is normally found in shale and sandstone, possibly due to the presence of fractures in the aquifer. The post-remedial cementing estimated transmissivities have a narrower range than the pre-remedial cementing estimates, but

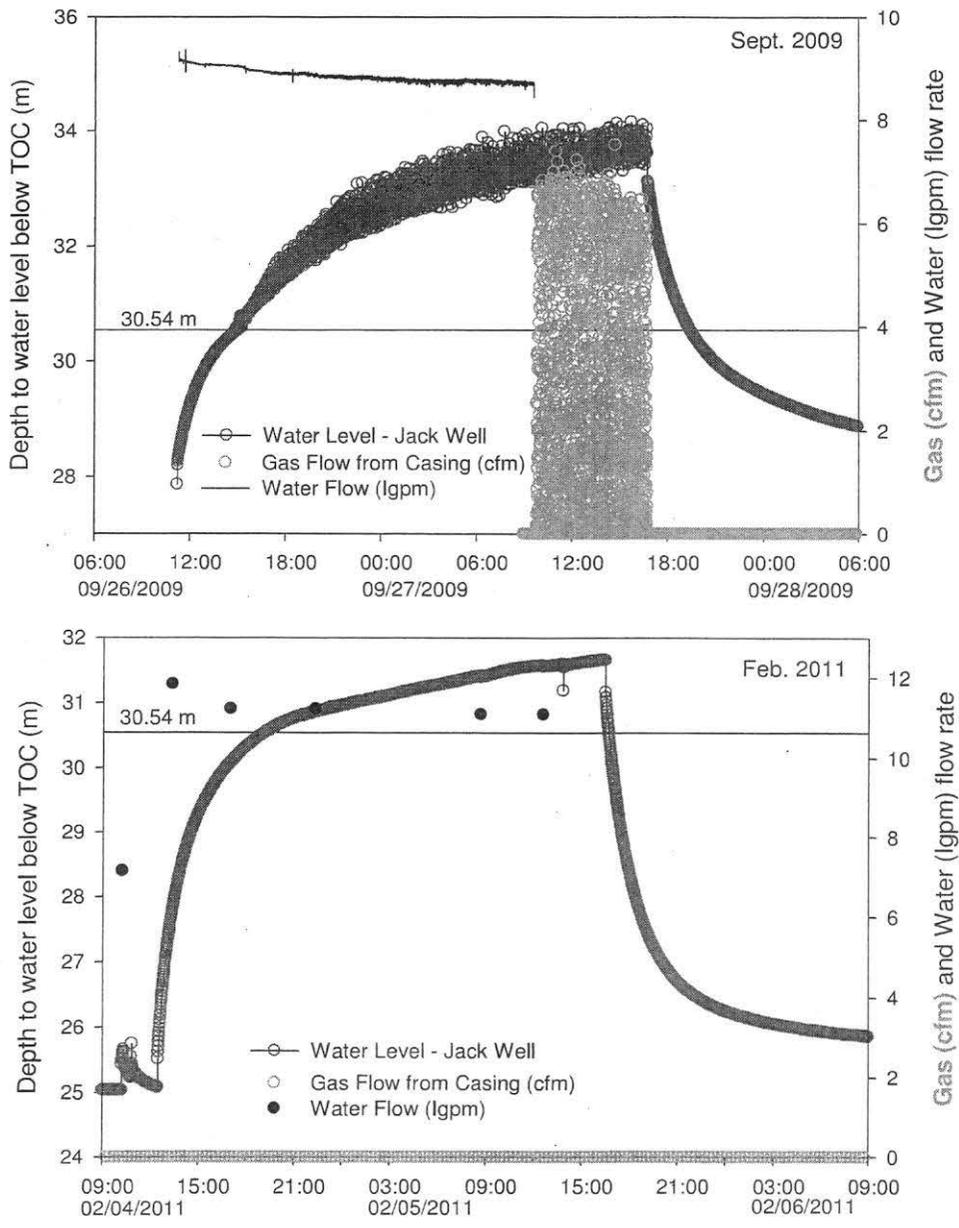


Figure 2: Comparison of the September 2009 pre-remedial cementing pumping test water levels and gas flow rates with those measured during the February 2011 pumping test. A reference line at 30.54 m below TOC is included to facilitate comparison.

Table 4: Changes in Jack water well behaviour over time.

		Pump Tests Conducted Pre-Remedial Cementing of 6-12				Pump Tests Conducted Post-Remedial Cementing of 6-12			
		November 19, 2001	February 20, 2008	March 18, 2009	September 24, 2009	January 29, 2010	February 27, 2010	May 23, 2010	Feb 4, 2011
Non-Pumping Behaviour	Depth to static water level	16.27 m (from TOC)	26.75 m (from TOC)	29.38 m (from TOC)	27.88 m (from TOC)	27.33 m (from TOC)	27.12 m (from TOC)	26.58 m (from TOC)	25.12 m (from TOC)
	Gas flow rate	NA	Constant flow of ~60 L/min Mr. Jack measured 100 cf/min during eruption	Constant flow of ~5 L/min	Constant flow of ~5 L/min	None detected	None detected	None detected	None detected
	Gas eruption frequency	NA	Every 5-10 min	None since Jan. 19, 2009	None	None	None	None	None
	Gas location	NA	Casing (top slot in liner), small amount exsolved from water	NA	Casing (top slot in liner)	No gas	No gas	No gas	No gas
Pumping Behaviour	Relation to pumping	NA	Immediate eruptive degassing, that stopped when pumping stopped	NA	Pumped for 3 hours before eruptive degassing started, stopped when pumping stopped	No eruptive degassing even after pumping, exsolution of gas after 6.5 h of pumping	No eruptive degassing after pumping, exsolution of gas after 6.5 h of pumping	No eruptive degassing after pumping, exsolution of gas after 11 h of pumping	No eruptive degassing after pumping, no exsolution of gas after 28 h of pumping
	Relation to water level	NA		NA	2.66 m drawdown before eruptive degassing	No eruptive degassing, exsolution after 2.3 m drawdown	No eruptive degassing, exsolution after 2.5 m drawdown	No eruptive degassing, exsolution after 3.6 m drawdown	No eruptive degassing, no exsolution after 5.9 m drawdown
	Water depth for degassing				30.54 m TOC	No degassing, water level drawn down to 29.63 m TOC	No degassing, water level drawn down to 29.62 m TOC	No degassing, water level drawn down to 30.18 TOC	No degassing, water level drawn down to 31.66 TOC
	Gas flow rate	NA	Mr. Jack measured 100cf/min during eruption	NA	~5 L/min	Below detection of flow meter	Below detection of flow meter	Below detection of flow meter	Below detection of flow meter
	Gas eruption frequency	NA	Constant	NA	Gas pulse every 50 sec	None	None	None	None
	Gas location	NA	Majority from casing (top slot in liner), small amount exsolved from water	NA	Majority from casing (~800 mL/min exsolved from water)	None from casing, <100 mL/min exsolved from water	None from casing, <100 mL/min exsolved from water	None from casing, <100 mL/min exsolved from water	None from casing, <100 mL/min exsolved from water

this could be due to a decrease in gas surging during the later pumping tests, allowing for easier curve matching.

Measurements of gas flow rates made during the pumping tests allow for some more qualitative comparisons of the behaviour of the Jack water well over time. Prior to the remedial cementing of the energy well at 100/06-12-078-08W6M a constant gas flow was measured discharging from the well under non-pumping conditions. However, the constant gas flow rate was observed to have declined substantially (from 60 L/min to 5 L/min) between the measurements made on February 20, 2008 and March 18, 2009, both of which are before remedial cementing of the energy well. This decline continued and for all of the pumping tests conducted after the remedial cementing of the energy well gas flow measurements were below detection under non-pumping conditions. Water levels were increasing during this time period, so slight increases in the solubility of methane due to slight increases in pressure head should be considered.

There was also a change in the behaviour of the Jack water well under pumping conditions. While AITF personnel were conducting the pumping tests, gas discharging from the Jack water well was measured using a gas flow meter and water level conditions, gas flow and gas in the separator were noted. Eruptive degassing of Jack water well was easily identified by surges in gas flow, and rapid variations in water levels. Gas exsolution (gas coming out of solution) was noted when the water coming out of the pump contained visible bubbles, when gas started accumulating in the gas separator or when bubbles started accumulating in an inverted bottle. Prior to the remedial cementing of the energy well at 100/06-12-078-08W6M degassing was measured during pumping conditions. There was no degassing during the 2010 pumping tests, but they were not successful in drawing down water levels in the Jack water well below where degassing had been observed in the past. The February 4, 2011 pumping test was able to draw the water levels down to 31.67 m below TOC without any degassing being measured or observed.

4.3 Gas Analyses

The gas samples taken over the duration of the pumping test and analyzed at AITF Victoria indicate fairly stable concentrations and isotopic compositions of gases as water levels in the Jack water well were drawn down (Table 5). There was a slight increase in the methane concentrations and decrease in the ethane and propane concentrations as the test progressed. Butane was below detection (<0.05 ppmv) for all three samples. There were also slight shifts in the isotopic composition of the gases with methane $\delta^{13}\text{C}$ values becoming slightly more positive, and ethane $\delta^{13}\text{C}$ values becoming more negative. This comparison was performed to see if there were significant variations over the duration of the pumping test, and give confidence that the values are fairly stable. The sample taken on February 5 13:00 was used for the interlaboratory comparison to maintain consistency with previous sampling of the water well.

Interlaboratory comparison of the Jack water well sample (Table 6) and the standard (Table 7) reveals good reproducibility by individual labs but slight offset between labs. The methane $\delta^{13}\text{C}$ results from AITF were the most negative, followed by the results reported by the University of Calgary and then the University of Alberta. In total there was a 1.6 ‰ spread between the results for methane (standard deviation of 0.81‰) and 1.9‰ spread for ethane (standard deviation 0.94‰). The gas compositional analyses revealed propane and butane concentrations of 9.00 ppmv and <0.05 ppmv respectively. The concentrations present in the Jack gas samples were too low for the $\delta^{13}\text{C}$ to be determined using standard techniques employed by the AITF

Table 5: Comparison of gas concentrations and isotopic compositions taken over the duration of the pumping test.

Gas concentrations (Vegreville)						
	methane (ppmv)	ethane (ppmv)	propane (ppmv)	i-butane (ppmv)	n-butane (ppmv)	CO ₂ (ppmv)
Feb 4 13:30	894000	512	13.80	<0.05	<0.05	1240
Feb 4 22:15	896000	410	10.10	<0.05	<0.05	1210
Feb 5 13:00	928000	366	9.00	<0.05	<0.05	1080
Isotope composition (AITF Victoria)						
	$\delta^{13}\text{C}_{\text{methane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{ethane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{propane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{i-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{n-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{CO}_2}$ (VPDB)
Feb 4 13:30	-71.0	-30.3	Too small	Too small	Too small	-27.2
Feb 4 22:15	-70.9	-30.5	Too small	Too small	Too small	-27.3
Feb 5 13:00	-70.3	-30.7	Too small	Too small	Too small	-29.2

na: not analyzed

and University of Calgary laboratories. The University of Alberta was the only laboratory to report the $\delta^{13}\text{C}$ values for propane or butane for the Jack water well. All of the isotope laboratories made the $\delta^{13}\text{C}$ measurements using a gas chromatography combustion system coupled in continuous flow mode to a mass spectrometer, but the methodologies used by the different laboratories results in different peak-resolving abilities. The challenge in analyzing the isotopic ratios in very low concentration samples is to increase the sample volume being injected into the gas chromatograph without causing the peak of that component of the gas to broaden too significantly. The peaks generated by the sample volumes used by the AITF and University of Calgary labs were not sufficient for isotopic analyses. The University of Calgary reports their reproducibility as 0.5 ‰ for methane and 0.2 ‰ for ethane, propane and butane, and they do not report isotope ratios for compounds that generate a peak of less than 200 mV on the gas chromatograph, which would translate roughly to concentrations of about 1000 ppm of methane. The AITF laboratory reports a reproducibility of 0.2 ‰ for methane, ethane and propane and the concentration required for isotopic analyses is about 300 ppm. The University of Alberta has a reproducibility of 0.5 ‰ for methane and 0.2 ‰ for ethane, propane and butane, and their detection limit is dependent on the sample composition.

Similar results were obtained for the interlaboratory comparison of the gas standard. Standards with known isotopic compositions of methane are available; however they typically consist of fairly pure methane gas. A gas with a known composition was chosen instead, so that the intercomparison would also include ethane, propane and butane. It should be noted that the concentrations of ethane, propane and butane were much higher in the standard than in the Jack water well samples which likely made their analyses much easier. The ranges in $\delta^{13}\text{C}$ values reported for the standards were 0.9‰ for methane, 1.3‰ for ethane, 2.0‰ for propane and 2.4‰ for butane (Table 7). The results for methane, ethane, propane and butane from AITF and the University of Alberta were consistent in their offset, with the AITF results being 0.9 to 2.4 ‰ more negative. The AITF laboratory did not distinguish which form of butane was reported.

The differences in the $\delta^{13}\text{C}$ values measured at the different laboratories indicates that the results need to be interpreted cautiously on a lab-by-lab basis. As such, temporal isotopic trends based on results from more than one lab may in fact be unreliable. This finding has implications for previous interpretation of the Jack water well isotope data that relied on amalgamated data

from several labs (AITF, 2011). As reported therein, the inferred negative shift in $\delta^{13}\text{C}$ for the water well sample taken after the remedial-cementing of energy well 100/06-12-078-08W6M, did not take into account interlaboratory differences. Comparing only results from the University of Alberta it appears that $\delta^{13}\text{C}_{\text{methane}}$ composition measured on February 5, 2011 after remedial cementing (-68.69 ‰) is about 3‰ more negative than the range of values reported prior to remedial cementing (-65.9 ‰ to -64.97‰, n=6). A similar conclusion would be reached if the AITF results reported for May 23, 2010 and February 5, 2011 were increased by +1.6 ‰ to account for the apparently systematic offset between these two laboratories.

Table 6: Interlaboratory comparison of the sample from the Jack water well and a standard. Concentrations from the Vegreville laboratory are included for reference.

Gas concentrations (Vegreville)						
	methane (ppmv)	Ethane (ppmv)	propane (ppmv)	i-butane (ppmv)	n-butane (ppmv)	CO ₂ (ppmv)
Feb 5 13:00	928000	366	9.00	<0.05	<0.05	1080
Isotope composition of the sample taken on February 5 13:00, submitted in triplicate						
	$\delta^{13}\text{C}_{\text{methane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{ethane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{propane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{i-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{n-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{CO}_2}$ (VPDB)
AITF, Victoria	-70.3	-30.7	Too small	Too small	Too small	-29.2
University of Alberta	-68.7	-29.8	-23.7	-26.6		-29.3
University of Calgary	-69.5	-28.8	Too small	Too small	Too small	-24.6
Standard deviation	0.81	0.94				2.69
Range	1.6	0.9				4.73

Table 7: Interlaboratory comparison of the results of the isotopic results for the gas standard. Concentrations are included for reference.

Gas concentrations						
	methane (ppmv)	Ethane (ppmv)	propane (ppmv)	i-butane (ppmv)	n-butane (ppmv)	CO ₂ (ppmv)
Standard	840000	30000	10000	-	10000	50000
Isotope composition of the standard submitted in triplicate						
	$\delta^{13}\text{C}_{\text{methane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{ethane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{propane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{i-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{n-butane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{CO}_2}$ (VPDB)
AITF, Victoria	-40.6	-31.7	-25.3		-33.7*	-33.5
University of Alberta	-39.7	-30.4	-23.3	-32.44	-31.3	-32.3
University of Calgary	-40.1	-31.3	-24.0		-32.7	-33.7
Standard deviation	0.44	0.65	1.02		1.21	0.76
Range	0.9	1.3	2.0		2.4	1.4

*- AITF did not differentiate which butane was measured.

The plot of C1/C2+ versus $\delta^{13}\text{C}_{\text{methane}}$ was updated with the February 2011 data to show the variability between the different laboratories as well as some changes in gas concentrations that have occurred over time (Figure 3). With the exception of one of the February 2008 samples analyzed at the University of Victoria, all of the solid green triangles were analyzed at the University of Alberta (Figure 3). These samples have a range in “wetness” C1/C2+ but a fairly tight range of $\delta^{13}\text{C}_{\text{methane}}$. The post remedial-cementing samples include an anomalous sample from the May 2010 sampling event, whose ratios of C1/C2+ seemed to indicate a larger

thermogenic component of gases in the Jack water well (concentrations of ethane and propane increased). The C1/C2+ values of the samples taken in February 2011 indicate that the gases in the Jack water well now are back within the range measured prior to 2008. The laboratory intercomparison has shown that differences in the measurements of $\delta^{13}\text{C}$ between AITF Victoria and the University of Alberta could account for some of the shift towards more negative $\delta^{13}\text{C}_{\text{methane}}$ values in May 2010 described in the previous report (AITF, 2011). Using the University of Alberta values measured in February 2011, or applying a +1.6 ‰ correction factor to the AITF values indicates a smaller change in the methane isotope composition over time.

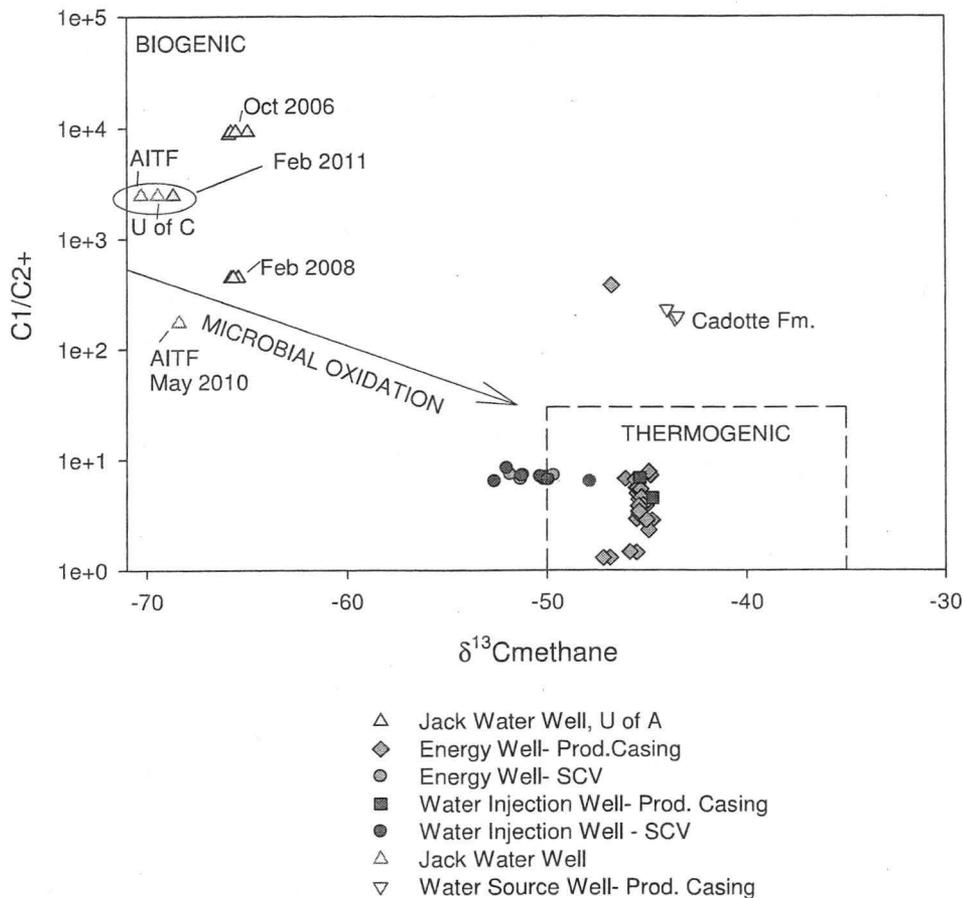


Figure 3: Summary of methane isotope data and gas C1/C2+ ratios.

The concentrations of i-butane measured in the February 5, 2011 sample from the Jack water well were <0.05 ppmv but the University of Alberta laboratory was able to report a $\delta^{13}\text{C}_{\text{i-butane}}$ value. Previous samples have had higher concentrations of i-butane, but this was the first time that an isotopic composition was reported. Given the very low concentration of i-butane present in the sample this measurement may not have the same accuracy and precision as the others and be more prone to measurement error, but we used it here to see if it matches the values reported for samples from the mudlog from 100/02-04-078-07 W6M for the Paddy, Cadotte or

Spirit River Group Formations (from 844 to 925 mbgs) (AITF, 2011) or any of the nearby energy wells that have been sampled in the area. Since it appears that the methane sampled in the Jack water well contains a significant proportion of biogenic gases we will focus on the $\delta^{13}\text{C}$ signatures of the higher order hydrocarbon gases: ethane, propane and butane. Comparison of this new Jack $\delta^{13}\text{C}_{\text{ibutane}}$ value with those measured in the mudlog shows about a 2.5 ‰ difference between the gas from the Jack well and those found at depths for the Paddy, Cadotte or Spirit River Group Formations, but as noted previously the $\delta^{13}\text{C}$ of propane does not match any results from the mudlog at 100/02-04-078-07 W6M (AITF, 2011). Comparison of the isotopic signatures of ethane, propane and the new i-butane value with energy well isotopic compositions in the area (Table 8 and Figure 4) reveals some overlap between the individual ranges of $\delta^{13}\text{C}$ values for ethane, propane and butane, but none of the energy wells in the dataset are a good match for the isotopic signature of all three gases (Figure 4).

Table 8: Average $\delta^{13}\text{C}$ values of methane, ethane, propane and butane for gases from the Jack water well and a mudlog and nearby energy wells observed to have the most similar isotopic signatures.

	$\delta^{13}\text{C}_{\text{methane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{ethane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{propane}}$ ‰ (VPDB)	$\delta^{13}\text{C}_{\text{ibutane}}$ ‰ (VPDB)
Jack Water Well	-66.79 (n=12)	-30.00 (n=12)	-23.46 (n=5)	-26.56 (n=1)
100/02-04-078-07W6M MUDLOG (844 925 mbgs)	-44.08 (n=5)	-28.72 (n=5)	-29.12 (n=5)	-29.01 (n=5)
100/06-12-078-08W6M SCV	-50.49 (n=4)	-31.59 (n=4)	-27.91 (n=4)	-28.93 (n=4)
100/11-18-078-07W6M	-43.70 (n=3)	-26.50 (n=3)	-25.79 (n=3)	-27.48 (n=3)
102/16-01-078-08 W6M	-46.45 (n=2)	-31.87 (n=2)	-30.57 (n=2)	-33.24 (n=2)

Time-series plots of the isotopic composition of gases measured at the Jack water well show the changes in isotopic composition (Figure 5) and gas concentrations (Figure 6) over time. Data from the SCV gases from the energy well at 100/06-12-078-08W6M are included for comparison. The 2008 measurements of $\delta^{13}\text{C}_{\text{methane}}$ of gases in the Jack well include a fairly large range, largely because of the very negative value reported by Zymax. If only the University of Alberta values are considered, the data show a decrease of 3.16 ‰ in $\delta^{13}\text{C}_{\text{methane}}$ from average pre-remediation values measured in 2008 (-64.97 ‰) to the most recent sampling in Feb 2011. The AITF measurements of $\delta^{13}\text{C}_{\text{methane}}$ made on May 23 2010 (-68.4 ‰) and on February 2011 (-70.3 ‰) also show decrease in $\delta^{13}\text{C}_{\text{methane}}$ of 1.9 ‰ over this period

The isotopic composition of ethane and propane are all within their pre-remedial cementing ranges. The samples taken after the remedial cementing of the energy well at 100/06-12-078-08W6M (January 2010) are within the range of values reported prior to remedial cementing when interlaboratory differences are taken into consideration. There is a fairly wide range in the $\delta^{13}\text{C}_{\text{ethane}}$ values reported by the different laboratories for the February 2011 gas sample from the Jack water well (Figure 4), but the U of A and AITF values are within the range reported prior to the remedial cementing of the energy well at 100/06-12-078-08W6M. The Jack water well sample obtained on February 5, 2011 contained very low concentrations of propane and as a result only the University of Alberta laboratory reported $\delta^{13}\text{C}$ values for this gas. The recent $\delta^{13}\text{C}_{\text{propane}}$ was found to be similar to values reported in 2008.

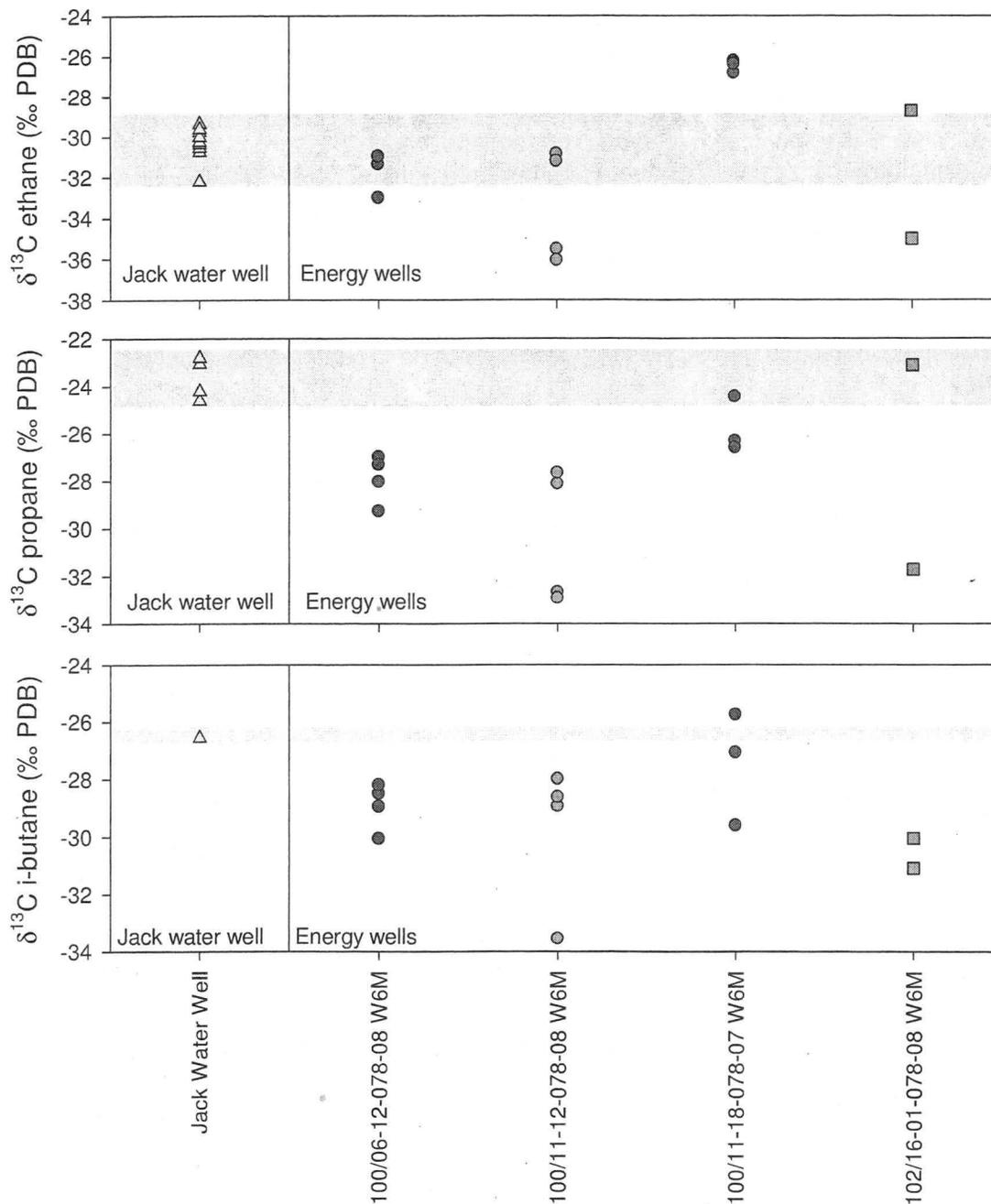


Figure 4 Comparison of the $\delta^{13}\text{C}$ values for ethane, propane and i-butane from gas from the Jack water well, with energy wells in the area with the most similar isotopic compositions. Grey bars are extended horizontally from the range of values reported for the Jack water well to facilitate comparison. There is overlap for individual components of the gases, but none of the energy wells sampled are a good isotopic match for all of the gases.

One of the reasons for resampling the Jack water well was concern over the increase in ethane and propane concentrations in the gas sample taken on May 23, 2010. All of the new gas concentrations results for the February 2011 samples indicate that ethane (366 to 512 ppmv) and propane (9.0 to 13.8 ppmv) concentrations have returned to levels measured in 2008 and earlier. This return to higher C1/C2+ ratios in the February 2011 sample is evident in Figure 3 and Figure 6a. The gas and energy wells were characterized by very low C1/C2+ ratios (e.g. blue circles on Figure 6a, note logarithmic scale) whereas the gases from the Jack water well have ratios more typical of biogenic gases. The May 2010 gas sample from the Jack water well had the lowest C1/C2+ ratio, but the most recent sample indicates ratios more similar to previous measurements. The methane concentrations were slightly higher in the Jack well than in the energy well at 100/06-12-078-08W6M (Figure 6b) whereas the ethane and propane concentrations were much higher in the energy well than in the Jack well (Figure 6c and d). The February 5, 2011 gas sample from the Jack water well shows a decrease in ethane concentrations from the anomalously high value measured on the May 2010 sample.

The $\delta^2\text{H}_{\text{methane}}$ of gas from the Jack water well was also measured by AITF on the sample taken on February 5, 2011 and can be compared with sample analyses conducted in 2006 by Zymax (Table 9). The previous interpretation of the Jack water well $\delta^2\text{H}$ results by Zymax (2007) was that they plot in a portion of the $\delta^{13}\text{C}_{\text{methane}}-\delta^2\text{H}_{\text{methane}}$ diagram characteristic of a biogenic gases. The samples from the energy wells from 2006 were interpreted as plotting in the region typical for thermogenic gases (Zymax, 2007). The data from 2011 do not indicate a significant change in the $\delta^2\text{H}_{\text{methane}}$.

Table 9: New $\delta^2\text{H}_{\text{methane}}$ for the Jack water well compared with 2006 analyses.

Well	Date	$\delta^{13}\text{C}_{\text{methane}}$	$\delta^2\text{H}_{\text{methane}}$	Laboratory
Jack water well	Oct. 19, 2006	-69.3	-297	Zymax
Jack water well	Feb. 5, 2011	-70.3	-293	AITF
Energy Wells				
100/06-12-078-08W6M	Oct. 19, 2006	-51.5	-233	Zymax
100/2-12-078-08W6M	Oct. 19, 2006	-45.4	-228	Zymax

4.4 Water Analyses

The water quality parameters measured in 2011 show no significant changes from those measured in 2008. During both sampling events there were no detectable concentrations of any of the EPP or VPP parameters. The only significant change was in the concentrations of sulfur and iron reducing bacteria. This may have been due to the samples being taken with the AITF pump in February 2011, whereas previous samples were taken using the pump installed in the Jack well. When the Jack's pump was removed to insert the AITF pump, it was observed to be covered in black slime typical of bacterial activity.

The new isotopic analyses (Table 10) have provided some additional information about the source of water and solutes in the Jack water wells. ^3H results indicate that there is no post-1950 water present in the Jack water well. This is consistent with the very negative $\delta^{18}\text{O}$ and $\delta^2\text{H}$ compositions which suggest water from a deeper aquifer and not a shallow aquifer receiving local recharge. The low sulfate concentrations, $\delta^{34}\text{S}$ composition and very negative $\delta^{13}\text{C}$ of DIC are typical of groundwaters having undergone bacterially mediated reduction of sulfate, organic matter or hydrocarbons. The isotopic composition of the Jack water well is consistent with a deep aquifer not hydraulically connected to shallow aquifers and not receiving recent recharge.

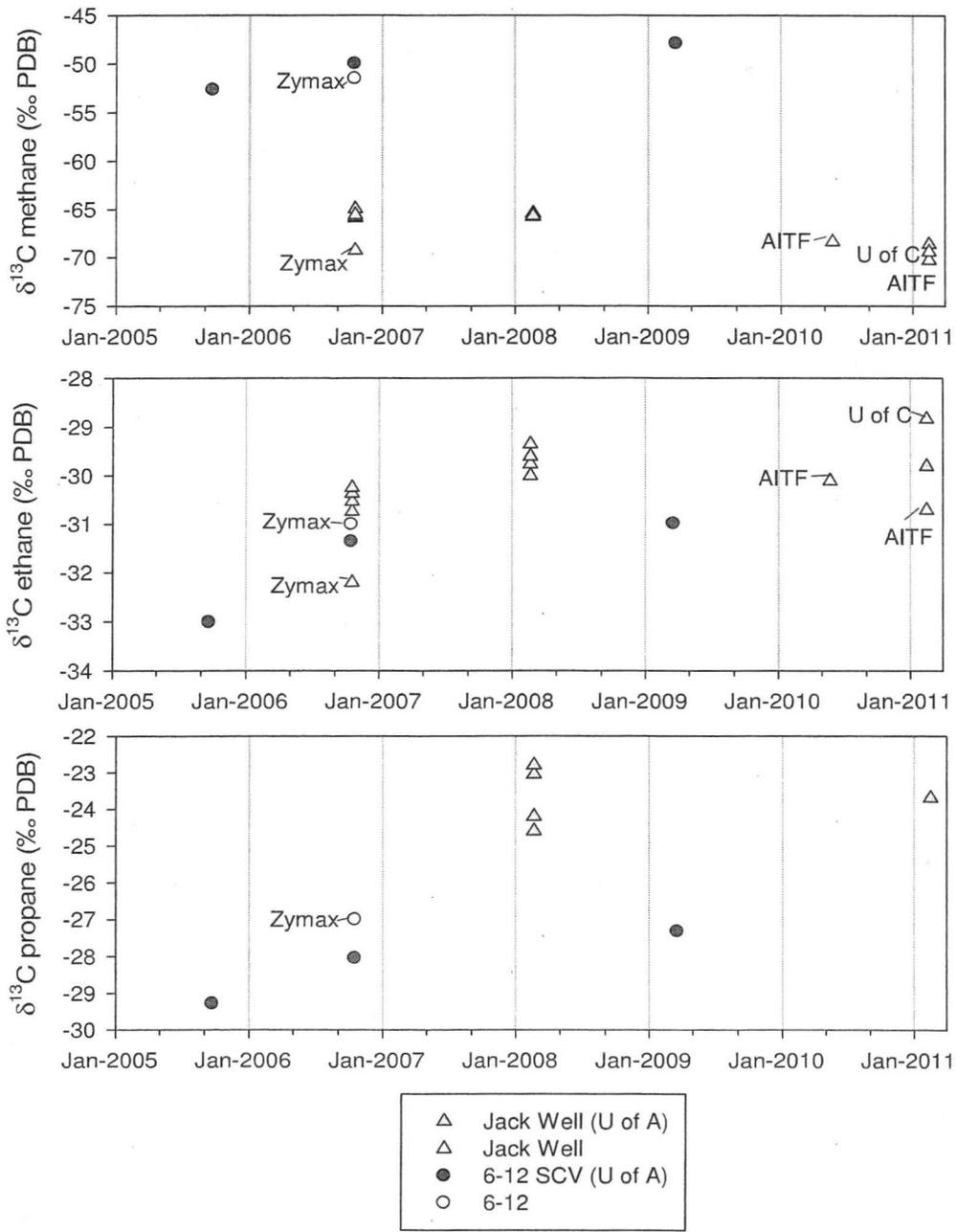


Figure 5 Time-series of the $\delta^{13}\text{C}$ composition of methane, ethane and propane over time. The solid symbols indicate analyses performed by University of Alberta, and the laboratory responsible for the open symbols is indicated by the text.

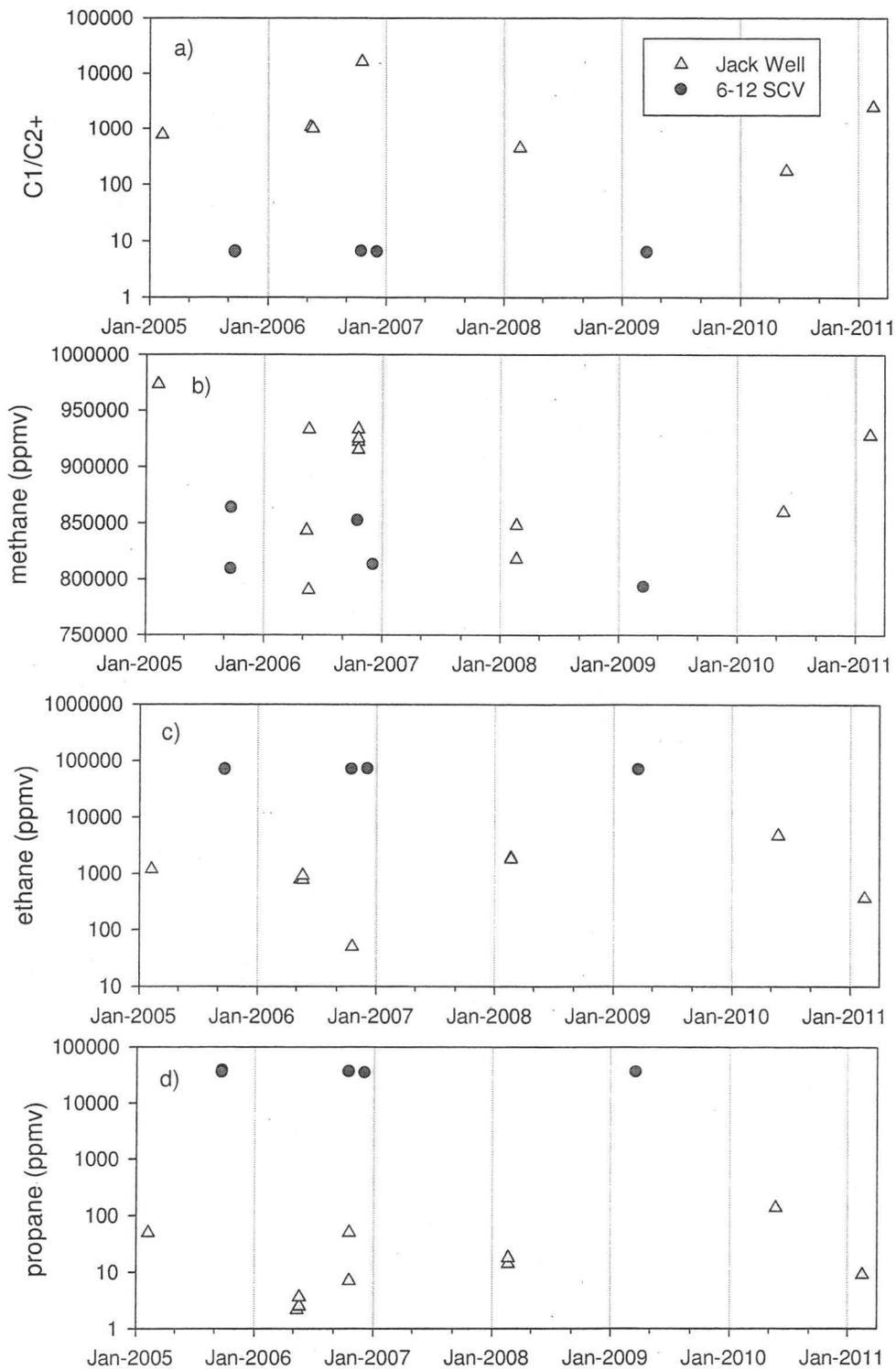


Figure 6: Variations in gas concentrations measured at the Jack water well and from SCV at 100/06-12-078-08W6M over time. Note: log scales on a, c and d.

Table 9: Comparison of water quality parameters measured in 2008 with those measured in 2011.

Parameter	Jack Well Water Feb. 20, 2008	Jack Well Water Feb. 5, 2011	CDWQG (2007)	
			MAC	AO
pH (units)	8.83	8.56		6.5-8.5
EC (µS/cm)	2060	2140		
TDS-calculated (mg/L)	1270	1370		≤ 500
Tot Alk as CaCO ₃ (mg/L)	968	998		
Sodium (mg/L)	547	603		≤ 200
Potassium (mg/L)	1.7	1.6		
Calcium (mg/L)	1.87	2.13		
Magnesium (mg/L)	0.793	1.03		
Iron (mg/L)	0.005	0.0187		≤ 0.3
Iron (tot) (mg/L)	0.0129	0.0327		
Manganese (mg/L)	0.00050	0.000555		≤ 0.05
Chloride (mg/L)	127	160		≤ 250
Fluoride (mg/L)	1.76	1.74	1.5	
Sulphate (mg/L)	7	7		≤ 500
Carbonate (mg/L)	58	31		
Bicarbonate (mg/L)	1060	1150		
NO ₂ as N (mg/L)	nd	0.002		
NO ₂ +NO ₃ as N (mg/L)	0.018	0.01		
Aluminum (mg/L)	nd	0.000825		0.1
Antimony (mg/L)	0.000009	0.0000109	0.006	
Arsenic (mg/L)	0.00128	0.00000126	0.010	
Barium (mg/L)	0.8710	0.929	1	
Beryllium (mg/L)	nd	0.000021		
Bismuth (mg/L)	nd	0.000001		
Boron (mg/L)	1.40	1.43	5	
Chromium (mg/L)	0.0058	0.00239		
Cobalt (mg/L)	0.00002	0.0000187		
Copper (mg/L)	0.0013	0.000206		≤ 1.0
Cadmium (mg/L)	0.000015	0.000009	0.005	
Lead (mg/L)	0.005	0.000001	0.01	
Lithium (mg/L)	0.037800	0.0404		
Mercury (mg/L)	0.00020	0.0000457	0.001	
Molybdenum (mg/L)	0.006630	0.00515		
Nickel (mg/L)	0.00011	0.000005		
Phosphorus (mg/L)	0.571	0.523		
Selenium (mg/L)	0.0025	0.00337	0.01	
Silicon (mg/L)	0.0049	0.00271		
Silver (mg/L)	nd	0.0000005		
Strontium (mg/L)	0.184000	0.124		
Sulphur (mg/L)	0.0032	0.00218		
Thallium (mg/L)	0.000009	0.0000024		
Thorium (mg/L)	0.00005	0.0000015		
Tin (mg/L)	nd	0.00003		
Titanium (mg/L)	0.00229	0.00161		
Uranium (mg/L)	0.000003	0.0000024	0.02	
Vanadium (mg/L)	0.00140	0.000697		
Zinc (mg/L)	0.0009	0.000288		≤ 5.0
Cations (meq/L)	24	26.5		

Parameter	Jack Well Water Feb. 20, 2008	Jack Well Water Feb. 5, 2011	CDWQG (2007)	
			MAC	AO
Anions (meq/L)	23.2	24.7		
Balance	1.04	1.07		
Tot Coliforms (MPN/100mL)	0	<1	0	
Fecal Coliforms (MPN/100mL)	0	<1	0	
Slime Bacteria (cfu/mL)	350000	na		
S Reducing Bacteria (cfu/mL)	5000	1200		
Hetrotrophic Bacteria (cfu/mL)	7000000	na		
Iron Reducing Bacteria (cfu/mL)	140000	35000		

na= not analyzed

Nd=not detected

Table 10: New isotopic analyses for the February 5, 2011 water sample.

Parameter	Result
$\delta^{18}\text{O}_{\text{H}_2\text{O}}$	-23.50 ‰ (VSMOW)
$\delta^2\text{H}_{\text{H}_2\text{O}}$	-184.9 ‰ (VSMOW)
$\delta^{13}\text{C}_{\text{DIC}}$	-19.72 ‰ (VPDB)
$\delta^{34}\text{S}_{\text{SO}_4}$	8.3 ‰ (CDT)
$\delta^{18}\text{O}_{\text{SO}_4}$	Too small
^3H	<0.08 TU

5.0 SUMMARY

- The increasing trend in static water levels that appears to have started in late 2008 or early 2009 has continued at a linear rate, with static water levels now at 25.12 m below TOC.
- The pumping test analyses show that transmissivity estimates have remained within the same order of magnitude as the pre-remedial cementing tests, indicating no significant change in hydraulic properties of the aquifers.
- With only sporadic observations and measurements of gas flow from the Jack water well it is difficult to reconstruct when changes in the amount and form of gas occurred. However, based on the limited observations available we can identify a couple of periods when the behaviour of the water well changed:
 - Between the February 20, 2008 and March 18, 2009 visits to the Jack water well the gas flow measured under non-pumping conditions decreased significantly from a constant flow of 60 L/min (2008) to about 5 L/min (2009) and the spontaneous eruptions decreased in frequency from every 5-10 min (2008) to only under pumping conditions (2009). This shift in the amount of gas occurred prior to the remedial cementing of the energy well at 100/06-12-078-08W6M and coincides with the start of the increasing static water levels at the Jack water well.
 - More frequent observations made during the pumping tests conducted pre- and post- remedial cementing also indicate a small change in the amount and form of gas present in the well during this time period. Between the September 24, 2009 and January 29, 2010 visits to the Jack water well the gas flow measured under non-pumping conditions decreased from a constant flow of 5 L/min (2009) to below detection (2010) and the eruptive degassing

stopped even under pumping conditions. The February 2011 pumping test drew water levels in the Jack water well to 31.66 m below TOC without any eruptive degassing occurring. The present lack of spontaneous degassing and absence of the constant discharge of gas from the Jack water well indicate a change in the amount of gas present in the well since 2009, but it is not clear if this is a continuation of the decreasing trend that started when the water levels in the Jack water well began increasing.

- The gas composition data from the Jack well indicate that the ethane and propane concentrations have decreased since the anomalously high values measured in the May 2010 sample, while methane concentrations have remained within their pre-remedial cementing range. The ethane and propane concentrations are now within the range measured between 2005 and 2008.
- The interlaboratory comparison of the $\delta^{13}\text{C}$ of hydrocarbon gases done on the sample taken 13:00 on February 5, 2011 and a standard indicates about 1-2 ‰ offset between the different laboratories. The values obtained from the University of Alberta laboratory generally more enriched in $\delta^{13}\text{C}_{\text{methane}}$ and $\delta^{13}\text{C}_{\text{ethane}}$ (+ 0.9 to 1.6‰) than the AITF values and this difference should be accounted for when evaluating trends in the data over time. The $\delta^{13}\text{C}_{\text{methane}}$ values reported by the University of Calgary were 0.5 to 0.9 ‰ more positive than the AITF values.
- The magnitude of the change in the isotopic signature of methane at the Jack well since remedial cementing of the energy well at 100/06-12-078-08W6M depends on which set of laboratory results are used. The results from the University of Alberta and AITF indicate a small decrease in the $\delta^{13}\text{C}_{\text{methane}}$ over time whereas the combined $\delta^{13}\text{C}_{\text{methane}}-\delta^2\text{H}_{\text{methane}}$ from 2006 and 2011 indicate no significant change.
 - Comparing the pre-remedial cementing $\delta^{13}\text{C}_{\text{methane}}$ values for the Jack water well obtained from the University of Alberta laboratory in 2006-2008 (-65.9‰ to -64.97‰, average $\delta^{13}\text{C}_{\text{methane}} = -65.53\%$, n=6, standard deviation 0.33‰) with the February 2011 post-remedial cementing value from the same laboratory ($\delta^{13}\text{C}_{\text{methane}} = -68.69\%$) indicates a decrease of about 3.2‰ over this period.
 - The AITF measurements of $\delta^{13}\text{C}_{\text{methane}}$ made on May 23 2010 (-68.4‰) and on February 2011 (-70.3‰) also show decrease in $\delta^{13}\text{C}_{\text{methane}}$ of 1.9‰ over this period.
 - There were two occasions where both the $\delta^{13}\text{C}_{\text{methane}}$ and $\delta^2\text{H}_{\text{methane}}$ were measured on gas samples from the Jack water well; 2006 at the Zymax laboratory and 2011 at AITF. Comparison of these two sets of values indicate no significant change in the isotopic composition of methane, with both being indicative of a predominantly biogenic gas.
- There was no change in the $\delta^{13}\text{C}$ composition of ethane and propane in the Jack well after remedial cementing of the energy well at 100/06-12-078-08W6M even when interlaboratory differences are considered. The isotopic composition of ethane and propane in the Jack well are within the ranges previously measured, indicating the isotopic composition of these gases have remained fairly constant despite changes in their concentrations and the total volume of gas discharging from the well. The lack of change in the $\delta^{13}\text{C}$ signatures of the ethane and propane present in gases from the Jack well indicate that the source of these

gases to the water well has not changed since the remedial cementing of the energy well at 100/06-12-078-08W6M.

- The primarily biogenic signature of the carbon and hydrogen isotope ratios of methane sampled in the Jack water well, and the presence of methane in the Jack well at concentrations higher than in the energy wells, together indicate that the majority of methane in the water well is biogenic in origin. Comparing the isotopic signatures of ethane, propane and the new i-butane value with the mudlog from 100/02-04-078-07W6M and the full dataset of energy well isotopic compositions in the area shows some overlap between the individual ranges of $\delta^{13}\text{C}$ values for ethane, propane and butane, but none of the energy wells in the dataset are a clear match for the isotopic signature of all of the gases.
- Comparison of the geochemistry of water sampled from the Jack water well sampled in 2008 with the new results from 2011 do not indicate any significant changes in water quality over time.
- The 2011 water sample was obtained using a clean AITF pump, whereas the 2008 sample was obtained using the Jack pump which was covered with a black slime, a typical indicator of bacterial activity. Differences in the bacteria present on the pumps likely contributed to the decrease bacteria concentrations in the February 2011 sample.
- The new isotopic analyses have provided some additional information about the source of water and solutes in the Jack water well. ^3H results indicate that there is no post-1950 water present in the Jack water well. This is consistent with the very negative $\delta^{18}\text{O}$ and $\delta^2\text{H}$ composition which suggests the Jack well is sampling water from a deeper aquifer not in connection with a shallow aquifer receiving local recharge.
- The new results do not alter the previous assessment that the Jack water well contains a mixture primarily of biogenic gases with a small thermogenic component. The similarities between the $\delta^{13}\text{C}$ signatures of some of the gases in the Jack well with the gases in some of the energy wells in the area may indicate similar geological origins, but the results were not conclusive in identifying the source, pathway or method of introduction of the thermogenic gas to the Jack well.
- Some of the parameters measured at the Jack well indicate small changes after the remedial cementing of the energy well at 100/06-12-078-08W6M such as:
 - the 2-3 ‰ decrease in $\delta^{13}\text{C}_{\text{methane}}$,
 - the decrease in gas discharging from the Jack well from a constant flow of 5 L/min to below detection and a stop in the eruptive degassing under pumping conditions.

Whereas other parameters measured at the Jack well are still within their original ranges:

- $\delta^2\text{H}_{\text{methane}}$,
- $\delta^{13}\text{C}$ of ethane and propane,
- concentrations of methane, ethane, propane and butane,
- transmissivity estimates,
- water quality parameters.

Based on consideration of all of these parameters and the increases in the Jack well static water levels that started in 2008/2009, the remedial cementing at 100/06-12-078-08W6M does not appear to have had a significant impact on the Jack well.

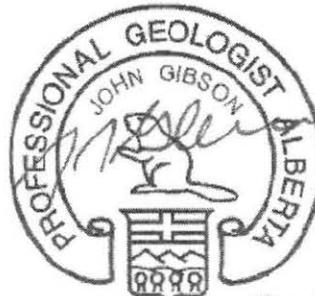
6.0 CLOSURE

The work described in this report was carried out in accordance with accepted hydrogeological practices.

Respectfully submitted,

S. Jean Birks

Jean Birks, Ph.D.
Senior Hydrogeologist
Integrated Water Management



17 AUG 2011

John J. Gibson, Ph.D., P.Geo., P.Geol.
Research Team Leader
Integrated Water Management

August 17, 2011
Alberta Innovates – Technology Futures

7.0 REFERENCES

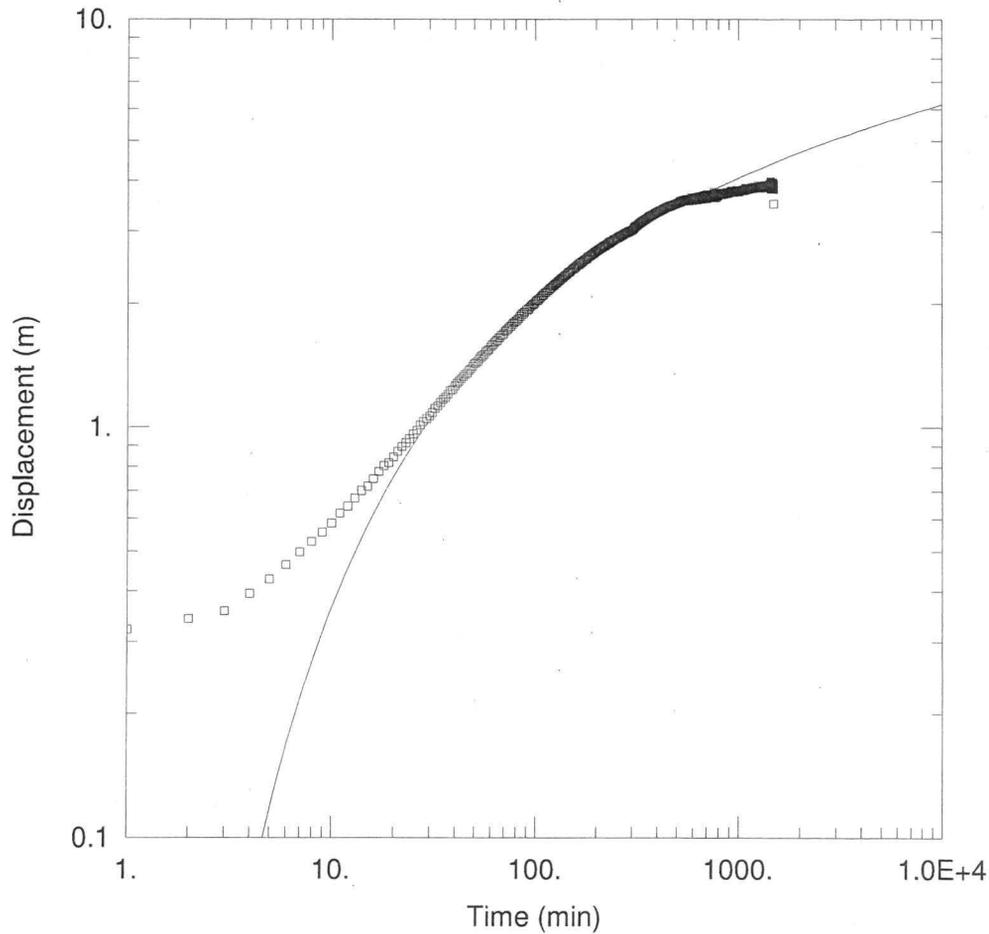
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APPENDIX A
Pumping Test Results



WELL TEST ANALYSIS

Data Set: C:\...\jack well May 22 2010 pumptest. _pumping.aqt
 Date: 08/13/10 Time: 07:07:12

PROJECT INFORMATION

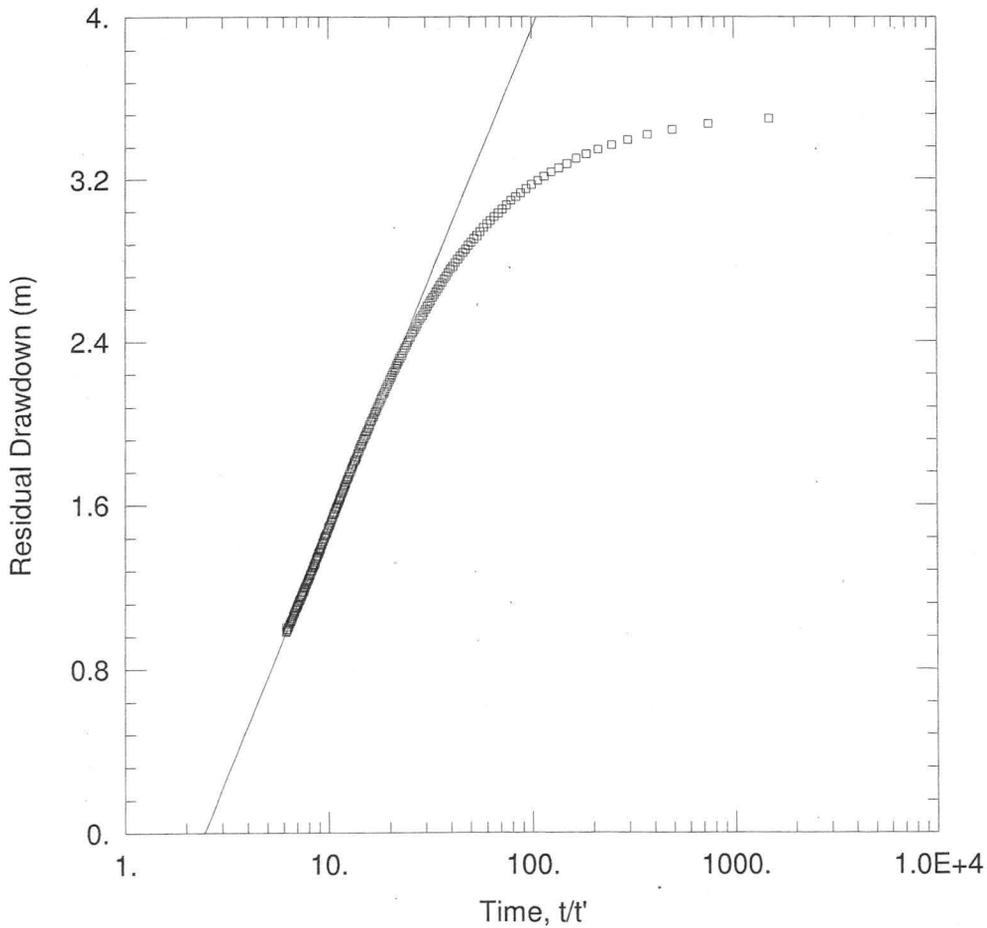
Company: AITF
 Client: AENV
 Location: Jack Well
 Test Well: Jack Well
 Test Date: May 22, 2010

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
Jack Well	0	0	□ Jack Well	0	0

SOLUTION

Aquifer Model: <u>Confined</u>	Solution Method: <u>Theis</u>
T = 0.002844 m ² /min	S = 23.41
Kz/Kr = 1.	b = 5.18 m



WELL TEST ANALYSIS

Data Set: C:\...\jack well May 22 2010 pumptest._recovery.aqt
 Date: 08/13/10 Time: 06:57:05

PROJECT INFORMATION

Company: AITF
 Client: AENV
 Location: Jack Well
 Test Well: Jack Well
 Test Date: Sept. 26, 2009

AQUIFER DATA

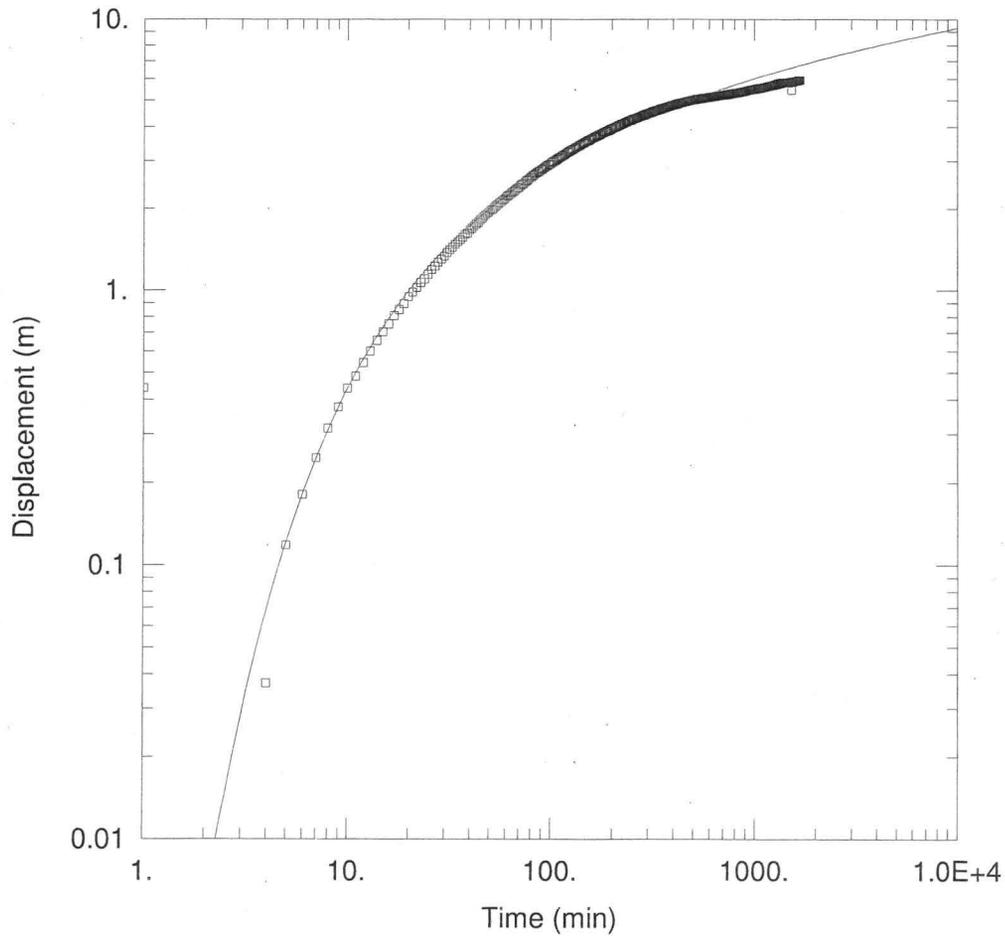
Saturated Thickness: 5.18 m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
Jack Well	0	0	□ Jack Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
 T = 0.002447 m²/min S/S' = 2.452



WELL TEST ANALYSIS

Data Set: C:\...\feb4 norecover.aqt
 Date: 03/29/11

Time: 23:18:30

PROJECT INFORMATION

Company: AITF
 Client: AENV
 Location: Jack Well
 Test Well: Jack Well
 Test Date: Feb. 2011

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

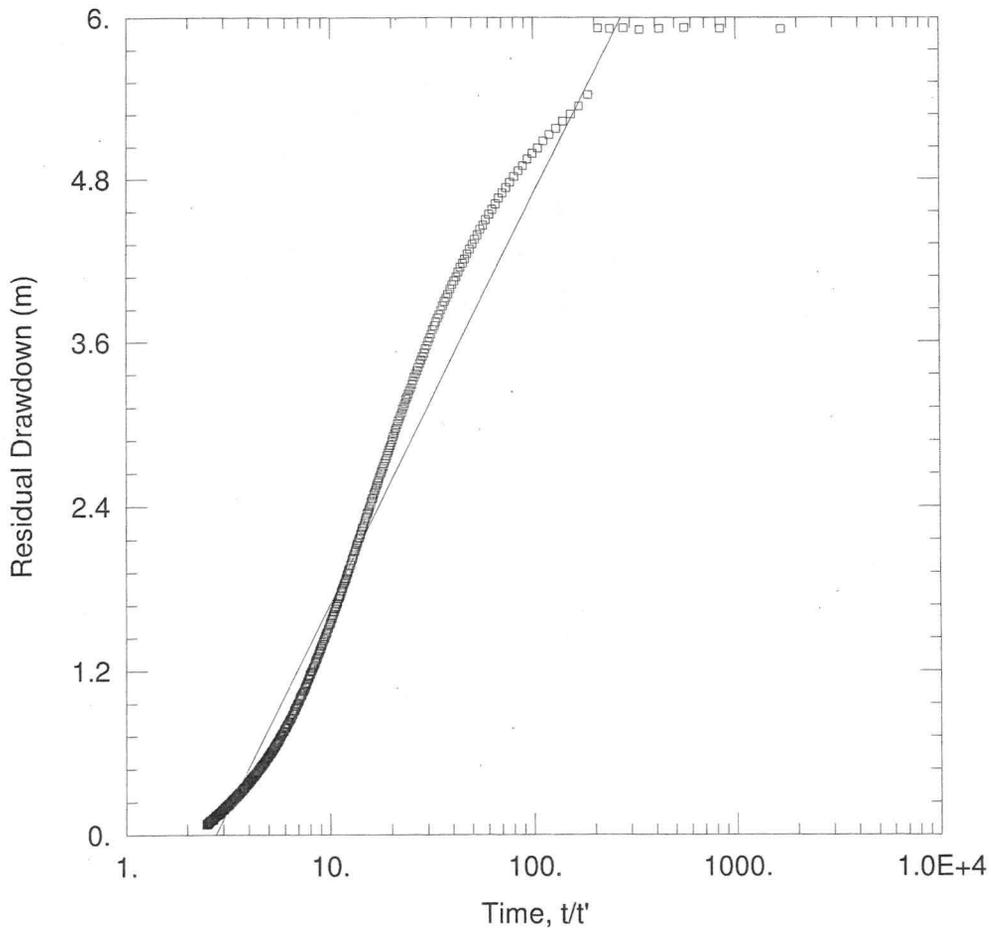
Solution Method: Theis

T = 0.002903 m²/min

S = 28.59

Kz/Kr = 1.

b = 5.18 m



WELL TEST ANALYSIS

Data Set: C:\Documents and Settings\birks\My Documents\Projects\Jack retest 2011\feb4 recovery.aqt
 Date: 03/29/11 Time: 23:34:50

PROJECT INFORMATION

Company: AITF
 Client: AENV
 Location: Jack Well
 Test Well: Jack Well
 Test Date: Feb. 2011

AQUIFER DATA

Saturated Thickness: 10.18 m Anisotropy Ratio (K_z/K_r): 1.

WELL DATA

Pumping Wells			Observation Wells		
Well Name	X (m)	Y (m)	Well Name	X (m)	Y (m)
New Well	0	0	□ New Well	0	0

SOLUTION

Aquifer Model: Confined Solution Method: Theis (Recovery)
 $T = 0.003125 \text{ m}^2/\text{min}$ $S/S' = 2.758$

APPENDIX B
Gas Concentrations and
Isotopic Composition Results

Sample	name	d13C methane vs VPDB	d13C CO2 vs VPDB	d13C ethane vs VPDB	d13C propane vs VPDB	d13C butane vs VPDB	stdv d13C		
							CH4	CO2 C2	
Feb 4 1015	free gas	-70.9	-27.3	-30.5			0.04	0.09	0.04
Feb 4 1330	free gas	-71.0	-27.2	-30.3					
Feb 5 1300	free gas	-70.3	-29.2	-30.7					
xtra	free gas	-40.6	-33.5	-31.7	-25.3	-33.7	0.12		0.10
Feb 4 1015	dissolved gas	-62.6	-27.3	-27.3			0.20		
Feb 4 1340	dissolved gas	-58.1	-25.2	-26.6					
Feb 5 1300	dissolved gas	-57.0	-29.2	-27.2			0.23		

Sample	name	dD methane vs VSMOW	dD ethane vs VSMOW	dD propane vs VSMOW	dD butane vs VSMOW	stdev dD			
						methane	ethane	propane	butane
Feb 4 1015	free gas	-290	-210			0.9			
Feb 4 1330	free gas	-290	-210						
Feb 5 1300	free gas	-293	-211						
xtra	free gas	-57	-203	-99	-149		1.2	2.7	5.5
Feb 4 1015	dissolved gas	-173							
Feb 4 1340	dissolved gas	-191							
Feb 5 1300	dissolved gas	-165				0.8			

ISOTOPE SCIENCE LABORATORY

Dept of Physics and Astronomy
University of Calgary
2500 University Dr. NW, Calgary, Alta.
T2N-1N4

Results

Contact S. Taylor
Tel. (403) 220-8268
Fax (403) 220 7773
e-mail taylor@phas.ucalgary.ca

Name: Don Jones / Alex Blyth
Alberta Research Council Inc.
3608 - 33 Street NW
Calgary, Alberta
Canada
T2L 2A6

IN 17-Feb-11
OUT 18-Feb-11

phone: 403 210-5348
fax:
email: jones@arc.ab.ca

Project:

#	Sample Name	$\delta^{13}\text{C}_{\text{CH}_4}$	$\delta^{13}\text{C}_{\text{C}_2}$	$\delta^{13}\text{C}_{\text{C}_3}$	$\delta^{13}\text{C}_{\text{C}_4}$	$\delta^{13}\text{C}_{\text{CO}_2}$	Sample (Date)	Sample (Time)	Comments
1	BMDJ-Jack Well (Feb 5, 2011)	-69.5	-28.8	too small	too small	-24.6	#####	1300	
2	BMDJ-Jack Well (extra)	-40.1	-31.2	-24.0	-32.7	-33.7	#####	1300	

 $\delta^{13}\text{C}$ -PDB of Hydrocarbon gases (GCC-IRMS)

All results reported in the permit notation on the PDB scale relative to IAEA stds

IAEA values used to normalize data

	^{13}C
NBS 18	-5.1 ± 0.1
NBS 19	1.95 (b.d.)
IsoMetric(CH4-239)	-23.9 ± 0.2
IsoMetric(CH4-383)	-38.3 ± 0.2
IsoMetric (CH4-545)	-54.5 ± 0.2
Messer CO2 I	-0.29 ± 0.20
Messer CO2 II	-40.13 ± 0.17

Precision and accuracy as 1 sigma of (n=10) lab stds are:
note: (b.d.) = 'by definition'

0.5 for $\delta^{13}\text{C}$

23-Mar-11	LSD	SEC	T	R	M	Company	Sample ID	13C1	13C2	13C3	13C4	13nC4	CO2
Jack's well Fe _{sw}		12	78	8	w6	AITF		-64.78	-30.14	-23.24	-28.96	-31.99	
Jack's well extra								-37.03	-29.55	-23.87	-32.74		
21-Apr-11													
Jack's well Fe _{sw}		12	78	8	w6	AITF		-68.69	-29.8	-23.68	-26.56		-29.33
Jack's well extra								-39.72	-30.42	-23.29	-32.44	-31.29	-32.3

APPENDIX C
Water Sample Results

LAB SAMPLE NUMBER 201100183-001	CLIENT SAMPLE NUMBER	SOURCE JACK WELL
TYPE AND DESCRIPTION WATER		SAMPLED BY
RESULTS TO DON JONES ALBERTA INNOVATES - TECHNOLOGY FUTURES (CALGARY) 3608-33 STREET NW CALGARY, ALBERTA T2L 2A6		DATE SAMPLED 05-Feb-2011 13:00
		DATE RECEIVED 10-Feb-2011

PARAMETER	ANALYTICAL		UNCERTAINTY	UNITS	MDL	METHOD/VMV	
	RESULTS					CODE	ANALYZED
+ Balance	1.07				N/A	111	07-Mar-2011
+ Cations	26.5			meq/L	N/A	00120E	07-Mar-2011
+ Anions	24.7			meq/L	N/A	00125E	07-Mar-2011
Conductivity	2140	±	3.4	uS/cm	1	02041L	11-Feb-2011
+ Solids, Total Dissolved (Calculated)	1370			mg/L	0.001	100536	07-Mar-2011
PH	8.56	±	0.07	units	N/A	10301L	11-Feb-2011
Alkalinity, Total	998	±	1	mgCaCO3/L	1	10101L	11-Feb-2011
+ Alkalinity, Partial	26	±	0	mgCaCO3/L	1	10151L	11-Feb-2011
+ Bicarbonate	1150			mg/L	1	06201L	11-Feb-2011
+ Carbonate	31			mg/L	1	06301L	11-Feb-2011
Calcium	2.13	±	0.025	mg/L	0.1	103969	25-Feb-2011
Magnesium	1.04	±	0.0073	mg/L	0.01	103979	25-Feb-2011
Hardness, Total	9.60			mgCaCO3/L	0.01	10602L	25-Feb-2011
Sodium	603	±	7.4	mg/L	1	102085	07-Mar-2011
Potassium	1.6	±	0.0	mg/L	0.4	102086	07-Mar-2011
Nitrate+Nitrite	0.010	±	0.005	mg/L	0.005	07105L	24-Feb-2011
Nitrite-N	<0.002			mg/L	0.002	07205L	24-Feb-2011
Silica	0.9	±	0.2	mg/L	0.1	102616	07-Mar-2011
Chloride	160	±	2.6	mg/L	0.3	102087	07-Mar-2011
Sulfate	7	±	3	mg/L	3	16306L	24-Feb-2011
Fluoride	1.74	±	0.02	mg/L	0.02	09107L	24-Feb-2011
Iron	32.7	±	0.57	ug/L	4	103975	25-Feb-2011
+ Nitrate-N Calculated	0.010			mg/L	0.005	80149	24-Feb-2011

"<" Denotes value less than method detection limit (MDL)

+ Parameter not accredited by CALA

** Recommended holding time exceeded

*** MDL under development

Method/VMV Code is a unique Test ID

COMMENTS

CERTIFIED BY **Diana Spasiuk**
Senior Technologist
FOR LARRY ROY
SUSTAINABLE ECOSYSTEMS
CONTACT: DIANA SPASIUK 780-632-8445

LAB SAMPLE NUMBER 201100183-001 CLIENT SAMPLE NUMBER SOURCE JACK WELL

(Dissolved) PARAMETER	ANALYTICAL RESULTS	STD ERROR	UNITS	MDL	METHOD/VMV CODE	ANALYZED
Aluminum	0.825 ±	0.014	ug/L	1	103927	17-Feb-2011
Antimony	0.0109 ±	0.0002	ug/L	0.05	103951	17-Feb-2011
Arsenic	1.26 ±	0.036	ug/L	0.1	103928	17-Feb-2011
Barium	929 ±	7.3	ug/L	10	103930	17-Feb-2011
Beryllium	0.0210 ±	0.0047	ug/L	0.1	103931	17-Feb-2011
Bismuth	<0.0010		ug/L	0.1	103932	17-Feb-2011
Boron	1430 ±	16	ug/L	80	103929	17-Feb-2011
Cadmium	0.0090 ±	0.0008	ug/L	0.1	103934	17-Feb-2011
Calcium	1.97 ±	0.010	mg/L	0.1	103933	17-Feb-2011
Chlorine	142 ±	1.8	mg/L	0.3	103935	17-Feb-2011
Chromium	2.39 ±	0.084	ug/L	0.3	103937	17-Feb-2011
Cobalt	0.0187 ±	0.0008	ug/L	0.1	103936	17-Feb-2011
Copper	0.206 ±	0.0088	ug/L	0.1	103938	17-Feb-2011
Iron	18.7 ±	0.44	ug/L	4	103939	17-Feb-2011
Lead	0.0010 ±	0.0003	ug/L	0.1	103949	17-Feb-2011
Lithium	40.4 ±	0.64	ug/L	0.2	103942	17-Feb-2011
Magnesium	1.03 ±	0.0075	mg/L	0.01	103943	17-Feb-2011
Manganese	0.555 ±	0.0053	ug/L	0.1	103944	17-Feb-2011
Mercury	0.0457 ±	0.0039	ug/L	0.05	103940	17-Feb-2011
Molybdenum	5.15 ±	0.055	ug/L	0.1	103945	17-Feb-2011
Nickel	<0.0050		ug/L	0.1	103947	17-Feb-2011
Phosphorus	523 ±	4.2	ug/L	5	103948	17-Feb-2011
Potassium	1460 ±	12	ug/L	20	103941	17-Feb-2011
Selenium	3.37 ±	0.17	ug/L	0.3	103952	17-Feb-2011
Silicon	2.71 ±	0.025	mg/L	0.8	103953	17-Feb-2011
Silver (Dissolved)	<0.0005		ug/L	0.01	103926	17-Feb-2011
Sodium	578000 ±	6200	ug/L	2000	103946	17-Feb-2011
Strontium	124 ±	1.3	ug/L	0.1	103955	17-Feb-2011
Sulphur	2.18 ±	0.018	mg/L	2	103950	17-Feb-2011
Thallium	0.0024 ±	0.0007	ug/L	0.1	103958	17-Feb-2011
Thorium	0.0015 ±	0.0001	ug/L	0.1	103956	17-Feb-2011
Tin	<0.0300		ug/L	0.1	103954	17-Feb-2011
Titanium	1.61 ±	0.019	ug/L	0.1	103957	17-Feb-2011
Uranium	0.0024 ±	0.0002	ug/L	0.1	103959	17-Feb-2011
Vanadium	0.697 ±	0.026	ug/L	0.1	103960	17-Feb-2011
Zinc	0.288 ±	0.015	ug/L	0.2	103961	17-Feb-2011

"<" Denotes value less than instrument detection limit (IDL)
+ Parameter not accredited by CALA
** Recommended holding time exceeded
*** MDL under development

Method/VMV Code is a unique Test ID

COMMENTS

CERTIFIED BY **Diana Spasiuk**
Senior Technologist

FOR LARRY ROY
SUSTAINABLE ECOSYSTEMS
CONTACT: DIANA SPASIUK

780-632-8445

Contact: Jones, Don			VOLATILE HYDROCARBONS - HCV	
SmpNo :	ProjNo :	GrpSmpNo :	METHOD: - - -	TimeLines (days)
StaNo :	StaType:		SCAN: HCV	from sample date
Comment: Jack Well				Max Actual
Matrix :			Date Received : 10-Feb-11 by: SS	- 5 --
SmpDate: 5-Feb-11 @ 1300	Samplers..ID1 :		Date Extracted: 11-Feb-11 by: SS	7 6 ok
EndDate: @	..ID2 :		Date Analyzed : 11-Feb-11 by: SS	7 6 ok
			Raw DataFile : V0248	

CONCENTRATION

RESULTS

ug/L

No volatile hydrocarbons were detected in the HCV 0 scan.

MDL is 10 ug/L. (F1 fraction)

Laboratory's comments regarding this sample:

The following items regarding the sample were recorded. A Yes notation indicates a problem with the specified item.

Inappropriate Sample Container - No
 Inappropriate Temperature - No
 Inappropriate Headspace - No
 Broken / Leaking Container - No

This sample was analyzed by GC/MS. An additional GC/FID scan may have been used for screening purposes and to assist with quantitative data analysis.

Concentrations for identified compounds are calculated using an external standard when appropriate.

The response may also be compared to the appropriate internal standard as an alternative technique.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.

** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Grant Prill	Program Leader	mail to: Jones, Don
	Organic Environmental Monitoring	Sustainable Ecosystems
	Alberta Innovates - Technology Futures	Alberta Research Council
Date: 14-Feb-11	Bag 4000, Vegreville, Alberta	3608-33 St NW
Contact No. (780) 632-8455	T9C 1T4	Calgary, Alberta
		T2L 2A6

"results relate only to the item tested"

Please check the mailing information and inform the lab if changes are required.

Contact: Jones, Don	EXTRACTABLE HYDROCARBONS - HCE	
SmpNo :	ProjNo :	GrpSmpNo :
StaNo :	StaType:	
Comment: Jack Well	Date Received : 10-Feb-11 by: SS - 5 --	
Matrix :	Date Extracted: 16-Feb-11 by: drc 7 11 *	
SmpDate: 5-Feb-11 @ 1300	Samplers..ID1 :	Date Analyzed : 17-Feb-11 by: drc 21 12 ok
EndDate: @	..ID2 :	Raw DataFile : E0249

CONCENTRATION

RESULTS

ug/L

No extractable hydrocarbons detected in the HCE 0
scan

mdl is 45 ug/L. (F2 F3 F4 fractions)

Laboratory's comments regarding this sample:

The following items regarding the sample were recorded. A Yes notation indicates a problem with the specified item.

Inappropriate Sample Container - No
Inappropriate Temperature - No
Inappropriate Headspace - No
Broken / Leaking Container - No

This sample was analyzed by GC/MS. An additional GC/FID scan may have been used for screening purposes and to assist with quantitative data analysis.

Concentrations for identified compounds are calculated using an external standard when appropriate.

The response may also be compared to the appropriate internal standard as an alternative technique.

* - asterik following the value for Actual days taken indicates the prescribed time for that event was exceeded.

** - the Date Sampled is unknown, therefore timeline calculations can not be performed.

Certified For: Grant Prill	Program Leader	mail to: Jones, Don
	Organic Environmental Monitoring	Sustainable Ecosystems
	Alberta Innovates - Technology Futures	Alberta Research Council
Date: 17-Feb-11	Bag 4000, Vegreville, Alberta	3608-33 St NW
Contact No. (780) 632-8455	T9C 1T4	Calgary, Alberta
		T2L 2A6

"results relate only to the item tested"

Please check the mailing information and inform the lab if changes are required.



Your Project #: JACK WELL
Site: JACKWELL
Your C.O.C. #: A047699

Attention: DON JONES
ALBERTA INNOVATES - TECHNOLOGY FUTURES
3608 - 33 STREET NW
CALGARY, AB
CANADA T2L 2H6

Report Date: 2011/02/15

CERTIFICATE OF ANALYSIS

MAXXAM JOB #: B110024
Received: 2011/02/07, 8:00

Sample Matrix: Water
Samples Received: 1

Analyses	Quantity	Date		Laboratory Method	Analytical Method
		Extracted	Analyzed		
Fecal Coliforms (MF)	1	2011/02/07	2011/02/08	EENVSOP-00157	SM 9222B & D
Total Coliforms and E.Coli	1	2011/02/07	2011/02/08	EENV SOP-00162	SM 9223 A,B
Iron Related Bacteria ☺	1	2011/02/07	2011/02/15	EIND SOP-00021	BART TM
Sulphate Reducing Bacteria ☺	1	2011/02/07	2011/02/15	EIND SOP-00025	BART TM

(1) Presence/Absence Method. Number is an estimate.

Encryption Key

Please direct all questions regarding this Certificate of Analysis to your Project Manager.

TANYA EUGINE, M.Sc., Project Manager
Email: TEugine@maxxam.ca
Phone# (780) 577-7100

=====
Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Total cover pages: 1

RESULTS OF CHEMICAL ANALYSES OF WATER

Maxxam ID		Z79593		
Sampling Date		2011/02/06 11:45		
COC Number		A047699		
	Units	JACK WELL	RDL	QC Batch

Microbiological Param.				
E.Coli DST	mpn/100mL	<1	1	4629044
Fecal Coliforms	CFU/100mL	<1	1	4629046
Iron Bacteria	CFU/mL	35000	25	4635275
Sulphate reducing bacteria	CFU/mL	1200	200	4635327
Total Coliforms DST	mpn/100mL	<1	1	4629044
RDL = Reportable Detection Limit				

Package 1	7.0°C
-----------	-------

Each temperature is the average of up to three cooler temperatures taken at receipt

General Comments

Results relate only to the items tested.



ALBERTA INNOVATES - TECHNOLOGY FUTURES
Attention: DON JONES
Client Project #: JACK WELL
P.O. #:
Site Reference: JACK WELL

Quality Assurance Report
Maxxam Job Number: EB110024

QA/QC Batch Num Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
4629044 RV	Method Blank	E.Coli DST	2011/02/08	<1		mpn/100mL	
		Total Coliforms DST	2011/02/08	<1		mpn/100mL	
4629046 RV	Method Blank	Fecal Coliforms	2011/02/08	<1		CFU/100mL	
4635275 RV	Method Blank	Iron Bacteria	2011/02/15	<25		CFU/mL	
4635327 RV	Method Blank	Sulphate reducing bacteria	2011/02/15	<200		CFU/mL	

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Maxxam Analytics International Corporation o/a Maxxam Analytics Edmonton: 9331 - 48th Street T6B 2R4 Telephone(780)577-7100 Fax(780)450-4187

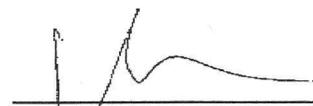
Validation Signature Page

Maxxam Job #: B110024

The analytical data and all QC contained in this report were reviewed and validated by the following individual(s).



DINA TLEUGABULOVA, Ph.D., Scientific Specialist



JAY ABBOTT, Bioassay Supervisor

=====

Maxxam has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per section 5.10.2 of ISO/IEC 17025:2005(E), signing the reports. For Service Group specific validation please refer to the Validation Signature Page.

Sample	Name	dD average	d18O average	d13C DIC	dD stdev	d18O stdev	d13C stdev
		vs VSMOW	vs VSMOW	vs VPDB			
Jack Well	Feb 5 1300	-184.9	-23.50	-19.72	0.5	0.02	0.05

ISOTOPE SCIENCE LABORATORY

Dept of Physics and Astronomy

University of Calgary

2500 University Dr. NW, Calgary, Alta.

T2N-1N4

Name: Don Jones

Affiliate: Alberta Innovates Tech. Futures

Address: Water Resource Management

Results

Contact : S. Taylor

Tel. : (403) 210-6003

Fax : (403) 220 7773

e-mail steve.taylor@ucalgary.ca

IN March 21, 2011

OUT

phone: (403) 210-5358

fax:

email: Don.Jones@albertainnovates.ca, Jean.Birks@albertainnovates.ca

W/O #

#	LIMs ID	SAMPLE ID	$\delta^{34}\text{S}$	$\delta^{18}\text{O}_{\text{BaSO}_4}$	%O	Comments
1		Jack Well	8.3			BaSO4 ppt by MikeN

 $\delta^{34}\text{S}$ -CDT and $\delta^{18}\text{O}$ -SMOW of BaSO₄ by EA-IRMS (Prism) & TC/EA (Delta+)

All results reported in the usual permil notation relative to IAEA stds

IAEA values used to normalize data

	^{34}S	^{18}O
NBS 127	21.1 ± 0.4 *	8.6 ± 0.4
IAEA S05	0.5 ± 0.2	12.0 ± 0.2
IAEA S06	-34.1 ± 0.2	-11.3 ± 0.2

Precision and accuracy as 1 sigma of (n=10) lab standards is: 0.3 for $\delta^{34}\text{S}$ * USGS report 01-4222 0.5 for $\delta^{18}\text{O}$



IT2#: 110039
Contact: Jean Birks

2011-03-04
1 of 1

Company: Alberta Innovation Technology Futures

#	Sample Name	Sample #	E3H	Result	$\pm 1\sigma$	Sample Size
1	Jack Well	4247	X	<0.8	0.83	500mL

Tritium is reported in Tritium Units.

1TU = 3.221 Picocuries/L per IAEA, 2000 Report.

1TU = 0.11919 Becquerels/L per IAEA, 2000 Report.

85 Bathurst Drive - Unit D - Waterloo - Ontario - N2V 1N2

Tel: 519-886-5555 - Fax: 519 886 5575 - Email: mirnas@it2isotopes.com - www.it2isotopes.com

APPENDIX D
Gas Analyses

APPENDIX E
Water Level Logger Data

A level logger (WL1) was installed in the Jack water well on September 28, 2009 and left in until May 20, 2010 to try to record any changes in water level that might have occurred as a result of the remedial cementing of the energy well at 100/06-12-078-08W6M and to get a better understanding of the smaller-scale water level fluctuations. The raw pressure data from WL1 could not be reconciled with manual measurements and contains periods of unrealistic water level changes that could not be explained. This was inferred to be due to a malfunction of the water level logger. For this reason, data from the logger was not used in the report, but is presented here for completeness (Figure A). A brief discussion of the logger record is given below.

There are some abrupt changes in the record that can be explained by known activities at the well including: removal of WL1 during the pumping test conducted on January 30, 2010, and disturbance of WL1 on February 27 as a second logger (WL2) was added to the well for the test. The second logger was added because of concerns that the first logger was not performing properly. Comparison of the WL1 and WL2 level records revealed that WL1 contained variations that were not present in WL2 and not consistent with manual measurements. The manual measurements were used to constrain the endpoints of each section of the WL1 record producing the water level time-series presented in the middle panel of Figure A. The two pumping tests appear as would be expected, however there are still some unexplained shifts in the water levels that indicating that the logger was not functioning properly. Even after the pressure data was normalized to match manual water level measurements made at the beginning and end of the February 27 pumping test, the WL1 logger recorded 1.7 m more drawdown than the WL2 logger or the manual measurements, and included abrupt changes in water level not measured in the WL2 logger. The WL1 logger recorded a dramatic decrease in water levels starting after the February 27 pumping test that continued until April 2010 only to be followed by a dramatic increase. The data from WL1 is included in the longer time-series of manual water level measurements (Figure A, bottom panel) to illustrate that these changes are beyond the range of water levels seen at the well even during pumping tests.

For these reasons the data from WL1 was not used in any of the pumping tests and did not contribute to the interpretation presented herein.

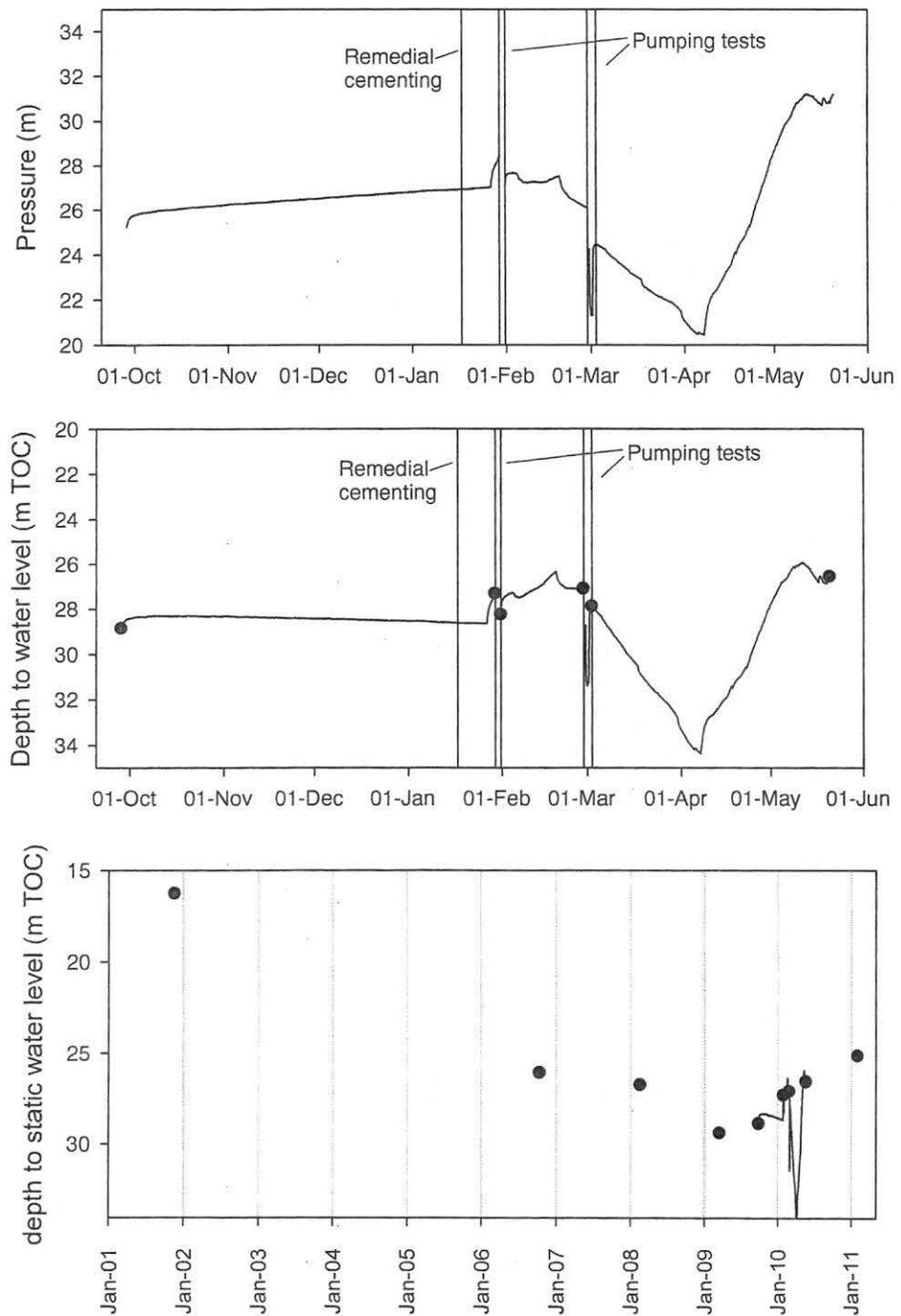


Figure A: Raw pressure data from WL1 (top panel) and water level time-series generated by forcing the pressure data to match manual measurements (middle panel). The water level data from WL1 are presented with manual water level measurements in the bottom panel for comparison.