JACK WATER WELL COMPLAINT REVIEW INTERIM REPORT

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

February 21, 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 overall conclusion of the evidence from the review of the AENV and ERCB files is that insufficient data exists to determine whether Mr. Jack's well has been impacted by conventional oil/gas wells in the area. Recommendations are made for additional sampling required.

TABLE OF CONTENTS

1	INTE	RODUC	TION	
2	REG	GIONAL	. GEOLOGIC AND HYDROGEOLOGIC SETTING	1
	2.1	STRAT	IGRAPHY	
	2.2	REGIO	NAL STRESS REGIME	
	2.3	HYDRO	STRATIGRAPHY AND GROUNDWATER FLOW AND GRADIENTS	4
3	ENE	RGY V	VELL INFORMATION	4
4	JAC	K WA1	ER WELL INFORMATION	
	4.1	INITIAT	ION OF WELL COMPLAINT	
	4.2	WELL	Design, Construction and Maintenance	8
	4.3	STRAT	IGRAPHY	
	4.4	HYDRO	DGEOLOGY	
		4.4.1	General Groundwater flow directions	
		4.4.2	Vertical Hydraulic Gradient	
		4.4.3	Hydraulic Conductivity	
	4.5	WATER	R AND GAS CHEMISTRY	
		4.5.1	Major lons, Metals and Bacterial Chemistry	
		4.5.2	Dissolved Organic Chemistry	
		4.5.3	Atmospheric Elements and Hydrocarbon Gas Chemistry	
		4.5.4	Stable Carbon Isotope Chemistry on Hydrocarbon Gas	
5	SUN	MARY	, CONCLUSIONS AND RECOMMENDATIONS	
6	CLO	SURE		
7	REF	ERENC	ES	

LIST OF TABLES

Table 1 Summary of ERCB and Lionhead Engineering and Consulting Ltd review of
cementing details from energy wells in the vicinity of the Jack well7
Table 2 Summary of Chemical Analyses for the Jack Water Well and surrounding energy
wells

LIST OF FIGURES

Figure 1 Stratigraphic column for the Northwestern Plains and Deep Basin	. 2
Figure 2 Map location of the Jack residence and surrounding energy wells (from Matrix	
Solutions 2007).	.5
Figure 3 Water well drilling report for the Jack well	.9
Figure 4 Completion details of the Jack water well	10
Figure 5 Histogram of the carbon isotope values of methane in the Jack energy wells*	14
Figure 6 Histogram of the carbon isotope values of ethane in the Jack and energy wells.	
· · · · · · · · · · · · · · · · · · ·	15
Figure 7 Methane concentration versus δ^{13} C of methane	16
Figure 8 Ethane concentration versus δ ¹³ C of ethane	17
Figure 9 δ ¹³ C Methane versus δ ¹³ C Ethane	18
Figure 10 Mixing plot of δ^{13} C of methane versus the methane/C2+ ratio	19
Figure 11 Mixing plot of δ ¹³ C of ethane versus the methane/C2+ ratio	20

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. Descriptions of the geology from older to younger that are encountered in the area of investigation are as follows:

JACK WATER WELL COMPLAINT REVIEW







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.





LEGEND

WATER WELLS IN THE AREA

APPROXIMATE LOCATION OF JACK RESIDENCE

PETROFUND WELL TO BE SAMPLED

O OTHER OPERATORS WELL

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 m³/day (Lionhead Engineering & Consulting 2006).

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 m³/day (Lionhead Engineering & Consulting 2006).

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 m³/day (Lionhead Engineering & Consulting 2006).

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 m³/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 m³/day (Lionhead Engineering & Consulting 2006).

The cement integrity of these energy wells may need to be further investigated after recommended new water and gas data from the Jack well has been collected and evaluated. The recommended new work is discussed in section 5 of this report.

JACK WATER WELL COMPLAINT REVIEW

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	Si	Hace Casing C	ement	Production Casin	g Cement (Stage 1)	Production Casing	Cement (Stage 2)	Uncemt	nted Zones	Cement	SCVF
				Top (mKb)	Bottom (mKb)	Returns (m3)	Top (mKb)	Bottom (mKb)	Top (mKb)	Bottom (mKb)	Top (mKb)	Bottom (mKb)	Bond Log	
Jack Well	SW-12-078-08 W6M	Smoky Group	Water well	0	36.58	0		and the second	*-	**	-14		No	**
Energy Well	100/06-05-078-07 W6M	Charlie Lake Fri	n 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 Fri	n Flowing gas	0.0	226.8	Yes	Not logged	1633.0	0.0	655.0	?	2		Yes
Energy Well	100/06-06-078-07 W4M	Charlie Lake Fri	n Pumping oil	0.0	188 0	Yes	<850.0	1746.0		20	205.0	<850.0	Yes	Yes
Energy Well	100/08-06-078-07 W6M	Charlie Lake Fn	n Pumping oil	0.0	207.0	Yes	2	1624.0			2	2		Yes
Energy Well	100/14-06-078-07 W6M	Charlie Lake Fn	n Pumping oil	0.0	206.0	Yes	2	1580.0			2	?		Yes
Energy Well	100/04-07-078-07 W6M	Charlie Lake Fr	n 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 Fn	n 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 Fri	n Pumping oil	0.0	236.0	Yes	?	1555.0	**	1997 S	?	?		Yes
Energy Well	100/14-07-078-07 W6M	Gething Fm	Flowing Gas	0.0	210.0	Yes	2	1565.0			2	?		Yes
Energy Well	100/14-01-078-08 W6M	Charlie Lake Fn	n 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	Gharlie Lake Fr	n 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 Fn	n 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 Fn	n 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 Fri	n 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 Fn	n 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 Fr	n Pumping oil	0.0	255.4	A =-	808.0	1607.0	Not logged	808.0			Yes	No
Energy Well	100/06-12-078-08 W6M	Charlie Lake Fn	n Water Injection	0.0	298.0	2.0	1163.0	1610.0	Not logged	1163.0	2	2	Yes	Yes
Energy Well	100/08-12-078-08 W6M	Charlie Lake Fn	n 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 Fri	n Flowing Gas	0.0	252.0	4.0	745.0	1628.0		• 0	252.0	745.0	Yes	Yes
Energy Well	102/11-12-078-08 W6M	Charlie Lake Fn	n Pumping oil	0.0	269.0	4 0	801.0	1620.0	Not logged	801.0	2	2	Yes	Yes
Energy Well	100/16-12-078-08 W6M	Charlie Lake Fn	n 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 Fr	n 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 Fn	n 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 Fr	n Flowing oil	0.0	269 0	4.0	800.0	1582.0	0.0	0.008			Yes	No
Energy Well	100/02-14-078-08 W6M	Chariie Lake Fn	n 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 Fri	n Flowing oil	0.0	259.0	Yes	858.0	1575.0	0.0	858.0		1	**	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

-7-

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 3. 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 4). 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.

A	ator	Well Drilling F	lone	ort	WellID			182000	1	
D. The data contained in this	alci renort is s	unplied by the Driller. The ord	vince di	Sclaims responsibility for its	Map Ver	nfied part Poo	oivod	Not Ver	ified	
Alberta	reportio	accuracy.	white at	ondanio rosponololiny for ito	Measure	ements:	Biveu.	Inperia	100	
1 Contractor & Well Owner Informat	ion				2 Well	Locat	ion			
Company Name			Drilling	Company Approval No :	1/4 or	Sec	Twp	Rge	Westof	
DU-ALL DRILLING			124424		LSD	10	0.70	0.0	M	
Mailing Address: City	or Town: HALLA CE	INTRE AR CA	Postal C	Code:	5W	in Quart	078 er	08		
WellOwner's Name: Well	Location I	dentifier:	101100		FT	from	N	E	oundary	
JACK. BRUCE					FT	from	E	B	oundary	
P.O. Box Number Maili	ng Addres	S'	Postal C	Lode.	LOI	BIO	CK	Plan		
City Prov. SPIRIT RIVER AB	ince		Country CA	,	Well Elev FT	ľ	Hov	v Obtain Obtain	1	
3. Drilling Information					6. Well	Yield				
Type of Work: New Well				Proposed well use	Test Date	e(yyyy/m	m/dd).	Start Ti	me	
Reclaimed Well	Matarial	a fland Holeneum		Domestic & Stock	2001/11/	19 hod Arr		5:05 PM	1	
Method of Drilling: Rolary	Materiai	. Used. Unknown		Requirements/day	Non pur	pring		53.4 FT		
Flowing Well No	Rate Ga	allons		5000 Gallons	static lev	el				
Gas Present No	Oil Presi	ent. No			Rate of v	vater		20 Gallons/Min		
4. Formation Log		5. Well Completion		0	Depth of	pump		200 FT		
Depth from around Lithology Description	1	Date Started(yyyy/mm/dd) 2001/11/19	Dat 200	e Completed(yyyy/nim/dd)	intake.	1				
evel (feet)		Well Depth: 200 FT	Bor	ehole Diameter: 7.02 Inches	Water ler	vel at		200 FT		
105 Gray Till		Casing Type: Steel	Line	er Type: Plastic	Distance	from tor	of	24 Inch	es	
141 Gray Medium Grained Shale		Size OD: 5 562 Inches	Size	e OD. 4.5 Inches	casing to	ground	level.	-		
164 Light Gray Shale		Wait HILKNESS U. Too IDCHES	5 Wrd	N 100 ET Bettern 200		epth To	water l	evel (fee	t)	
181 Dark Gray Shale & Sandstone		Bottom at: 120 FT	FT	5. TOUPT BOLLOM: 200	Drawd	own M	psed i inutas:	ime Sec Re	covery	
200 Dark Gray Shale		Perforations	Per	forations Size:		•	1.00	500 110	146	
		from 155 FT to: 180 FT	0 13	25 Inches x 12 Inches			2:00		101	
		from FT to FT	Inch	hes x Inches			3.00		86	
		from FT to FT Deforated by Saw	Incl	hes x Inches	}		4:00		75	
		Seal Driven & Bentonite					6.00		66	
		from FT	to:	120 FT			7.00		63	
		Seal. Shale Trap	in: 1	160 67			8.00		60 5	
		Seal Other	tO.	100 F 1			9.00		58 1	
		from 115 FT	to: I	FT			12:00		56	
		Screen Type: Unknown	Scr	een ID: Inches			14.00		55 3	
		Screen Type Unknown	Scr	een ID Inches			16.00		55	
		from FT to FT	Slot	t Size: Inches			25.00		54 2 53 8	
		Screen Installation Method: L	Jnknown	1			30:00		53.6	
ĸ		Eittings Top: Uaknown	Bat	tom Unknown			35:00		53 5	
		Pack Unknown			1.10		120:00)	53.4	
		Grain Size	Am	ount. Unknown	If water r	emoval v	vas les	s Iban 2	br	
	<i>`</i>	Geophysical Log Taken: Retained on Files:			duration.	reason	why	o man z		
		Additional Test and/or Pump Chemistries takes By Drillor	Data						1	
		Held	Dac	cuments Held	0					
		Pitless Adapter Type		"Bull Scherosten (* 1999) 1990 1990 1990 1990 1990 1990 199	Gallons	lended p Ulin	umping	rate: 1;		
		Drop Pipe Type	Dia	motor Inchos	Recomm	ended p	ump int	ake 17	FT	
		Comments	Dia	meter mones	Type Pur	mp Insta	lled			
		4.181 DARK GRAY SH/SS L	AYERS	20 GPM 4 200 DARK GRAY	Pump Ty	pe.			1	
		SH LAYERS SEAL TYPE. AL	LSO K-P	PACKER	H.P.	JUEI			-	
	1				Any furth	er pump	test info	ormation	? No	
	1									
		7. Contractor Certifica	ation		1					
		Dnller's Name	ALF	RED STEINKE	1					
		Certification No	408	61A						
		This well was constructed in a regulation of the Alberta Environmentation	accordat	nce with the Water Well tal Protection & Enhancement						
		Act. All information in this rep	port is tru	ie						
		Signature		Yr Mo Day	1					

Report 1 Pump Test 1 page1

Figure 3 Water well drilling report for the Jack well.

JACK WATER WELL COMPLAINT REVIEW



Figure 4 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/m³ (fresh water).

The vertical gradient is estimated from = $\Delta h/\Delta I = (737-446)/(703-(-758) = 0.2$. 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} m²/min to 9.79×10^{-3} m²/min (1.5 to 14.1 m²/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 3.3×10^{-4} m/min (equivalent to a transmissivity of 2.5 m²/day). This value suggests that the aquifer has higher transmissivity than is normally found in sandstone.

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 6 IGPM. This driller recommended

pumping rate (15 IGPM) is much higher than the rate calculated by the Q20 equation and could lead to aquifer depletion.

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 lons, Metals and Bacterial Chemistry

No major ion chemistry (historical or new) 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. This is a deficiency in the investigation of the well complaint as there is no data to comment on the water quality.

4.5.2 Dissolved Organic Chemistry

Analysis for EPA volatile priority pollutants and extractable priority pollutants are not available for the Jack well. A dissolved gas analysis was also not done on the Jack well to determine dissolved concentrations of C1 to C4 and atmospheric gases. These analyses can be very indicative of hydrocarbon contamination of a water well. This is a deficiency in the investigation of the well complaint as there is no data to comment on organic components of the water quality.

4.5.3 Atmospheric Elements and Hydrocarbon Gas Chemistry

Several free gas analysis are available for the Jack well (Table 2). 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. One ethane value (1200 ppm) is anomalous and is therefore in question. 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.

FEBRUARY 21, 2008

Table 2 Summary of Chemical Analyses for the Jack Water Well and surrounding energy wells.

	e	stu it	0.54	A protocol and the second	- 4 ⁴	Shirtary	station for after	. d'		 (b) (b) (b) (b) (b) (b) (b) (b) (b) (b)	and in the	Nitrade."	Carton linest	5.7		1.4.0	· Futer in	N Isata et	15.4	N	5 6	- 5°C.C.	8.1.800.44	$C = \frac{1}{V_{\rm c}} \left(\frac{1}{N_{\rm c}} \frac{1}{\mu^{2} \sigma^2} \right)$	TT Despois	2.018.194	C & CNRASH
					cheve in						3.0.4		360.00	(11)		1922	164011	1054701	120703	EDRA 2	(roa	VID (8-1	685				15.1
	1.4.24	16.576.57	Stat 12:078-08 W077	.e	With Carl St.	Walnut & two		the sets	9.5.5	S	12124	2.25	16112	1. 28.			1.0	1500	- 100	- 2.24	36 33	and the second		and the second of			
	and the	4 (5 ¹ , 1 ⁵ ¹)	to a straight the start	1.1.1 Contraction (1.1.1.1)	47. 44. 6	distances with a trace	Veril attel parat	Waxes .	St		100 10 20	150	1205	Sec. 201			542	- Terr	×1.0	12.30	100 > 1	00 - 54 47	25.25	15.24			
	54215 (MI)	122 50	TOP 11 COLOR VALUE	545	47.2 2.20	Senter the arrive	1 sector and	Maxes	55-25-2	2 5 *	3.001.05g20.08		\$ \$ D.42		10.00	A				er 1971 - 1	40. 44	30 30.57	1.4 11 1				
	1999 B.	regions -	2M-15-048-06 MAP	21.81 × 14.5	4 * 2 × * 4 6	Alasen Bara Baraka	great family out	Marris	1. 200		1.8 31.24	1.25	76.	1.48.200						130 .	105 - 1	66 - 25 10	A.S. 200	14 M.S.			
		10 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -	2/01/12/07/6/00 2002/	17 (19 g) (19 g)	41 a 104 a	Color Art Allant	West partiplant	ALCIAN	V 1.4	N. ALMARK	1											\$7.30	-054 LLC	12.20			
	Card Card	KOLINE RE ATTENTION	NOV 12 1010 111 10000		4 1 104 10	Collection 4 Collection	- Lociente	ALLAN A.			1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	1.414	13.		1.1	112	- united -	1.11	1.1		diri x	54.85	4.5.1	2.34			
	a de la clas	CONTRACTOR CONTRACTOR	12.05.025.07.0668		1. AT	CONTRACTOR OF		1		and the second second	A STATISTICS	Sec. a. a.	0000	11 12 1 12		1.6751.6	1.00			11.00							
	Contraction of the second	1 - 1	The factor of a first states	A STREET STREET AND	1944 C 1 1 1 1 1 1 1 1 1	C. 6. 20 ST 52 2 2 4 5	NO.V.	AL. 1.14	52 III (6)	the substitution of stage	 bitisk /g.f.b. 	10.194	11.202	S. 1860.1		100.00	14.1	2.12	100	101 1	200 80						
	Kommun Viell	Manufacture Automatic Parks	Color Strate Const.	The location of the	Or an a street of	Part and a star	19 Y	A		the second second second	1 1 1 1 1 1 1 1 1 1	4.00	1	A						1.000	• 15 · · · ·						
Number Number Number Number <td>A And Silver</td> <td>Local Account in a sheet</td> <td>14 OF 1176-D7 WYSA</td> <td>C. Compare 1</td> <td>14. 1. 1 10 1 10 1</td> <td>Paratana</td> <td>146.10</td> <td>6.00</td> <td></td> <td>over A and A county hand</td> <td>The second second</td> <td></td> <td>14.001</td> <td>AND A DECK</td> <td></td> <td></td> <td>- A</td> <td>Tenes 1. h.</td> <td>TROUGH STORE</td> <td>12000 C</td> <td>1003 24</td> <td>teres.</td> <td></td> <td></td> <td></td> <td></td> <td></td>	A And Silver	Local Account in a sheet	14 OF 1176-D7 WYSA	C. Compare 1	14. 1. 1 10 1 10 1	Paratana	146.10	6.00		over A and A county hand	The second second		14.001	AND A DECK			- A	Tenes 1. h.	TROUGH STORE	12000 C	1003 24	teres.					
	A trade a line	101-04-07-076-07 VMM	04 (U 078-07 WOAK	Charles Look Col.	DERICAL TRACK	Putricine is a	Prostar 2000 Castron	Address			25 184 YOR W.	16.2	14003	1941103	100000	Kapity.	60000	1.4155	Maria	Safe 1	200	n/s	34.55	16.112	26.403		12.428
	5 St. 100 Sec.		64 67 679 67 6695	Burner Jacket Burn	10. 1 20.0.1	Automatica en	Personnellaring	Marro	S		11112 11	2.24	4.712.	here a				-20.1 m	1.000	Sale .	100		41.14	in the	12.00	12.00	34 65
	1 - garages	112.0 pt 117 1375 107 (2013)	centrate of weeks	Contractories For	-4 x (x 645.)	Variation - Include	NC V	minist	P.C. STOR	our fourtheory frust	220104/2004		16002	******			ALCACION.	W. CONF	28-01	23992	407. 11	31					
Image: Amplitude interval Im	Weining Value	the open of 1078 (17 Wester	09 (c7-078 D8 W6M	Province & grant Barry	514 . 16315	Paris again	560	A.U.A.1	1.1.11 1	A. D. Stands, Ross	210092036	× 30	4800	-187 m	ditte.		(criss)	5700	2.64	1000	geo e	2					
Image Image <th< td=""><td>F or as work</td><td>546, 14-37, 1776 - 7 MeM</td><td>14 07-078-08 W/M</td><td>Test safer</td><td>1 382 M3 84</td><td>Ferring scars</td><td>1.Cx</td><td>decars"</td><td>St. 1. 4</td><td>Level Course Lowers</td><td>23/06/2005</td><td>6.02</td><td>2066</td><td>1.27.20</td><td></td><td></td><td></td><td>-+100</td><td></td><td>2261</td><td>700 12</td><td>30</td><td></td><td></td><td></td><td></td><td></td></th<>	F or as work	546, 14-37, 1776 - 7 MeM	14 07-078-08 W/M	Test safer	1 382 M3 84	Ferring scars	1.Cx	decars"	St. 1. 4	Level Course Lowers	23/06/2005	6.02	2066	1.27.20				-+100		2261	700 12	30					
Alter Alter <th< td=""><td>AF Dentroy when</td><td>100-14 01 075 05 02532</td><td>14 OT 078-08 Weth</td><td>City in Grand Land</td><td>anazia interazie</td><td>Parentiphon</td><td>24. 6</td><td>n</td><td>1.1.10</td><td>conduct transportant -</td><td>25052006</td><td>12/02</td><td>6.54300</td><td>5.442.00</td><td>10.1207</td><td>17000</td><td>8.5.2</td><td>387410</td><td>28.73</td><td>1999.0</td><td>207 80</td><td>01</td><td></td><td></td><td></td><td></td><td></td></th<>	AF Dentroy when	100-14 01 075 05 02532	14 OT 078-08 Weth	City in Grand Land	anazia interazie	Parentiphon	24. 6	n	1.1.10	conduct transportant -	25052006	12/02	6.54300	5.442.00	10.1207	17000	8.5.2	387410	28.73	1999.0	207 80	01					
Number Number<	1 margin alera		14 G1 Q76 16 VARP	Charles Land, R. W.	1102.0 15.04.5	Dall Services	1.014	Same .		Sector Sector	12 16 20.00	2 赤布	13-	43.105	All the state	24,815		1.4110	2500	AREAS I	10. 1.		6.1.41	1.64	2012 3	27 611	
Import Import<	States and States		14 G1 076 D8 WERL	Walter Free Rev	15-03-0 1594.5	Karnabyer	8077	P.Lacka	12.000	Sen Diola	17.1.22006	4.59	7(40	通知的なご		Million.	5930	92703	24:20	1606	100 6	3	As lan	30 94	27.80	28.75	27.87
P = P = P = P = P = P = P = P = P = P =			14 LIN 678 UN VALM	fragment power and	1592 C 3594 K	Ellistra anti-	Philde Istra Description	Maxwell	- × 198	14 17 - 17 × ···	AMR/2002	1.2.4	4.2	1.1.14-10	2601 (J	419 5, 61		2 14:22	626.27		1955. 25	342	4	3.4	12.64	37.02	12.50
	Lever the		14-01-078-06-W6M	Charles Frank (199	1692 S. 1194 S.	Mumming and	Production Calling	1.1.2 + + +	1.1	${}^{\mathbf{n}}_{\mathbf{n}} = {}^{\mathbf{n}} {}^{\mathbf{n}}_{\mathbf{n}} = {}^{\mathbf{n}} {}^{\mathbf{n}}_{n$	1.4.1053636	\$ C5	400	1,392.00		1240.	4605	69200	12:0	1100 4	107 +	CC.	45.2.3	38. 33	25.09	32.60	1121
Charden Constraint Constraint Constraint Constraint </td <td>1 . 24 AND</td> <td>THE TO DE DRAWE WEAT</td> <td>TO OT OTHING WENT</td> <td>Charles Free Kite</td> <td>1991.9.2 19931.5</td> <td>Planeter spice</td> <td>Perdoment Casary</td> <td>Market</td> <td>10.1403</td> <td>and the second second</td> <td>211 CH 21 CH</td> <td>2.70</td> <td>370</td> <td>213100</td> <td>20001-0</td> <td>26200</td> <td>55RW</td> <td>36000</td> <td>21.13</td> <td>1.25</td> <td>700 34</td> <td>96</td> <td>45 24</td> <td>25 T.S.</td> <td>33.05</td> <td>32.25</td> <td>32.28</td>	1 . 24 AND	THE TO DE DRAWE WEAT	TO OT OTHING WENT	Charles Free Kite	1991.9.2 19931.5	Planeter spice	Perdoment Casary	Market	10.1403	and the second second	211 CH 21 CH	2.70	370	213100	20001-0	26200	55RW	36000	21.13	1.25	700 34	96	45 24	25 T.S.	33.05	32.25	32.28
Number Number Number </td <td>LITET IN KIN</td> <td></td> <td>10-01-078-08 W6M</td> <td>a the second second second</td> <td>the 2 month</td> <td>Recommendation and</td> <td>1.1.1.2.2.1.2.1.2.1.2.1.2.1.2.1.1.2</td> <td>2.1.5× 8 (c.1.</td> <td>L</td> <td>1 . H - 1 a</td> <td>410 * 0+2000</td> <td>2.43</td> <td>400</td> <td>A.4.5-1.6-1</td> <td>15. 15</td> <td>1.04.000</td> <td>1. A. C.</td> <td>+ s. 4 (*</td> <td>2.4</td> <td>1921</td> <td>40 2,</td> <td>00</td> <td>-45 010</td> <td>25-29</td> <td>32.223</td> <td>33.54</td> <td></td>	LITET IN KIN		10-01-078-08 W6M	a the second second second	the 2 month	Recommendation and	1.1.1.2.2.1.2.1.2.1.2.1.2.1.2.1.1.2	2.1.5× 8 (c.1.	L	1 . H - 1 a	410 * 0+2000	2.43	400	A.4.5-1.6-1	15. 15	1.04.000	1. A. C.	+ s. 4 (*	2.4	1921	40 2,	00	-45 010	25-29	32.223	33.54	
Display Display <t< td=""><td>the second</td><td>THE PART FURDERS WANT</td><td>10-01-078-06-49694</td><td>C. T. WIND, Lawren B. Citt</td><td>15/17/0 25/10/1</td><td>and the second second</td><td>Productors Caleng</td><td>Magazi</td><td>A = 1 = 1 M</td><td></td><td>25.000.50.30</td><td></td><td>5/0</td><td>19403-011</td><td>2.00</td><td></td><td>513</td><td>1</td><td>· * * * *</td><td>1.12</td><td>105 4</td><td>00 -16 15</td><td>-46 75</td><td>18.52</td><td>13.13</td><td>- 31) (£)</td><td>10.73</td></t<>	the second	THE PART FURDERS WANT	10-01-078-06-49694	C. T. WIND, Lawren B. Citt	15/17/0 25/10/1	and the second second	Productors Caleng	Magazi	A = 1 = 1 M		25.000.50.30		5/0	19403-011	2.00		513	1	· * * * *	1.12	105 4	00 -16 15	-46 75	18.52	13.13	- 31) (£)	10.73
	- 100029 \$2500	Locate and state the state	DESCRIPTION OF WORK	Charlet de l'a	TROVE TRACE	2 2024-60 V, 1.2-	Michaelser-Gasava	Mornies	Months	0.4	10/10/26/06	12-60	55400	Stord.			2.20.16	TROG	1.8.63	7263	300 6	(c) (3.6.65)	140-11	- SA 07	10112	133.04	2011
Image Image <th< td=""><td>Total Contract of Contract</td><td>1.</td><td>15 11 378 OF 24194</td><td>The second second</td><td>74.00.07 78.75</td><td>Providence and the</td><td>Minigan Meny Gassing Nanatan King Panata</td><td>1.1 1.8 1.1 1</td><td>11</td><td>the second second</td><td>1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1</td><td>10.20-1</td><td>6540</td><td>A 1 1 1 1 1 1 1</td><td>1000</td><td>10.10</td><td>10 - 11 - 11 - 11 - 11 - 11 - 11 - 11 -</td><td>ALC: NO</td><td>140.02</td><td>14101</td><td>40 20</td><td>11. Hale</td><td>44 54</td><td>5418.3</td><td>21.20</td><td>3.1. 1901</td><td>34.00</td></th<>	Total Contract of Contract	1.	15 11 378 OF 24194	The second second	74.00.07 78.75	Providence and the	Minigan Meny Gassing Nanatan King Panata	1.1 1.8 1.1 1	11	the second second	1 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	10.20-1	6540	A 1 1 1 1 1 1 1	1000	10.10	10 - 11 - 11 - 11 - 11 - 11 - 11 - 11 -	ALC: NO	140.02	14101	40 20	11. Hale	44 54	5418.3	21.20	3.1. 1901	34.00
Scale Bit Mark Mark Mark Mark Bit Mark Mark Mark Mark Mark Bit Mark Mark Mark Mark Mark Mark Mark Mark	CONTRACTOR CARL	10011-01-02003 2203	15 12 976 05 West	1.2 Million & other Birth	They are strength of	Magnesian y 111	Production Control of Control of	11	ACTIVATION N	A DEDON	1 1 4 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	2.000	eters)	Calleton	** *****	*	5 2 C 1	14500	4.0	6 Day 1	A/4 *	100	100.00	1.4	11 12	2.7 565	7.1.04
Implie Implie<	Contras Nett		15 11-076-DE WHAT	of active Loanse Long	Added to Annal A	Darmanaver	Production Conver	1.5	1.1	10	1 7 1 1 A DAY M	0.004	1000	12016 CT	14.84 (272.4	10.2224	10.0000	10222010	66.25	1000000 IA	NT IN IN	ALC: NO	45.61	(K) (c)	12.15	12.74	31.54
N 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Construct View	TOGON IN DRIVEN WERE	15 11 078 DE WEAR	Charles Land Law	144.2 1 242.2 4	Autor Insurface	tally	6. 61	14.11.1	down with more front	2.3.3.3.20.45	4.4	55053	P.4 100 10	h.m.n.	14.112.11	6.2	5.6623		Auto	(20) 0	<u>.</u>			218 - 218 -	24. 1 4	1.1.6.3
Image Image <th< td=""><td>The stars works</td><td></td><td>10-11-078-09 Webs</td><td>Gherie Lawe Fre</td><td>16.57 2 11.02 1</td><td>Water storedraft</td><td>5.1</td><td>Lines</td><td>NUMBER OF STREET</td><td>No. Busics</td><td>12 Car 2008</td><td>4.27</td><td>54</td><td>P23665</td><td>635.00</td><td>Vitto</td><td>5400</td><td>8100</td><td>1100</td><td>19.70</td><td>6.31 5</td><td>7.7</td><td>193.11</td><td>\$1.36</td><td>27.69</td><td>28 161</td><td>27.75</td></th<>	The stars works		10-11-078-09 Webs	Gherie Lawe Fre	16.57 2 11.02 1	Water storedraft	5.1	Lines	NUMBER OF STREET	No. Busics	12 Car 2008	4.27	54	P23665	635.00	Vitto	5400	8100	1100	19.70	6.31 5	7.7	193.11	\$1.36	27.69	28 161	27.75
	Contract, Most		15 11-078 CE WEAK	Charling Law Fig.	1167.0 1162.6	Vantos constinse	150 V	Marrie	Maria	The Although	12/10/07/09	1.03	636	8554(3)	66530	14460	6635	8000	2902	2403	1600 N	367	6.0.34	31.23	27.70	29.42	28.33
Import Import<	Section for the		15-11-076-06 W0M	Ramarian Arriv	15-2 0 1-1-1-1-1-1	Willies interation	Production Caling	Maxim	Vana	N . 19	2.21 1.10.25 5.05	12. 22	200	2.000001	tool v	154411	12800	121.0	124.92	414 10 1	Miller 19	Silver	41. 75	- 05 U.S.	54.71	37.000	50.31
Image Description Descripi Description De	In menga Warm	CONTRACT AND A CONTRACT	12-12 d78-D8 Welth	Charlens and Kor	1104 8 1142.2	Carl danag and	Freduction Galaxy	2.2.488.4.1	5.1 Gette	172	Partie Same	2.5%	44:	815105	84500	179613	55634	199682	2552	2700	1000 4	00	45.52	64 8 10	-4 tr.	34 17	15 72
Prime Prim Prime Prime	terre lay vee		(4) 12-078-08 WebM	1.20 Sec. 1. (a) of \$1.35	11454 e - 11464 p	Pumping 61	Production Caring	Maxia	Marsh .	1t -	110-110-20180	2.7%	100	No terra	874:01	55411.1	1.0.0	10時(11)	27993	1248	19:35 2.	012	11. 21.	10 2 2	52. 225	12.92	11.53
Imp An Web 2-10 (2 MeV) Web 1-10 (2 MeV) Deb 1 with Web 1 (2 MeV) And Web 2 (2 MeV) Met 1 (2 MeV)	A nor by state		02 12 078-D8 WOM	The sectors of a	15/04/8 11:06/12	Purgargia	Production Casing	18 30	1.1 16.1	-31	18-10/2006											6.60	45.45	35 64	2162	.32 59	
Image And Mode S 2000 MM Special and is Mode S 2000 MM Special and is Special and	A harring wear	TOUGH TRACK OF WORK	265-121-678 198 44644	Thanks Love From	2510 0 05720	Water weedtoo	SOV	Asia	to at a	entry, arrivery frast	a 1833 28-18	0.48	2400	-9001300	13404	20.201	的法院	6500	15.02	2090 - 2	260 1	3					
is bit bit is bit bit bit is bit bit bit is bit is bit is bit is bit is	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1		143 15 028-08 Weld	"hatter Lone Lon	1820 0 1625.0	Verter Ine. 201	-90V	Marris	1.0 10.00	$\Phi_{1,1}= \prod_{i=1}^{n-1} \sum_{j=1}^{n-1} p_{ij} p_{ij} \cdots p_{ij}$	554.3 20 Je	1.25	670	A08 PM	0.35.04	316402	x (\$1.50)	10.00	2905	2600	100 2	1	-52 51	23.04	29.28	30.62	29.71
Image of the state and the state an	of the right states		05 12 078 05 WEM	Charles Lover Line	- 420 G - 423 D	Vealer method	SOV	Marner	Parts.	• • · · · · · · · · · · · · · · · · · ·	27-1102 Gr.M.	1.53	8.34	\$ 12 LON	The Read	3640	59.00	1922/23		\$100	40, 6	0.	-4 (A - 4 -	81.34	28 (14	2.8 34	25.33
Process does Process does<	t rise py see		193-12 U28-181 WERE	1.0.311 P 3.24 P 4.15	1970 6 1977 6	syanak kolagalok	NULW.	CALL NO.	MATCH	NOTISAS	100000000	100.00	1.00		-		10100					74.121	10.52	- 11 29.0	21103	-68 20	man filmer
International and all all all all all all all all all al	I carries them	Provide the Alberta states	12 12 12 12 12 12 12 12 12 12 12 12 12 1	Course & pare i da	1000 C 1000 C	Contract subjection	Production Lawing	ALLER A.	A. The Party	· · · · · · · · · · · · · · · · · · ·	A CONTRACTOR	12 013	1.05		111100	0.0.000	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	ALC: NO.	ALCONT.	100010	1.00	14.42	4.5.114	15.4.	1. 1.	11.67	12.40
Institution The Direct Server Se	A Design Sec		COLUMN AND ADDRESS AND ADDRESS	for the part of the	1919 C 1919 C	Par arrangers	Production (1987)	ACCREATE THE	11.000.000	Store and a store	10.2010.00	3	No. 10.	Kara di		181.5.1.1	1.47910-1	120.00	3 215	11.241	20 44 (1) 1		21. 04	12.44	13.000	3.1.76	11.37
Lambe Lambe <th< td=""><td>Liverdy dev</td><td>TOWNED TO ARE DO WARM.</td><td>11 12 078 OS WEAT</td><td>to the second second</td><td>1847.6. 8002.6</td><td>Farmeric Con</td><td>March Contractory</td><td>A</td><td>1.1.1.1.</td><td>and death room. Deat</td><td>22006821007</td><td>1.01</td><td>272593</td><td>859400</td><td>095250</td><td>COUNCE.</td><td>42160</td><td>79243</td><td>22(8):</td><td>1400</td><td>100 4</td><td>0</td><td></td><td></td><td>STOR LEVEL</td><td>2010/06/07</td><td></td></th<>	Liverdy dev	TOWNED TO ARE DO WARM.	11 12 078 OS WEAT	to the second second	1847.6. 8002.6	Farmeric Con	March Contractory	A	1.1.1.1.	and death room. Deat	22006821007	1.01	272593	859400	095250	COUNCE.	42160	79243	22(8):	1400	100 4	0			STOR LEVEL	2010/06/07	
Dime Halpstrate Mail Marie	E. Arren Vier	and the second sec	11 12 076 DE WHAT	Mother Lance Free	1467 8 1654 6	A low and shake	50.0	Maria	Lora listona	New Desites	20103/2006	0.0.0	60	6737	1 Cast le	55.655	1300	86/33	275%	1850	000 9	3	50.34	NO 84	26.13	26 00	
Number Internation Number Nu	It hericige views		11-12-078-098 W058	C.C. access France Arees	SANT & SLOT 5	Envirousans	58. V	Maxed	Marriet	New Works	TO GUILDER	1.57	s 1061	estator	1. 1. 1. 1.	494 Jan	200.30	Sw53217.4	24.32	20430	4:11 1	in,	20.15	31.41	27.67	20.94	.15.34
Jerry Mer In 12 2006 MAM Chard Land MAM Chard Land MAM Data Land	Prenting Setting		11-12-07# D8 WOM	She was been by	1547.5 1801.5	Freeman and services	Production Control	Maxim	1.0	Sec. Burgar	22/16/27/24	76.37	90	110200	167200.	6.96.48.5	1.97630	4.9000	117(6)	11105	0 30	00	45.57	35.63	32.69	30.56	11.60
Interry Net Dial 1 (2) (2) (6) (4) (2) (6) (4) (2) (6) (4) (2) (6) (4) (4) (4) (4) (4) (4) (4) (4) (4) (4	Energy Service		17 12 07K 08 WWA1	Charles Lands Free	1557.6 1606.1.	Filmentg Suren	Prochastic of County -	Marxis .	V	54 c - 12 to 1s	17:302006	34 74	×163	34910	BOL SX	81107	YMADE	39.400	13.162	15400	54:00 3	06	47.75	200 OC1	3,5403	28 a.s	13.22
1 k Nov min 11 20 M k With 2 k N k M in Mark 1 k M k M k M in Mark 1 k M k M in Mark <t< td=""><td>derivings for</td><td>112 11 12 116 As 48.00</td><td>11-12-078-08 West</td><td>Plathy Lawy Free</td><td>15m 4 15m3 4</td><td>Phurosparks and</td><td>SOV</td><td>A.C.A.T</td><td>Matrix.</td><td>Conductly ready land</td><td>23-06-2005</td><td>10.03</td><td>400</td><td>2762.53</td><td>47.036</td><td>347.23</td><td>5.8044</td><td>8464</td><td>26561</td><td>18.001</td><td>10k00 E4</td><td>3</td><td></td><td></td><td></td><td></td><td></td></t<>	derivings for	112 11 12 116 As 48.00	11-12-078-08 West	Plathy Lawy Free	15m 4 15m3 4	Phurosparks and	SOV	A.C.A.T	Matrix.	Conductly ready land	23-06-2005	10.03	400	2762.53	47.036	347.23	5.8044	8464	26561	18.001	10k00 E4	3					
interf 11 Los Mode Marcial Research Marcial Resear	E Derde exect		11 12 078 C6 WOM	Literation & Series & Pro-	1585.4 1586.4	Humping of	54 A	8,810 x 1.71**	1.12 - 414-7	, 0.)	2010/04/20138	17.01	140	15470005	1. 1.4 D L	\$1600	42.30	54(31)	1969	1300	FHU IA		42.00	NC 242	78.49	28.87	231.50
Description 17 12 Did NMM Charle Letter for the 4 total Note of Latter in the 4 total Numer Numer<	ed anotage watti		11.12.578-56 Brefst	C. P. Stand County Free	13-14-13-58 4	Panongxe	29.14	Maxia	Mana	GI.	17(1)(212)6	1 × 10.4	~ 10.1	Palgers .	4 641	746.00	4(1,15)	6.8183	1500	1400	500 - S	d.	-51.77	- 17 6-1	27.47	28.57	464
$ \begin{array}{c} 1 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ $	Stront Ch. Anna		11 15 019 66 MOVA	Charlie Larg For	Love V. Lovery	erem de mil en	NUM Deptember	Maxym	Massar	.913	12020202026												23.46	51.42	18.72	29.31	20.47
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	I worth Karn		11 12 076 08 WUM	and the Long Long	1586.4 1568.4	e mustike ker	Production Case of	Maxim	1-15 - WE (F)		1000000000		1/6	CONTRACT.	1.14.100	1,1100		5610 41	11.52,51	4100	NU K	00 01	45.95	10.146	32.13	12.37	1 10
$ \begin{array}{c} 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 $	A new gay week	110 11 12 U.S. Co. 44.14	TE 12 CON DO WOM	Charles 1 store From	1120.4 1539.4	CTU Charles Con	Conduction and style	1.1.1.1.1	North Street	(R.)	1 LACK MA		700	Sold Street		121100	1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1	0.000	144-211	10.00	100 10		- 44 (S 10 ()	32.02	1.3.1.1	10.00	1.1.1.1.1
profile model profile	it menga anen	THE REAL OF US MON	10-12-078-06 WEAR	CD2010012-See 1. 11	14,35	Address in the last	SUV	ACCAL	P. C. +	defendent Los of Trast	2,0114 2,000	1.00	1.00	8.17(3)(d) 8.17(-2)(d)	1.4.4.5	22.224	1.4.5.5	Sec. 1. 1	APRIL 1	10000	1000 E		61.30	21.04	37.64	33.60	27.62
Amount Series 10 10 20 10 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40 20 40	1-0010-1100		NO REPORTE UN MADE	CONTRACTOR NO.	10.54 10 10.040 3	CORPORT IN DESCRIPTION	2No.V	ALLAND.	115	A DESCRIPTION OF THE OWNER OWNER OF THE OWNER	Contraction and the	1.11	2.115.1	M. Lines I. I	1.1.1.1.1.1	196.20.10	N. FLA	5.5241	1210	100.0	11.41 85		N. 174	43.43	21	147.549	1. 765
All controls with the state of the stat	d not as West		10-12-075 Do WEAR	Statley Lower Line	14.15.0 14.417	Acamet Internation	Distance Concern	Marrie	Sur Ducks	New Wester	101010-0020-0020	26.23	276	trates.	Sec.D	260.0	1400	200	11.50	003		20	45 39	32.06	11.65	-36 00	37.03
Limits des 5512 0750 MMM Limits for 10 550 MMM Limits for 10 552 MMM <thlimits 10="" 552="" for="" mmm<="" th=""> Limits for 10 5</thlimits>	A A MARTINE WAR .		16-12-078-05 steet.	Distribution and a later	16.2. 7 16.4.7 1	the about the up to the	Production Constant	Marcan	Marra	to a trist at	17.502235	12.54	1.100	1.56.13		10000	\$7:35	3/38%.4	19610	15/6.	15.05	10	-44 74	32.37	12:16	211 27	29.65
International Control 10 (10 (10 (10 (10 (10 (10 (10 (10 (10	1 Deriva viente		15-12-076-06 WRM	Charlins Later 4 mil	15 85 11 1545 8	Waters around from	First Caparit that is also	Masta	Uneren	Ser Wester	17102100											11 19	4324	32.43	81.23	20 44	27.92
Therma with Dial Dial Tradit With Dial Dial Tradit With Dial Dial Dial Dial Dial Dial Dial Dial	Schergy Version	1.0002 13 078 08 WeM	NRW 50 970 670 67 90	stationates from	150.0 1642.0	Representation of the	SUY	ALAI	M. com	Contational Encourse Transf	16(01/2008	0.57	204	676300	1450.00	34403	5 Tele	1004	14.91	600	100 2	0					
$ 1 = 0.2 \ 100 \$	Exercise Vice		02-13-076-08 With	Charles Love For-	1506 2 1542.0	Etain names and	815.8	14.24	S.S. atres	Control of Friday Friday	23/59/2005	5 44	2605	785-15	01856	35800	14.15	262253	27142	1800	1000 4	Q.					
Demokration Control Solution MMMM Demokration for the Solution MMMMM Demokration for the Solution MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM	Course View		01133.076.08 WMM3	I have call for	15:35 0 11-42.0	Dumping or	Sector .	1.5	Let Marchine	Trans	223.56.27065	12.35	3 (AC	14:000	13750	24,0000	4.3000	* 78 E.)	21424	1450	150 2		743 BY.	31.12	34.64	25: 64	28.61
Time Yells (1) Time Y	Remaining a status		02-10-078-08 W(M	Other iss Lawren Free	1010 0 10420	Providence	Displayment Casing	20. 245.5	La costaluar	Tes is	28.33425.935	3.224	4.2	7.50.2.c.	MARKER	51400	2003	18.50	5 S.K.S.	53(8)	43 4	385	-45-07	-35 0%	32.47	32, 7%	-31.35
Investive United 10:11:01:02:01:04:04 United 10:11:01:02:04:04 United 10:11:01:02:04:04 United 10:01:01:02:04:04 United 10:01:01:02:04:04 United 10:01:01:02:04:04 United 10:01:01:01:04:04 United 10:01:01:01:01:04:04 United 10:01:01:01:01:04:04 United 10:01:01:01:01:01:01:01:00:01:01:01:01:0	S . un de Vente	-	02-13-028-06 W6M	Charlin Lake Fish	1535 0 1542 0	Purry ing and	Production Casing	Mataria	Marcas	2 · · · · ·	$1.5 \sim (0.5)^{5} (61$	2 2.9	2-24	815900	M2506:	39600	2:4(x3	81.00	34200	1406	890 18	65	41: 34	35 65	-32.70	33.40	31.55
Demokration Control Mode Control Mode </td <td>Freeda www.</td> <td>to our to oth or weld</td> <td>CI 13 076-08 WMM</td> <td>12508/Res Elastic First</td> <td>154.0015420</td> <td>Pumping kin</td> <td>Production Case o</td> <td>Ataexan.</td> <td>L CONTRACTOR</td> <td>Second Second</td> <td>120.00.2000</td> <td>21 - 11</td> <td>3 (417</td> <td>722000</td> <td>141407</td> <td>4. 31.1</td> <td>165.00</td> <td>1.112.2</td> <td>3.183</td> <td>3000</td> <td>6.3 5</td> <td>40</td> <td>45 26</td> <td>158.2</td> <td>A3 74</td> <td>32.57</td> <td>31.86</td>	Freeda www.	to our to oth or weld	CI 13 076-08 WMM	12508/Res Elastic First	154.0015420	Pumping kin	Production Case o	Ataexan.	L CONTRACTOR	Second Second	120.00.2000	21 - 11	3 (417	722000	141407	4. 31.1	165.00	1.112.2	3.183	3000	6.3 5	40	45 26	158.2	A3 74	32.57	31.86
International Internat	the name of the state		0.3 13 076 68 W6M	Charley Laster Free	1543 0 1546 0	Edulation for	Production Casting	Maxian	Witter	Nother	12,2975006	3.54	400	746400	09500	45100	86.30	15100	65.00	12000	2900 1	1943	45.24	32.53	32.3	33.60	-27 193
permeterment under endergen vanze onerene overene over	CONTRACTOR STAND	TOO 14 TH OZIS ON MANN	04 13 078 05 WHAT	Charles Lawer Envi	(544 2 33421)	COMPLETE	Production Laboration	Maxxa	s of carps.	16.2	15.0367.096	2.45	240	7.81204.93	5.35400	4750.1	(100	17200	6.000	THEFT I	982 5	10	45.45	35.65	528.3	32 67	14.67
	la native Ven	CONTRACTOR CONTRACTOR CONTRACTOR	02-14-018-08 WOM 07-14-078-28 WMM	Charley Long-Fre-	dentes faithad	Turing the set	Production Gaynag	P.C. P. B. MILL	Alexandre Alexandre	No. Collar Resolution	17 Acres 196	4.40	5315	7452(2)	1038/40	51.9(4)	1000	10400	43.82	ES.C	5 100 A	10	45.43	15 51	32.6.1	31 61	17 611
Tening the 101(22) 091 (5 Well 062) 093 (5 Well 062) 193 (5 Well 062) 193 (5 Well 062) 193 (5 Well 062) 194 (5 Well 062) 193	Survey of the	100, 19, 14 (016-06-VIA82	10-14-176 DB Wett	t Diather Vianar Area	100005-001046 054507011524-0	Example Contractor	CONTRACTOR CONTRACTOR	410000	Materia	French and Franks Trens	CONTRACTOR OF A	3.24	10.57	HOUSE AND	10080180	1943631	ALC: N	N200	of the late	142.85	testi a				- 4, 1111	0.001.001	8050760
	te warge war	1041 CA 23 078 58 West	08 23 078 68 WADA	Gentlerigen	1293.0 1267.5	Flore and with	500	Arian	12.4 10	French of the general	25/09/2006	2.17	75.00	027750	17800	10700	2230	36:33	1.260	1400	1000 7	č.5					

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 2). 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 5. 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 5 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 6. 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 6 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 ($\delta^{13}C_{Methane}$) is presented on Figure 7. 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 $\delta^{13}C_{Methane}$ 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 7 Methane concentration versus δ^{13} C of methane.

A plot of the ethane concentration versus the ethane carbon isotope signature ($\delta^{13}C_{Ethane}$) is presented on Figure 8. Most of the analyses from the Jack water well have ethane concentrations below the lab detection limit (which was high at 100 ppm). One anomalous sample had 1200 ppm. The samples with less than 100 ppm are below the method detection limit to run carbon isotopic analysis of ethane at the University of Calgary and the University of Waterloo (personal communication with Dr. Bernhard Mayer, University of Calgary and Robert Drimmie, University of Waterloo). The method, including the detection limit, used to determine ethane isotopes in the Jack well is not stated. Ethane isotope results on such low concentration may not be accurate. Ethane concentrations in the Jack well are at least 500 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).



Figure 8 Ethane concentration versus δ^{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 9. 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 9 δ^{13} C Methane versus δ^{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 10. 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 0.01% mix of the conventional gas member with a biogenic end-member. This is a very small portion of thermogenic gas.



Figure 10 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 11). 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], $\delta^{13}C_{ethane}$ =-31.1 ‰). Again, the Jack well mixing curve shows a possible 0.01% mix of the conventional gas member with a biogenic gas with an ethane isotope signature more typical of water wells ([Ethane=1 ppm], $\delta^{13}C_{ethane}$ =-31.1 ‰). Again, the Jack well mixing curve shows a possible 0.01% mix of the conventional gas member with a biogenic end-member.



Figure 11 Mixing plot of δ^{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.
- 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 a δ¹³C methane value that is typical of shallow, biogenic methane. The production casing samples from energy wells have δ¹³C methane values that are less depleted and are typical of thermogenic gas. The SCV gas has δ¹³C 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 to the ethane signatures of the surface casing vent flows. Ethane concentrations are very low (<100 ppm) and, may be below the detection limit for isotopic techniques, especially when the associated methane concentrations are so high (>900,000 ppm).
- 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 0.01% of a thermogenic gas with a composition the same as the SCF gas could produce results similar to the Jack well. This is a very small potential component of thermogenic gas.

There are several deficiencies in the data that has been collected for the Jack well investigation. ARC recommends the following work be carried out:

- A water sample should be taken from the Jack well to be analysed for major ion chemistry and bacterial parameters. If gas is present in surrounding water wells, it should be sampled for compositional and isotopic analysis.
- While it would be ideal to sample several adjacent water wells in the area, a review of available wells (>6 km radius) indicates the Jack well is the only well completed at this interval. Several deep wells have been drilled in the area, but were dry and were abandoned. All other wells were shallow (<10 m).
- A no headspace water sample should be taken from the Jack well to be analysed for USEPA volatile priority pollutants (vpp) and extractable priority pollutants (epp).
- A no headspace water sample should be taken from the Jack well to be analysed for dissolved hydrocarbons (C1 to C4) and atmospheric gases.
- A gas canister sample should be taken from the Jack well to be analysed for volatile organics and ozone precursors (EPA T014).
- A gas canister sample of the Jack well gas should have a high quality gas chromatograph analysis or C1 to C4.
- A gas canister sample (in duplicate) should be taken from the Jack for carbon isotope analysis in two independent labs (suggest University of Alberta and University of Victoria).

Overall Conclusion

 Alberta Research Council's overall conclusion of the evidence from the review of the AENV and ERCB files is that insufficient data exists to determine whether Mr. Jack's well has been impacted by conventional oil/gas wells in the area.

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

- 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.
- 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.
- Hackbarth, D., 1977. Hydrogeology of the Grande Prairie area, Alberta. Alberta Research Council report 76-4.
- 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.
- 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: CO₂ reduction vs. acetate fermentation – Isotopic evidence. Geochimica et Cosmochimica Acta, Vol. 50, p. 693-709.

APPENDIX A PUMPING TEST GRAPHICAL SOLUTION





