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SHELL CANADA LIMITED

Quest Carbon Capture and Storage Project

SIXTH ANNUAL STATUS REPORT

Prepared By:
Shell Canada Limited
Calgary, Alberta

March 31, 2018

The Sixth Annual Status Report addresses the AER application approval referenced in the Carbon Dioxide Disposal Approval No. 11837C the “Approval”, issued on May 12th, 2015 to Shell Canada Limited [1]. This report addresses Conditions 10 and 17 of the Approval.

TABLE OF CONTENTS

1. SPECIFIC REQUIREMENTS

The following Table 1-1 lists the requirements for Annual Reporting as listed in the AER QUEST Project Approval No 11837C [1], and the corresponding Section in this report:

Table 1-1: Concordance Table.

Requirement as listed in the Alberta Energy Regulator (AER) Quest Project Approval No 11837C	Section
10) The Approval Holder must provide annual status reports and presentations. The reports must be aligned with the most current MMV plan and submitted to ResourceCompliance@aer.ca. The report must be in metric units and include:	
a) a summary of scheme operations including, but not limited to,	2
i) any new project wells drilled in the reporting period,	2.2
ii) any workovers/treatments done on the injection and monitoring wells including the reasons for and results of the workovers/treatments,	2.3
iii) changes in injection equipment and operations,	2.3
iv) identification of problems, remedial action taken, and impacts on scheme performance.	2.3 4.5
b) complete pressure analysis including but not limited to stabilized shut-in formation pressures and a discussion on how the pressure compares with the formation pressure expected for the cumulative volume of CO_2 injection, along with an updated estimate of what the actual cumulative injection volume will be at the maximum shut-in formation pressure specified in clause 5) a),	3
c) discussion of the overall performance of the scheme, including: how the formation pressure is changing over time; updated geological maps; and updated CO_2 plume extent and pressure distribution models, if needed. The updated models should be based on all new data obtained since the last model run including the cumulative CO_2 injected to the end of the reporting period.	3 3.4
d) a summary of MMV Plan activities, performance and results in the reporting period, including, but not limited to:	4
i) a report on any event that exceeded the approved operating requirements or triggered MMV activities,	4
ii) comparison of measured performance to predictions,	3.3 4.1
iii) summary of operations and maintenance activities conducted,	4.1

Requirement as listed in the AER Quest Project Approval No 11837C	Section
iv) details of any performance or Measurement, Monitoring, and Verification (MMV) Plan issues that require attention,	4.5
v) pressure surveys, corrosion protection, fluid analyses, logs and any other data collected that would help in determining the success of the scheme, and	2.3
vi) discussion of the need for changes to the MMV plan.	5.1
e) a table for all wells listed in clause 3)(1) a), showing the following injection data for each month of the reporting period:	3.1
i) mole fraction of the CO_2 and impurities in the injection stream,	3.1
ii) volume of the CO_2 injected at standard conditions,	3.1
iii) formation volume factor of the injected CO_2 stream (not applicable since CO_2 is in dense phase),	N/A
iv) cumulative volume of the injected CO_2 at standard conditions following the commencement of the scheme,	3.1
v) volume of the CO_2 injected at reservoir conditions,	3.1
vi) hours on injection,	3.1
vii) maximum daily injection rate at standard conditions,	3.1
viii) average daily injection rate at standard conditions,	3.1
ix) maximum wellhead injection pressure (MWHIP) and corresponding wellhead injection temperature,	3.1
x) average wellhead injection pressure, corresponding average wellhead injection temperature,	3.1
xi) maximum bottom hole injection pressure (MBHIP) at the top of injection interval and the corresponding bottom hole injection temperature, and	3.1
xii) average bottom hole injection pressure at the top of injection interval and the corresponding average bottom hole injection temperature.	3.1
f) a table showing the volumes of injected CO_2 on a monthly and cumulative basis,	3.1
g) Hall Plots of constant average reservoir pressure where unexplained anomalous injection rate and pressure data could indicate fracturing.	3.2
h) a plot showing the following daily average data at standard conditions versus time since the commencement of CO_2 injection:	3.1
i) daily CO_2 injection rate,	3.1
ii) wellhead and bottom hole injection pressure, and	3.1

Requirement as listed in the AER Quest Project Approval No 11837C	Section
iii) estimated or measured average reservoir pressure in the Basal Cambrian Sandstone (BCS) formation.	3.1
i) the potential need for installing additional monitoring towards the periphery of the pressure build up area later in the project life,	5.2
j) evaluate the need for additional deep monitoring wells adjacent to the four legacy wells in the approval area. Based on the information provided the ERCB may require the Approval Holder to drill one or more such deep monitoring wells, and	5.4
k) discussion of stakeholder engagement activities in the reporting period.	6
17) The Approval Holder must provide ongoing annual reports beginning March 31, 2016 through to March 31, 2040. The report must include all the requirements listed in clause 10. The Approval Holder must provide a report and presentation of general performance of prior calendar year, identification of operations problems, and discussion of the need for MMV changes. Include updates, conclusions and review of:	
a) need for additional deep monitoring wells adjacent to the four legacy wells in the approval area,	5.4
b) results from well testing including data from annual hydraulic isolation logging,	2.3
c) need for further hydraulic isolation logging beyond the first five years of injection,	2.3
d) projected timing for additional 3D surface seismic surveys,	5
e) required frequency of time-lapse seismic surveys,	5
f) update of CO_2 plume and pressure front models including the results of the prescribed BCS Formation reservoir pressure fall-off test two years after the start-up of each injection well,	3.4
g) need for ongoing BCS Formation fall-off shut-in reservoir pressure tests in all injection wells,	5.2
h) updated geology, and	3.4.1
i) potential need for additional monitoring wells towards the periphery of the pressure build up area.	5.2

N/A means that the specific requirement is not applicable at this time.

2. CONSTRUCTION AND SCHEME OPERATIONS UPDATE

2.1. Capture and Pipeline Construction

Capture and pipeline construction was completed in 2015 [5], and on 29th September 2015, the commercial operations' certificate for Quest was issued.

2.2. Project Wells / SCVF

Shell completed drilling all the wells currently planned for the operations phase of the Project in 2012 and 2013. Table 2-1 is a synopsis of all the completed drilling activity for the Quest Project. No more wells are expected to be drilled for this project unless required as per the conditions in AER approval 11837C [1].

In February 2017 a request was made for a non-routine suspension approval for the IW 5-35 as per AER Directive 013: Suspension Requirements for Wells. In March 2017, temporary approval was obtained to suspend the well in the current configuration, conditional to the well not being used for CO_2 injection.

Post drilling, surface casing vent flows (SCVF) were identified in all deep monitoring and injection wells, as well as gas migrations (GM) in IW 7-11 and IW 5-35.

As required, annual testing was completed in 2017 for surface casing vent flow (SCVF) and gas migration (GM) at the injection pads. Reports were sent to AER in June 2017.

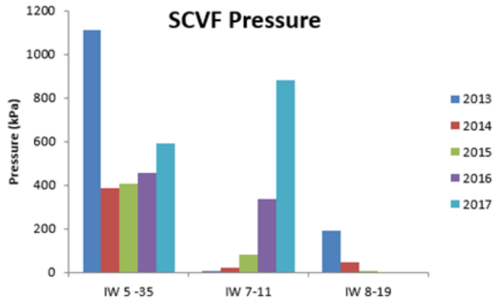
The SCVF flow test results for both IW 5-35 and IW 7-11 are summarized in Figure 2-1. Measurements at the IW 5-35 well are at similar levels to those observed in June 2016. The measured SCVF flowrate reading for IW 5-35 in June 2017 was TSTM (Too Small To Measure). Although there is an increase at IW 7-11 SCVF buildup pressure, the overall level is still low. (Figure 2-1).

No gas was detected on the SCVF measurements on IW 8-19 for a second consecutive year, indicating that the surface casing vent flow on this well has declined to zero. The compositional results indicate that the SCVF and GM gas at the IW wells is predominately methane

Gas Migration testing as per the suggested method in AER Directive 20, Appendix 2 was performed on both wells. Previously, the gas migrations observed on IW 5-35 and IW 7-11 occurred as bubbles in the well cellars.

In June 2016, no gas bubbles were observed in the IW 7-11 cellar; however, in June 2017, the gas bubbles had reappeared. The IW 7-11 gas migration is now intermittent. Gas bubbles were observed in the IW 5-35 cellar in both 2016 and 2017.

In 2017, the gas concentration measurements at 30 cm were taken using an inverted funnel and hose for the first time. As such, the results obtained are not directly comparable to historical measurements of whole air collected via methane meter suspended over cellar. The 2017 method preferentially samples lighter gases and as a result recorded LEL measurements in the 96-98% LEL range, however the 2016 and earlier method used whole air measurements which resulted in LEL measurements in the 4.6-31% LEL range. The gas migration measurements further away from the well are generally very low with a couple relatively higher measurements that are still below the measured values at the cellar. The gas migrations still have very limited impact and no potential for concern beyond the lease.



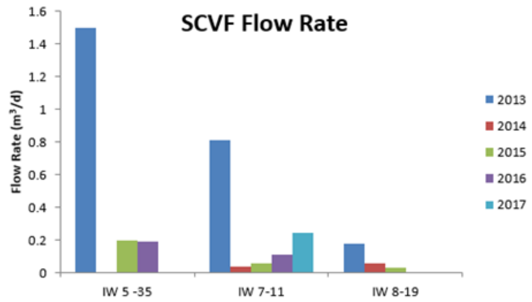


Figure 2-1: SCVF Pressure and Flow rate summary graphs for IW 5-35, IW 7-11, and IW 8-19.

2.3. Well Workovers and Treatments

2.3.1. Injection Wells

No new wells have been drilled since completion of the 2012-2013 drilling campaign. During 2017, the following activities were executed in the Injector wells:

IW 8-19:

- Wellhead Integrity Test and Packer Isolation Test: passed.
- Perform fluid shot on annulus Drillsol level, top up N_2 in annulus and Top up Drillsol in annulus to ~200m below WH. Perform fluid shot after Drillsol top up.
- Tubing integrity logging (caliper) and hydraulic isolation logging (PNx).
- SCVF and Gas Migration Test

IW 7-11:

- Wellhead Integrity Test and Packer Isolation Test: passed.
- Perform fluid shot on annulus Drillsol level, top up N_2 in annulus and Top up Drillsol in annulus to ~200m below WH. Perform fluid shot after Drillsol top up.
- Tubing integrity logging (caliper) and hydraulic isolation logging (PNx).
- SCVF and Gas Migration Test

IW 5-35:

- Wellhead Integrity Test and Packer Isolation test: passed.
- Perform fluid shot on annulus Drillsol level, top up N_2 in annulus and Top up Drillsol in annulus to ~200m below WH. Perform fluid shot after Drillsol top up.
- SCVF and Gas Migration Test

The results and interpretation of the 2017 PNx hydraulic isolation logging are included in Appendix B, and the logs are submitted through the standard log submission process.

2.3.1. Deep Monitoring Wells

No well workovers or operations occurred in 2017 at the four deep monitoring wells.

2.3.2. Groundwater Wells

The groundwater well drilling and completion campaign was completed in 2013. A full report can be found in the Second Annual Status Report [3].

No new project groundwater wells have been drilled since the 2012-2013 drilling campaign.

Table 2-1: 2017 Quest Well Summary.

UWI	Well type	Well name in this report	Spud date [d/m/y]	Rig release [d/m/y]	Total Depth [m MD]	TD formation
103113205521W402	Appraisal (Abandoned in PCMB)	Redwater 11-32	10/11/2008	02/01/2009	2240.6	Precambrian
103030405720W400	Observation (in CKLK)	Redwater 3-4	23/01/2009	18/03/2009	2190.0	Precambrian
100081905920W400	Injection	IW 8-19	01/08/2010	08/09/2010	2132.0	Precambrian
102081905920W400	Deep Monitoring	DMW 8-19	30/09/2012	15/10/2012	1696.0	Ernestina Lake
102053505921W400	Injection	IW 5-35	21/10/2012	20/11/2012	2143.0	Precambrian
100053505921W400	Deep Monitoring	DMW 5-35	24/11/2012	06/12/2012	1710.0	Ernestina Lake
103071105920W400	Injection	IW 7-11	14/12/2012	20/01/2013	2105.0	Precambrian
102071105920W400	Deep Monitoring	DMW 7-11	23/01/2013	05/02/2013	1664.5	Ernestina Lake
1F1081905920W400	Groundwater	GW 1F1/8-19	08/12/2010	08/01/2011	201	Lea Park
110000911151UL00*	Groundwater	GW UL1/8-19	14/01/2011	17/01/2011	101.0	Foremost
110000911152UL00*	Groundwater	GW UL2/8-19	12/01/2011	13/01/2011	62.8	Foremost
110000911153UL00*	Groundwater	GW UL3/8-19	09/01/2011	10/01/2011	37.5	Foremost
110000911154UL00*	Groundwater	GW UL4/8-19	11/01/2011	11/01/2011	20.0	Oldman
1F1053505921W400	Groundwater	GW 1F1/5-35	08/02/2013	17/02/2013	200	Lea Park
UL1053505921W401*	Groundwater	GW UL1/5-35	17/02/2013	18/02/2013	23	Foremost
1F1071105920W400	Groundwater	GW 1F1/7-11	19/02/2013	26/02/2013	180	Lea Park
UL1071105920W400*	Groundwater	GW UL1/7-11	26/02/2013	27/02/2013	30.7	Foremost

Legend: * well name used in Shell but not official UWIs as these wells do not require a well licensed because they are less than 150m depth.

2.4. Well Integrity Summary

This section includes a discussion on the status of the Quest injection well integrity and well leak detection methodology.

Well integrity assurance is supported by, but not limited to, the data in Table 2-2. In 2014, an independent well integrity review was submitted to support the suitability of the Quest injection wells for long-term CO_2 storage and the MMV Plan activities [9].

As of 2017, there is no indication of integrity issues in IW 7-11 and IW 8-19. The following is a summary of the evidence of the integrity of the Quest injection wells:

The SCVF and GM testing that occurred and were reported in 2017 (Section 2.2) continue to indicate low flow levels. DTS data continue to behave in a manner similar to typical wells without any leaks; no expected leak profiles have been identified in the data (discussion in Section 4.3).

Tubing integrity logging (caliper) does not show any indication of corrosion in the tubing strings. Hydraulic isolation logging (PNx) in the injection wells demonstrates the containment of the CO_2 in the BCS (Section 4.3 and Appendix B). Packer isolation tests were performed in the injection wells and all wells passed.

Injection well monitoring occurs continuously using tubing head pressure (THP), casing head pressure (CHP) and tubing head temperature (THT). Data are summarized in Table 3-6 and Table 3-7.

The injection wells have a Drillsol filled annulus with an N_2 cushion on top. Figure 2-2 shows an example of the annulus pressure variations (teal) alongside the wellhead temperature (yellow) and pressure measurements (green). The annular pressure seasonal variations correlate with injected CO_2 temperature. Seasonal temperatures affect the amount of cooling that the CO_2 undergoes in the Quest pipeline. The injected CO_2 temperature then warms or cools the annular fluid thereby affecting the annular pressure. Under current typical injection conditions, the injection tubing head pressure is 9 MPa with an annular pressure of 11 MPa. The CO_2 is a liquid under current typical injection conditions (9 MPa and below 30°C). Monitoring the change in annular pressure over 24 hour periods under stable injection conditions effectively isolates the temperature effects from daily temperature variations. In addition to the continuous pressure monitoring, the annular liquid level is measured annually and before/after service rig workovers.

Table 2-2: Well integrity activities (modified from the 2017 MMV Plan [8], Table 4-1).

Monitoring technology	Areal coverage	Frequency
SCVF testing as per AER ID 2003-01	DMWs and IWs, as required	annually by June 30th
Gas migration testing as per AER Directive 020	DMWs and IWs, as required	annually by June 30th
Wellhead pressure-temperature monitoring	IWs	continuous
Downhole pressure-temperature monitoring	IWs	continuous
Annulus pressure monitoring	IWs	continuous
Time-lapse ultrasonic casing imaging	active IWs	every 5 years
Time-lapse electromagnetic casing imaging	active IWs	every 5 years
Time-lapse cement bond log	active IWs	every 5 years
Mechanical well integrity testing (packer isolation test)	IWs	every 5 years
Tubing caliper log	active IWs	every 5 years
Injection rate monitoring	IWs	continuous
Temperature and RST logs	active IWs	as per AER Approval No. 11837C condition 5c and associated logging extension request granted on March 22, 2016
Distributed temperature sensing	IWs	continuous

Table 2-3: Well integrity logging activities.

	IW 8-19	IW 7-11	IW 5-35
2010	CBL-VDL-USIT		
2012			CBL-VDL-USIT
2013		CBL-VDL-USIT EMIT	CBL-VDL-USIT EMIT
2015	RST	RST	RST
2016	PNx Tubing Caliper	PNx Tubing Caliper	
2017	PNx Tubing Caliper	PNx Tubing Caliper	

The combination of monitoring annular pressure with injected CO_2 temperature trends, measuring annular liquid levels and monitoring annular pressure changes over 24 hour periods provides a comprehensive analysis to distinguish between small packer leaks and seasonal changes in annular pressure.

A lower pressure limit is in place on Quest injection well flowlines, with a low pressure ESD setpoint at 8 MPa. The BCS reservoir quality is very good (see Section 3.2 Injectivity) and consequently the bottom hole injection pressure is only a few hundred kPa above the reservoir pressure. As such, any changes in the reservoir pressure due to a theoretical leak could not physically cause a significant drop in the IW tubing head pressure.

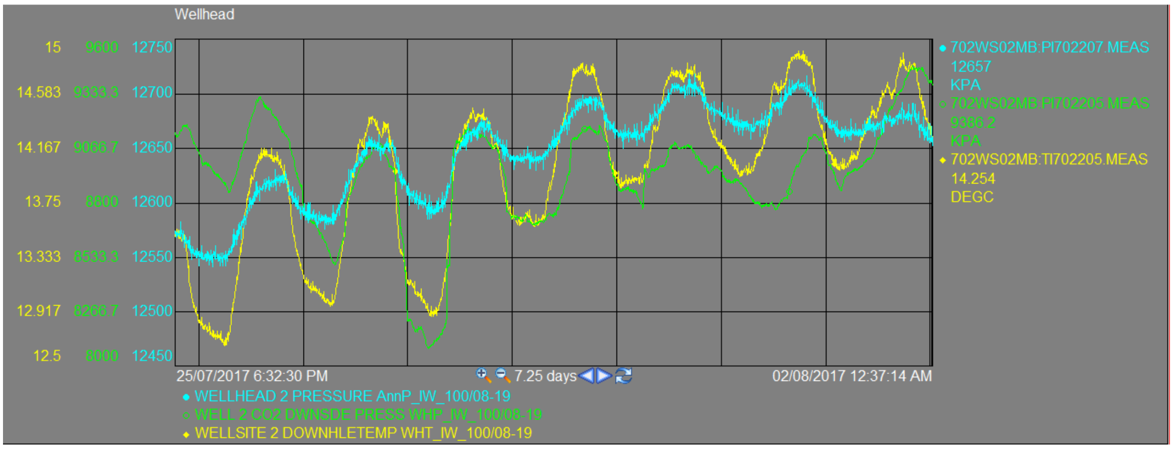


Figure 2-2: Annulus pressure monitoring in IW 8-19 demonstrating the correlation with the diurnal variations associated with the injected fluid temperatures. Annulus pressure variations (teal), wellhead temperature (yellow) and pressure measurements (green).

3. INJECTION WELL PERFORMANCE

3.1. Injection Data Reporting

The monthly totals for the Quest operations demonstrate rate changes primarily as a consequence of capture facility optimizations (Table 3-1, Table 3-2).

To date, no CO_2 has been injected into IW 5-35. It was suspended as of Q2/2017 (Section 2.2) and has remained in observation mode.

Table 3-1: 2017 Quest CO_2 Injection Summary.

Mass of Injected CO_2 (thousand-tonnes) in 2017					
Month	05-35	08-19	07-11	Total	Cum Total for 2017
Jan-17	-	56	54	110	110
Feb-17	-	49	48	97	207
Mar-17	-	56	54	111	318
Apr-17	-	54	45	99	417
May-17	-	37	40	78	494
Jun-17	-	32	53	85	579
Jul-17	-	39	37	77	656
Aug-17	-	54	54	109	764
Sep-17	-	52	48	100	865
Oct-17	-	51	37	88	952
Nov-17	-	53	38	91	1043
Dec-17	-	55	40	95	1138

Table 3-2: Total Quest CO_2 Injection Summary.

TOTAL Mass of Injected CO_2 (thousand-tonnes)					
Year	05-35	08-19	07-11	Total	Cum Total
2015	-	210	161	371	371
2016	-	568	540	1108	1479
2017	-	589	549	1138	2617

3.2. Injectivity

Overall the Quest project has more than sufficient injectivity, demonstrated by the utilization of only two of the three injection wells injecting at rates in excess of 150t/hr. Therefore, with IW 5-35 as a standby injection well, the project is more than capable of sustaining injectivity greater than the project goal of 140t/hr (1.2Mt/year) for the duration of the project and no infill well development will be needed to meet injectivity requirements.

IW 8-19 well has been injecting consistently at approximately 67 t/hr over this time period (Figure 3-1). IW 7-11 has been receiving the remaining available volumes which averages to approximately 63 t/hr over this time period (Figure 3-2). IW 5-35 has remained in observation mode.

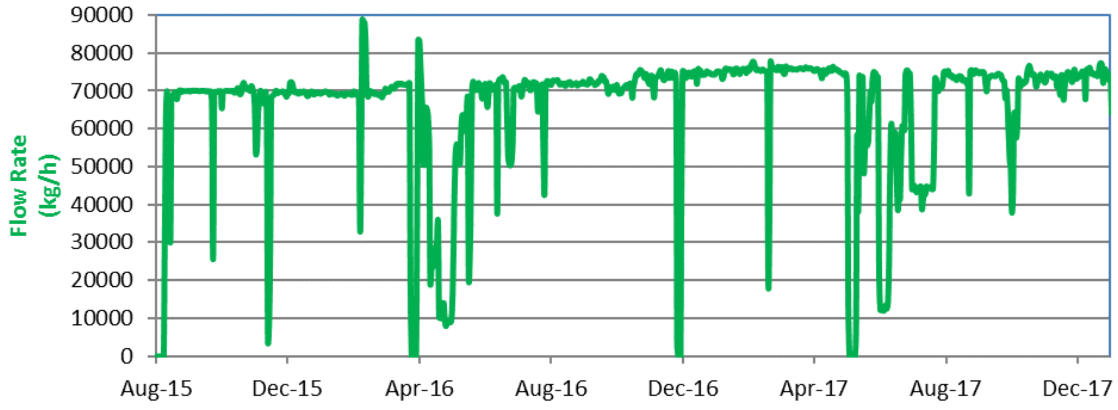


Figure 3-1: Flow Rate for 8-19 over time.

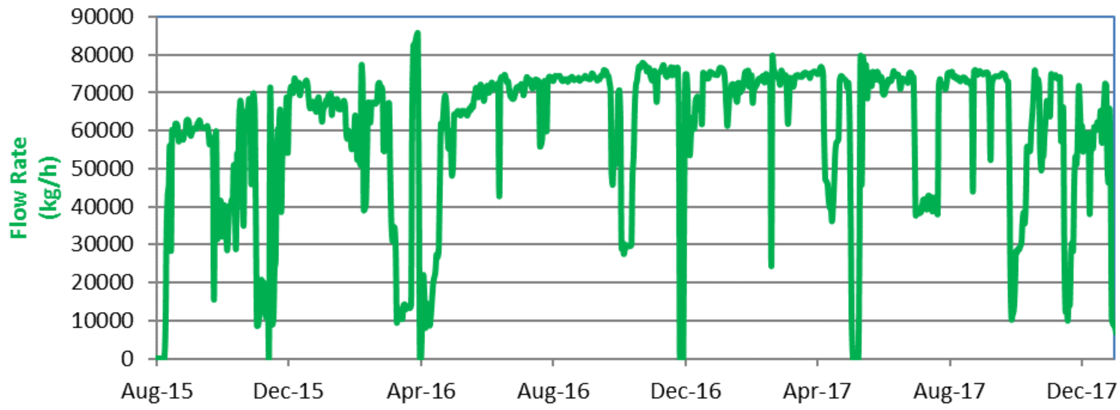


Figure 3-2: Flow Rate for 7-11 over time.

The injectivity stability is illustrated in the Dynamic Injectivity Index plots shown in Figure 3-3 and Figure 3-4. Both wells were shut-in for logging in May and thereby induced some overriding pressure transients. Beyond the transient affects, the plot illustrates that IW 8-19 and IW 7-11 appear to have an inverse relationship to injection temperature. This phenomenon is well recognized in the CCS community, and research is ongoing. Further data collection and evaluation of this relationship will be ongoing in 2018.

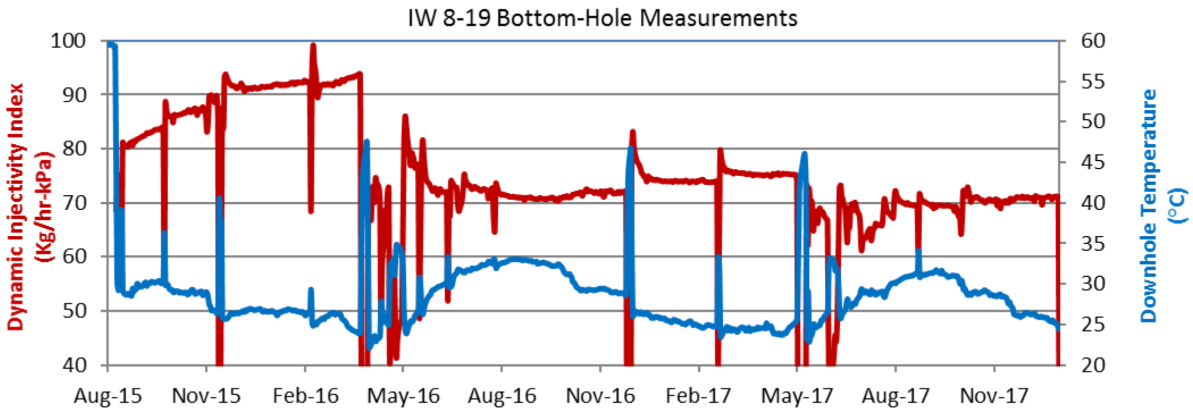


Figure 3-3: Dynamic Injectivity Index and BHT for 8-19 over time.

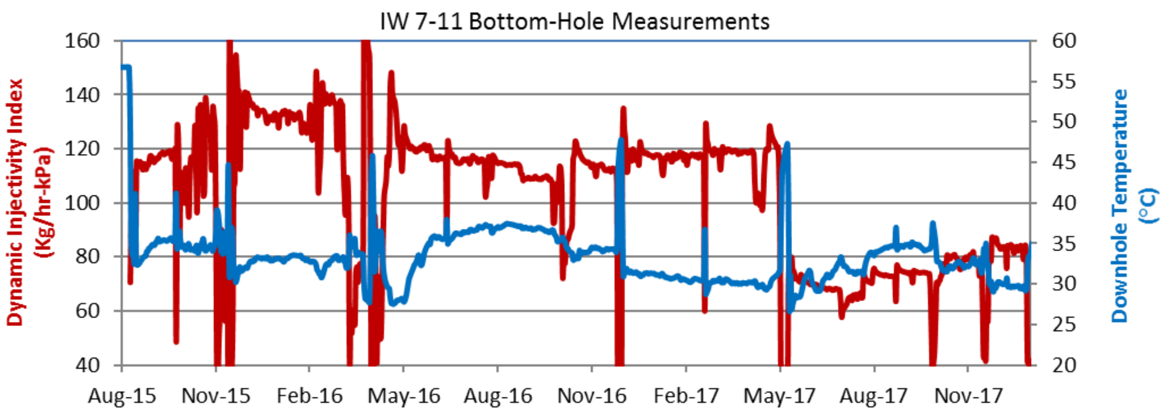


Figure 3-4: Dynamic Injectivity Index and BHT for 7-11 over time.

Injection stream compositions and variations are shown in Table 3-3. These values are within design scope and have not impacted operations. There are no concerns on reactivity of the impurities or impact on the phase behavior.

2017 monthly injection data summaries for rate, mass and pressures are reported in Table 3-3, Table 3-4, Table 3-5, Table 3-6, and Table 3-7.

Table 3-3: 2017 Quest CO_2 Injection Summary: Injection Stream

MONTHLY DATA	Injection Stream Content (Volume %)				
	CO_2	H_2	CH_4	CO	H_2O
Jan-17	99.59	0.42	0.05	0.008	0.004
Feb-17	99.50	0.46	0.06	0.001	0.004
Mar-17	99.44	0.48	0.06	0.008	0.005
Apr-17	99.41	0.47	0.06	0.006	0.005
May-17	99.53	0.48	0.06	0.008	0.005
Jun-17	99.49	0.51	0.06	0.005	0.004
Jul-17	99.40	0.50	0.06	0.007	0.004
Aug-17	99.45	0.47	0.06	0.004	0.004
Sep-17	99.43	0.48	0.06	0.004	0.005
Oct-17	99.43	0.48	0.06	0.006	0.005
Nov-17	99.45	0.48	0.06	0.010	0.005
Dec-17	99.46	0.46	0.06	0.010	0.005

Table 3-4: 2017 Quest CO_2 Injection Summary: Injection data – Mass.

MONTHLY DATA	INJECTION WELLS		
Mass of CO_2 Injected[1] (kt)	IW 7-11	IW 8-19	IW 5-35
Jan-17	54	56	-
Feb-17	48	49	-
Mar-17	54	56	-
Apr-17	45	54	-
May-17	40	37	-
Jun-17	53	32	-
Jul-17	37	39	-
Aug-17	54	54	-
Sep-17	48	52	-
Oct-17	37	51	-
Nov-17	38	53	-
Dec-17	40	55	-
Cumulative Mass of CO_2 Injected[1] (kt)			-
Total at end of 2016	700	778	-
Jan-17	754	834	-
Feb-17	802	883	-
Mar-17	857	939	-
Apr-17	901	993	-
May-17	942	1030	-
Jun-17	995	1062	-
Jul-17	1032	1102	-
Aug-17	1086	1156	-
Sep-17	1134	1209	-
Oct-17	1171	1259	-
Nov-17	1209	1312	-
Dec-17	1249	1367	-

[1]Volume of CO_2 is reported in standard units for CO_2, i.e. mass.

Table 3-5: 2017 Quest CO_2 Injection Summary: Injection data.

MONTHLY DATA	INJECTION WELLS		
Total Monthly Hours on Injection (hours)	IW 7-11	IW 8-19	IW 5-35
Jan-17	744	744	-
Feb-17	657	644	-
Mar-17	744	744	-
Apr-17	720	720	-
May-17	563	561	-
Jun-17	720	720	-
Jul-17	744	744	-
Aug-17	735	734	-
Sep-17	720	720	-
Oct-17	744	744	-
Nov-17	720	720	-
Dec-17	744	744	-
Maximum Daily Injection Rate (t/h)			
Jan-17	78	78	-
Feb-17	85	79	-
Mar-17	79	78	-
Apr-17	78	78	-
May-17	83	78	-
Jun-17	77	77	-
Jul-17	76	76	-
Aug-17	78	77	-
Sep-17	77	77	-
Oct-17	78	78	-
Nov-17	76	77	-
Dec-17	73	78	-
Average Daily Injection Rate (t/h)			
Jan-17	72	75	-
Feb-17	72	73	-
Mar-17	73	76	-
Apr-17	62	75	-
May-17	54	50	-
Jun-17	73	45	-
Jul-17	50	53	-
Aug-17	73	73	-
Sep-17	67	73	-
Oct-17	50	68	-
Nov-17	53	73	-
Dec-17	54	75	-

[1]Maximum of the daily averages.

Table 3-6: 2017 Quest CO_2 Injection Summary: Well Head Pressures and Temperatures.

MONTHLY DATA	IW 7-11		IW 8-19		IW 5-35	
Maximum[1] WHIP and WHIT	WHIP (kPa-g)	WHIT (°C)	WHIP (kPa-g)	WHIT (°C)	WHIP (kPa-g)	WHIT (°C)
Jan-17	9006	13	9121	9	-	-
Feb-17	9024	12	9282	9	-	-
Mar-17	8773	12	9049	8	-	-
Apr-17	8969	13	9012	8	-	-
May-17	9245	18	9030	17	-	-
Jun-17	9464	17	9377	13	-	-
Jul-17	9408	18	9335	14	-	-
Aug-17	9883	19	9817	16	-	-
Sep-17	9854	19	9789	16	-	-
Oct-17	9481	16	9685	13	-	-
Nov-17	9424	16	9354	12	-	-
Dec-17	9483	13	9378	10	-	-
	IW 7-11		IW 8-19		IW 5-35	
Average WHIP and WHIT	WHIP (kPa-g)	WHIT (°C)	WHIP (kPa-g)	WHIT (°C)	WHIP (kPa-g)	WHIT (°C)
Jan-17	8386	12	8956	8	-	-
Feb-17	8396	11	8760	7	-	-
Mar-17	8448	12	8954	8	-	-
Apr-17	7125	10	8878	8	-	-
May-17	6945	12	6586	9	-	-
Jun-17	8915	14	5991	7	-	-
Jul-17	6382	13	6557	11	-	-
Aug-17	9513	18	9442	15	-	-
Sep-17	8921	17	9416	15	-	-
Oct-17	6475	12	8509	12	-	-
Nov-17	6989	10	8982	11	-	-
Dec-17	7048	10	8971	9	-	-

[1]Maximum of the daily averages.
Note: kPa-g refers to gauge pressure.

Table 3-7: 2017 Quest CO_2 Injection Summary: Bottom Hole Pressures and Temperatures.

MONTHLY DATA	IW 7-11		IW 8-19		IW 5-35	
Maximum[1] BHIP and BHIT	BHIP (kPa-g)	BHIT (°C)	BHIP (kPa-g)	BHIT (°C)	BHIP (kPa-g)	BHIT (°C)
Jan-17	20579	31	21045	26	-	-
Feb-17	20583	37	21070	33	-	-
Mar-17	20593	31	21052	25	-	-
Apr-17	20608	31	21060	25	-	-
May-17	21009	47	21136	46	-	-
Jun-17	21044	32	21138	33	-	-
Jul-17	21037	34	21125	30	-	-
Aug-17	21037	37	21178	34	-	-
Sep-17	21045	37	21186	32	-	-
Oct-17	20969	36	21194	30	-	-
Nov-17	20989	35	21189	29	-	-
Dec-17	20916	34	21218	26	-	-
	IW 7-11		IW 8-19		IW 5-35	
Average BHIP and BHIT	BHIP (kPa-g)	BHIT (°C)	BHIP (kPa-g)	BHIT (°C)	BHIP (kPa-g)	BHIT (°C)
Jan-17	20552	31	21027	25	-	-
Feb-17	20561	31	21008	25	-	-
Mar-17	20571	30	21037	24	-	-
Apr-17	20503	30	21047	24	-	-
May-17	20678	33	20807	30	-	-
Jun-17	21005	31	20712	29	-	-
Jul-17	20694	32	20822	29	-	-
Aug-17	21008	34	21136	31	-	-
Sep-17	20947	35	21158	31	-	-
Oct-17	20676	32	21077	29	-	-
Nov-17	20714	32	21160	27	-	-
Dec-17	20710	30	21179	26	-	-

[1]Maximum of the daily averages.
Note: kPa-g refers to gauge pressure.

3.3. Model to Performance Conformance

Figure 3-5 illustrates that the measured Bottom Hole Pressure (solid lines) to the end of 2017. The modeled BHP (dashed lines) illustrates that the reservoir model is responding to varying rates in a reasonable fashion. Therefore, it is reasonable to use the model for pressure prediction forecasting for injection rates similar to those observed to date. The IW 5-35 continues to serve as a BCS pressure observation well.

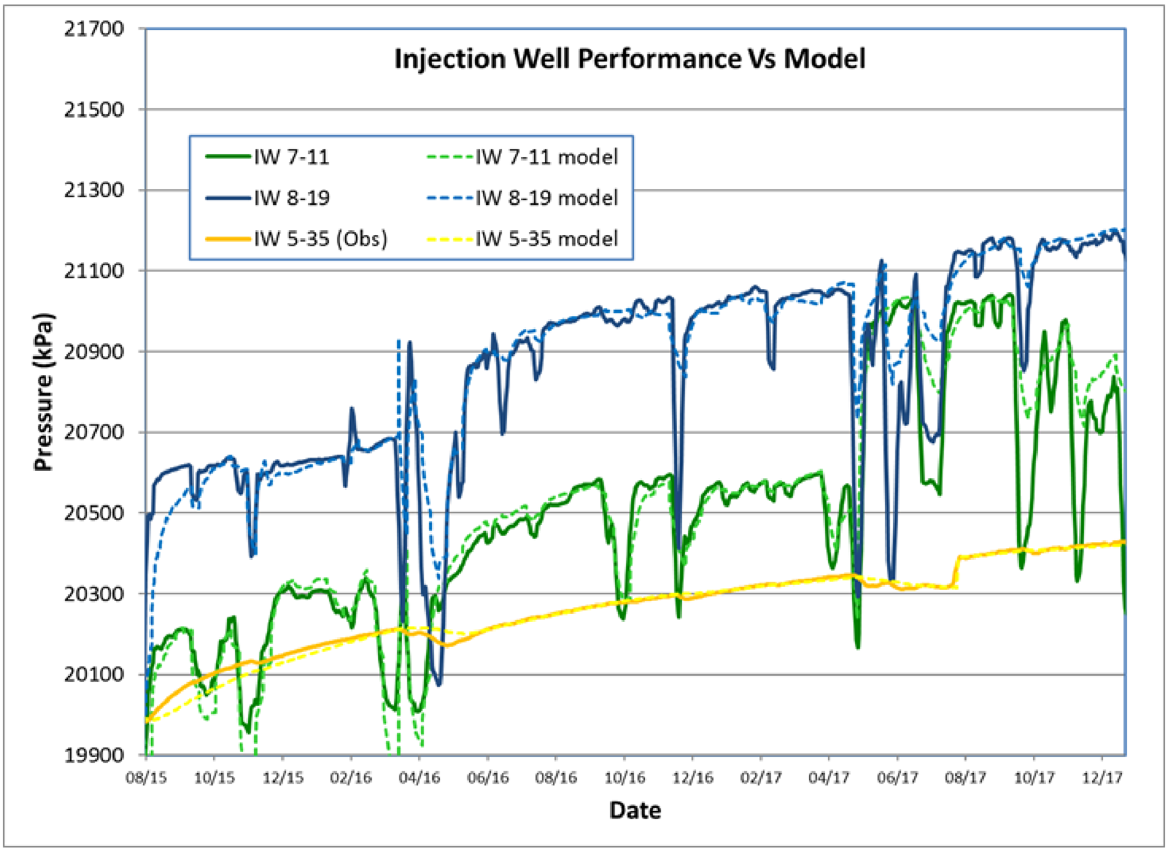


Figure 3-5: Actual BH Gauge Response vs Modeled Pressure Response.

3.4. Reservoir Modelling

3.4.1. Modelling Updates

No significant update to the reservoir model occurred in 2017 as no new wells were drilled, and the early performance is close to our expectation case. The weekly well rate history has been incorporated into the model controls as illustrated in Figure 3-5. The correlation between injectivity and temperature has been accounted for with seasonal skin factors. Going forward, work will include tuning the model to a growing performance data set including the second monitor VSPs, and injectivity sensitivity to temperature.

3.4.2. Pressure Prediction

By the end of project life, the pressure build-up in the BCS is forecasted to be less than 2 MPa of differential pressure (DeltaP) at the injection wells (Figure 3-6). This pressure increase represents less than 12% of the delta pressure required to exceed the BCS fracture extension pressure and less than 25% of the pressure increase required to exceed the AER Approval operating constraint on bottom hole pressure [1]. Continued trending of low end-of-life reservoir pressures increases our confidence that it is extremely improbable for CO_2 leakage to occur via fracturing or fault reactivation.

The assumption for the 2018 forecast below is that from 2018 onward an equal amount of CO_2 will be injected into each of the two injection wells for the remainder of the life of the project at a constant rate. Note that the pressure incline observed at IW 5-35 is responding to the injection at IW 8-19.

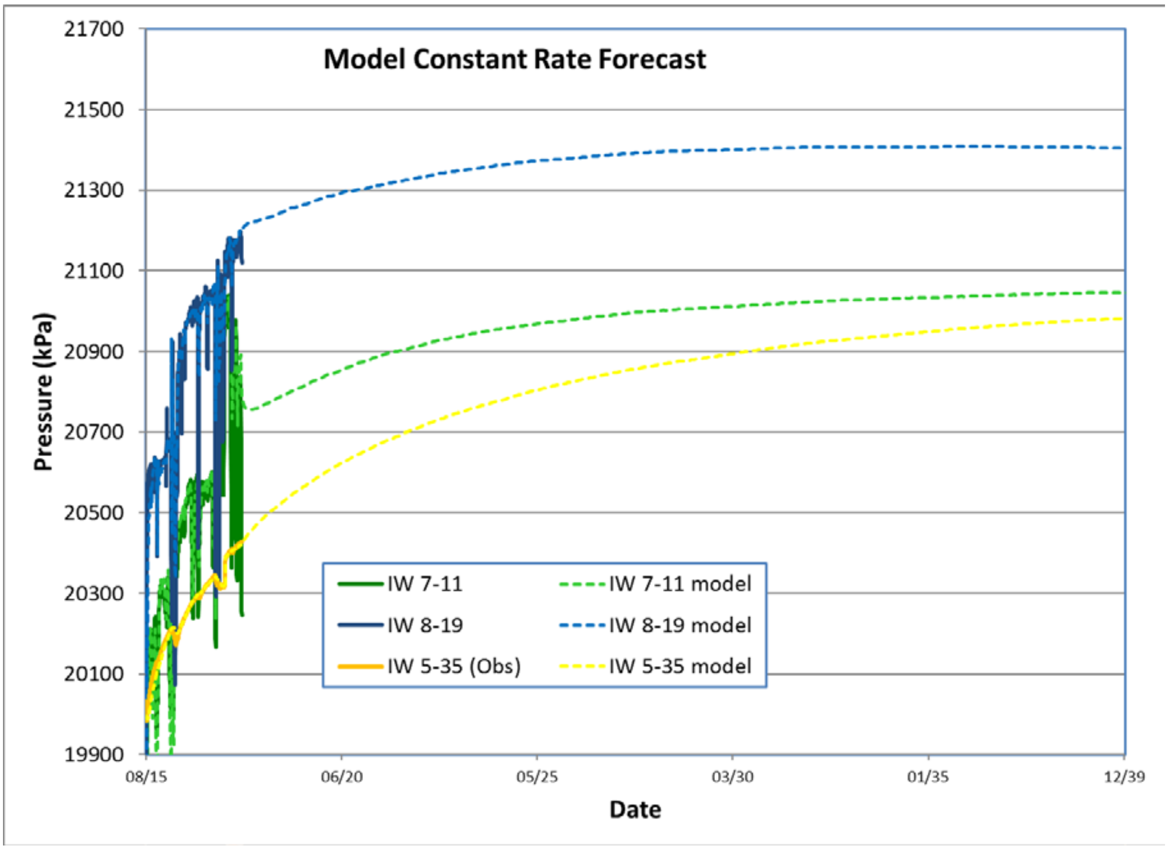


Figure 3-6: Well by well expected pressure build forecast.

On Dec 2nd of 2016 the pipeline had an emergency shut-down which created an opportunity to monitor the pressure fall-off at both of the injection wells. This 5 day shut-in observed the reservoir pressure stabilize as defined in directive 40 as a pressure that does not build over 2 kPa/hour during a 6 hour period. In Figure 3-7 and Figure 3-8, it can be observed the bulk of the pressure dissipates within 12 hours and that the readings reach a representative stabilized reservoir pressure after 24 hours of shut-in.

The average stabilized reservoir pressure as measured in the injection wells is less than 20.2 MPa. As the initial average reservoir pressure from these two wells is 19.7 MPa, it is concluded that less than 0.5 MPa of pressure has been escalated since the start of injection. This supports the model conclusion that the current rate of injection is insufficient to cause significant escalation of reservoir pressure.

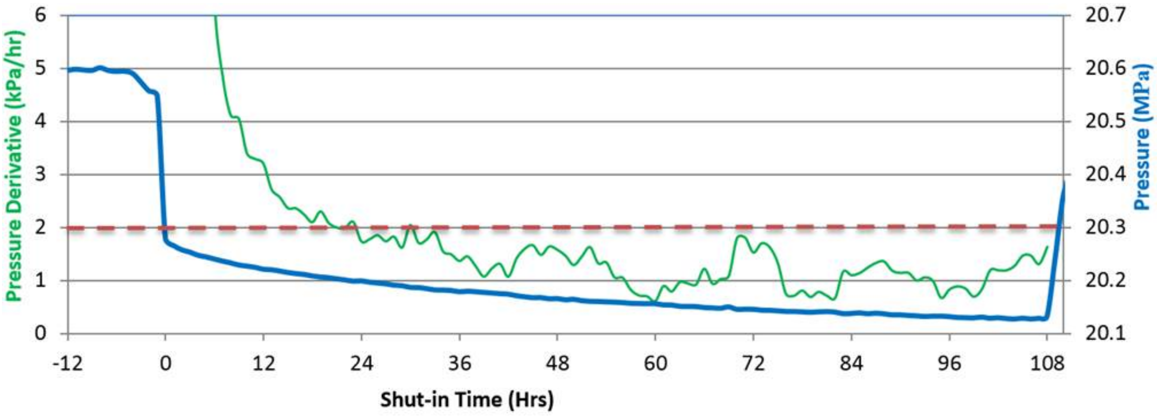


Figure 3-7: IW 7-11 pressure fall-off and stabilization. Red line indicates the 2kPa/hour threshold.

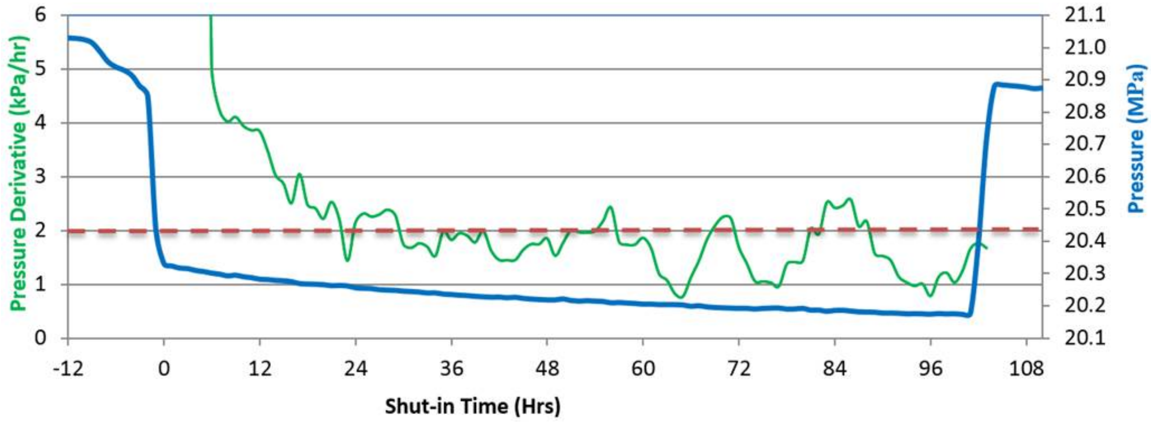


Figure 3-8: IW 8-19 pressure fall-off and stabilization. Red line indicates the 2kPa/hour threshold.

3.4.3. Plume Prediction

The current dynamic model incorporates injection well rates & pressure data to the end of 2017, and the 1st monitor VSP results. Assuming we continue to only inject into IW 8-19 and IW 7-11 the modelling shows maximum plume lengths in 2040 of 2 to 4 km. The resulting end-of-life plumes are illustrated in Figure 3-9. The most significant impact on CO_2 plume size will be whether or not IW 5-35 is required for injection. Additional uncertainty will be reduced in 2018 as the model is tuned to additional pressure data, the 2nd monitor VSP interpretation, and injectivity temperature dependence.

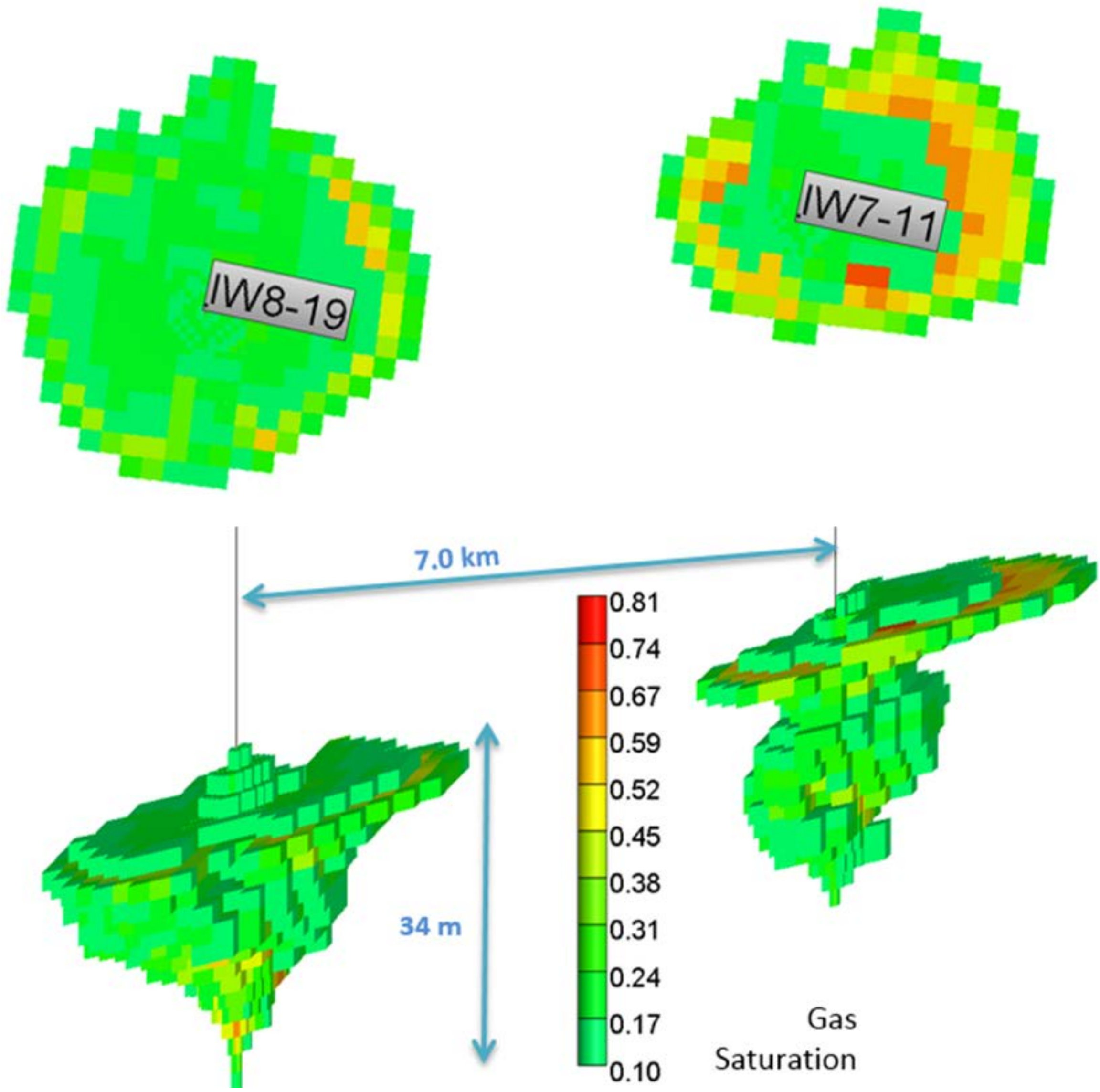


Figure 3-9: Map view and 3D views of the predicted CO_2 plume in 2040.

3.5. Reservoir Capacity

A base case pore volume of 14.3 billion m^3 within the SLA could store 27 Mt of CO_2 at just under 70% potential storage capacity [10]. This is an extremely conservative calculation because displacement of water outside the SLA relieves all of the pressure over time. Dynamic pressure modeling indicates that 27 Mt of CO_2 can be injected while keeping the reservoir pressure below 23 MPa (compared to the BHP limitation of 28 MPa).

The full 27 Mt of CO_2 is still expected to be sequestered without ever approaching the limit specified in clause 5) a) of the Approval [1]. The First Annual Status Report [2] states that the Quest project will not raise the stabilized reservoir pressure at any injector beyond the AER approved 26 MPa limit within the life of the project. This has not changed as there is no expectation for the flowing bottomhole pressure to ever approach the 26 MPa maximum shut-in formation pressure.

Based on injection volumes since inception and the pressure limitations, the remaining capacity of the Quest Sequestration Lease Area is reported in Table 3-8, as per the data from Table 3-1.

Table 3-8: Remaining capacity in the Sequestration Lease Area as of end 2017

Year	Yearly Injection Total	Remaining Capacity
Pre-injection	-	27 Mt CO_2
2015	0.371Mt	26.629 Mt CO_2
2016	1.108 Mt	25.521 Mt CO_2
2017	1.138 Mt	24.383 Mt CO_2

4. OPERATIONAL MMV PLAN ACTIVITIES AND PERFOMANCE

4.1. Summary of Operational MMV Activities in 2017

In 2017, MMV activities included: atmosphere, hydrosphere, geosphere, and well-based monitoring (Table 4-1). The following is a summary of the activities:

Atmosphere Domain: Monitoring of CO_2 levels in the atmosphere at the injection well sites continued using the LightSource technology.

Hydrosphere Domain: Four discrete sampling events (Q1, Q2, Q3, Q4) were executed. Project groundwater wells located on the 3 injection well pads were sampled on a quarterly basis. Landowner groundwater wells within 1 km of the injection well pads were sampled on a quarterly or biannual basis dependent upon well location. Note that additional groundwater well testing/sampling was undertaken in conjunction with the Q1 2nd monitor VSP campaign. Further details on the hydrosphere monitoring activities can be found in Appendix A.

Biosphere Domain: No activities took place regarding soil gas and soil surface CO_2 flux measurements.

Geosphere Domain: The second monitor VSP campaign was executed in Q1 around well pads 7-11 and 8-19. A baseline 2D surface seismic survey was also acquired with the VSP campaign. Monthly satellite image collection for InSAR continued. Between January and August 2017, images were collected using two satellite frames. Since September 2017, a single frame centered over the 3 injection well pads has been used for image collection.

Well based Monitoring: ongoing data collection via wellhead gauges, downhole gauges, downhole microseismic geophone array, and DTS lightboxes.

4.2. MMV Infrastructure

- The infrastructure to enable fully automated on-line DTS data access/retrieval has been successfully completed.
- Work started to optimize data transmission of the LightSource system.
- The DTS lightbox at well pad 8-19 was out-of-service for maintenance between mid-March to mid-April.

Table 4-1: Summary of MMV activities planned and executed in 2017.

Domain	Activity planned for 2017 ^	Executed	Comment
Atmopshere			
	LightSource measurements at pads 8-19, 7-11, & 5-35	✓	
Biosphere			
	not applicable		conducted on an as needed basis, as per 2017 MMV plan
Hydrosphere			
	Downhole pH & EC monitoring at Project groundwater wells	✓	
	Discrete water and gas (if possible) sampling at Project groundwater wells	✓	quarterly sampling events
	Discrete water and gas (if possible) sampling at landowner wells within 1km of each injection well pad	✓	quarterly and biannual sampling events dependant upon well location
	Once per year for landowner wells located within expected CO_2 plume size	✓	covered under 'landowner wells within 1km of each injection well pad', as CO_2 plume size < 1km
	Landowner wells associated with VSP surveys	✓	pre- and post-VSP campaigns
Geopshere			
	Injection rate monitoring	✓	
	Annulus pressure monitoring	✓	
	DHPT monitoring at all 3 DMWs	✓	
	DHPT monitoring at all 3 IWs	✓	
	DHP monitoring at Redwater 3-4	✓	
	WHPT monitoring at all 3 IWs	✓	
	Mechanical well integrity testing (packer isolation test) and tubing caliper log of IWs	✓	
	Routine well maintenance, including Temperature & RST logs and measurement of hold-up depths (HUD) of IWs at which injection started	✓	completed in Q2 2017
	MSM at DMW 8-19	✓	
	DTS monitoring at IWs	✓	
	DAS monitoring at IWs	✓	used for VSP survey data collection in Q1
	InSAR: monthly satellite image collection	✓	
corrosion probes	at injection skids	✓	
SCVF/GM	annually by June 30th	✓	
Injected CO_2	analysis of captured CO_2 at Scotford Upgrader	✓	
Notes:	^ list of MMV activities as per 2015 and 2017 MMV plans		

4.3. Assessment of MMV objective 'Containment'

A new MMV plan was submitted and approved in 2017. The 2017 MMV plan includes a tiered system to review and assess the MMV data. The focus in this report will be on Tier 1 technologies. These form the basis for assessing whether or not there is an indication of loss of containment. Depending on the outcome of that assessment, further analysis or investigation of the Tier 2 technologies will be undertaken, and then, if needed, Tier 3 technologies will be assessed.

No trigger events were identified during 2017 that would indicate a loss of containment (Table 4-2). In other words, data to-date indicate that no CO_2 has migrated outside of the Basal Cambrian Sands (BCS) injection reservoir during 2017. Reasons for this observation are described below.

Table 4-2: Overall assessment of trigger events used to assess loss of containment in 2017.

Tier	Technology ^	Trigger	2017
Tier 1	IW DHP	Measuring greater than 26 Mpa	
	DMW DHP	Anomalous pressure increase above background levels	
	MSM	Sustained clustering of events with a spatial pattern indicative of fracturing upwards	
	DTS	Sustained temperature anomaly outside casing	
Tier 1 - when available	Pulsed Neutron log	Indication of CO_2 out of zone	
	SCVF	Change in geochemical composition indicating presence of project CO_2	
	VSP2D	Identification of a coherent and continuous amplitude anomaly above the storage complex	
	SEIS3D	Identification of a coherent and continuous amplitude anomaly above the storage complex	not applicable yet
	SEIS2D	Identification of a coherent and continuous amplitude anomaly above the storage complex	baseline survey executed in Q1

^ based on Table 4-3 of the 2017 MMV Plan

Legend	
	no trigger event
	trigger event
	not evaluated

4.3.1. *IW DHP (Pressure monitoring Basal Cambrian Sand Formation)*

Continuous pressure data in the Basal Cambrian Sand via three injection wells, IW 7-11, IW 8-19, and IW 5-35 are plotted in Figure 4-1. The pressure data has remained far below the 28 MPa maximum operating pressure [1].

4.3.2. *DMW DHP (Pressure monitoring with Cooking Lake Formation)*

Continuous pressure data in the Cooking Lake Formation via three monitoring wells, DMW 7-11, DMW 8-19, and DMW 5-35 are plotted in Figure 4-2. A pressure fluctuation greater than 200 kPa is the threshold for indication of a leak in the 2017 MMV Plan. Thus far pressure data have been very steady. This provides evidence that a leak path from the BCS to the Cooking Lake near IW 7-11 and IW 8-19 does not exist. Pressure data in the Cooking Lake Formation (Figure 4-3) is also collected at DMW 3-4. Data was not collected for a period in 2017 at 3-4 due to equipment malfunction and repair.

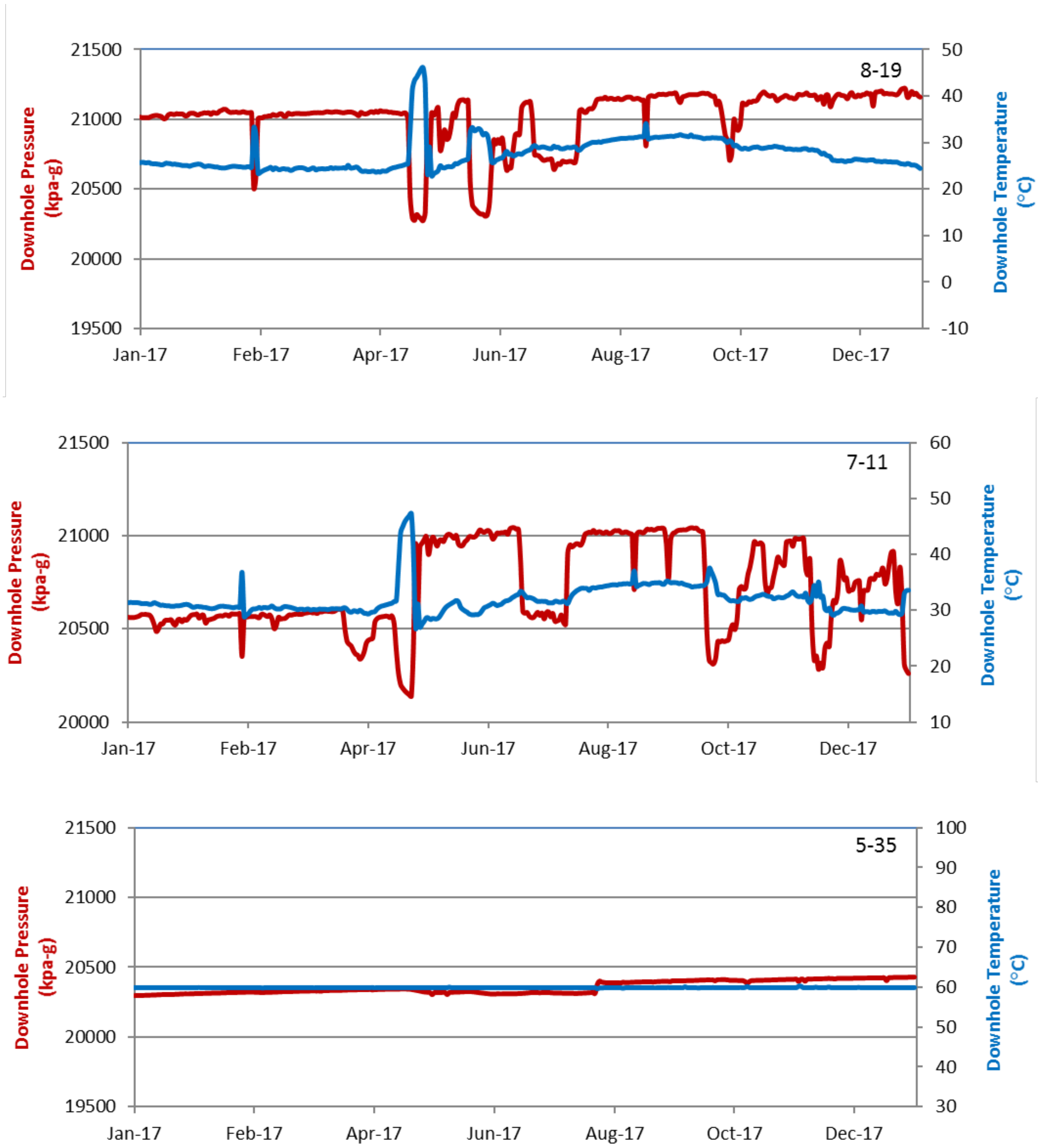


Figure 4-1: Quest injection wells downhole pressure and temperature trends.

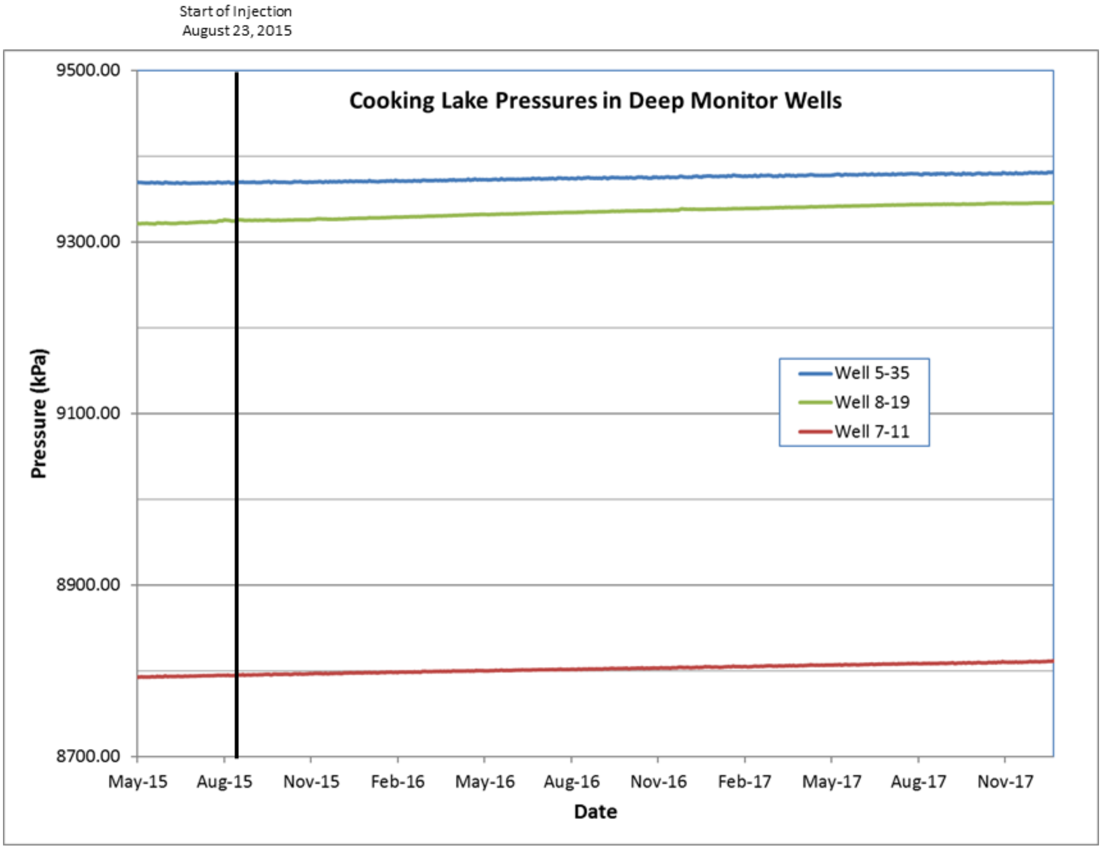


Figure 4-2: Quest deep monitoring well pressure history before and after injection.

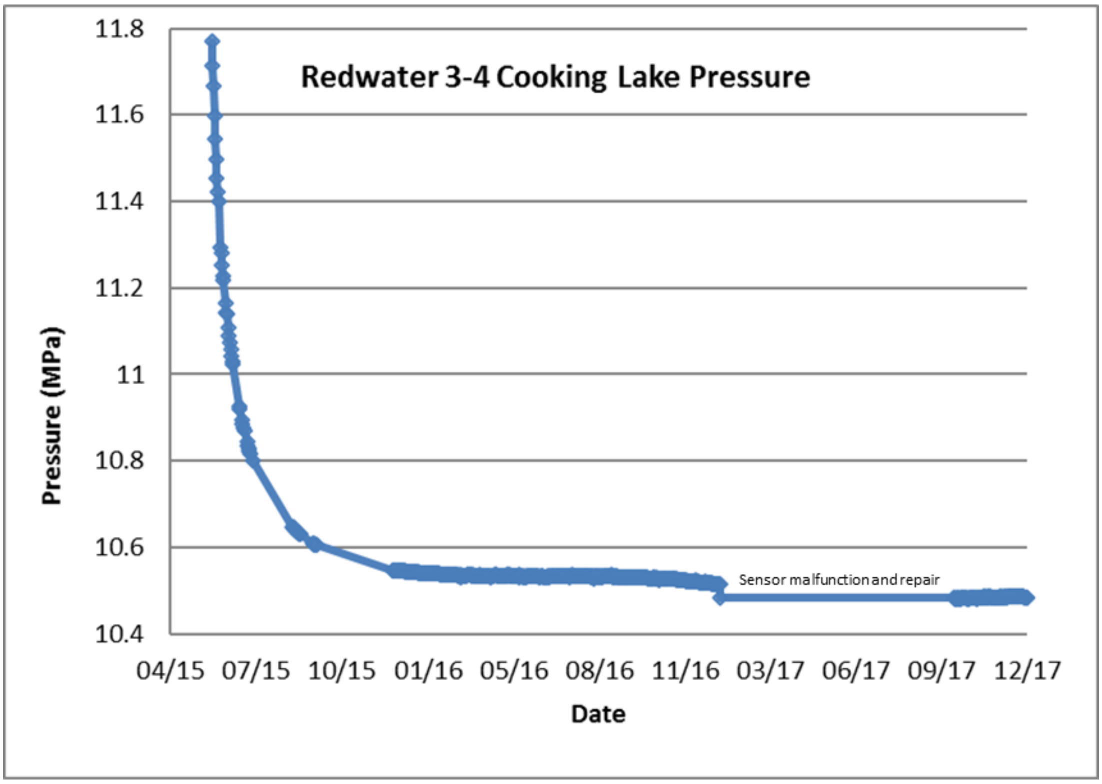


Figure 4-3: Quest DMW 3-4 pressure history.

4.3.3. MSM

Since the start of injection, the microseismic array has been functioning continuously without any interruptions. In 2017, there were no microseismic events that constituted a containment trigger event.

A report is received daily from the microseismic contractor, ESG, with the date, number of triggers, and breakdown of trigger type (Table 4-3). Figure 4-4 shows the daily statistics for major categorized events in 2017. Appendix C documents the location, time, magnitude information for all locatable events in 2017 within the AOR. Figure 4-5 and Figure 4-6 are plan and depth views respectively of all event locations in reference to DMW 8-19.

Table 4-3: Trigger classifications used for the Quest Project and trigger totals from January 1st, 2017 to December 31st, 2017

Trigger Type	Description	Total
Automatic	Hourly triggering intended to ensure health of the system	8713
High Frequency Noise	Caused by elevated, high frequency background noise	6201
Acoustic	Caused by energy travelling up and down the wellbore	209
Hammer Tap Test	Tap test on the wellhead to test geophone functionality	0
Locatable Events	Events in the AOR with clear P- and S-wave arrivals exhibiting waveform characteristics typical of microseismic events	111
Single-Phase Events	Seismic signals that lack significant P- and S-wave arrivals and cannot be located	55
Surface	Events that originate at the surface	634
Electrical	Caused by electrical interference	0
Vibes	Vibroseis shots	7367
Potential Regional Events	Far offset earthquake events that occur beyond the AOR	697
Total		23987

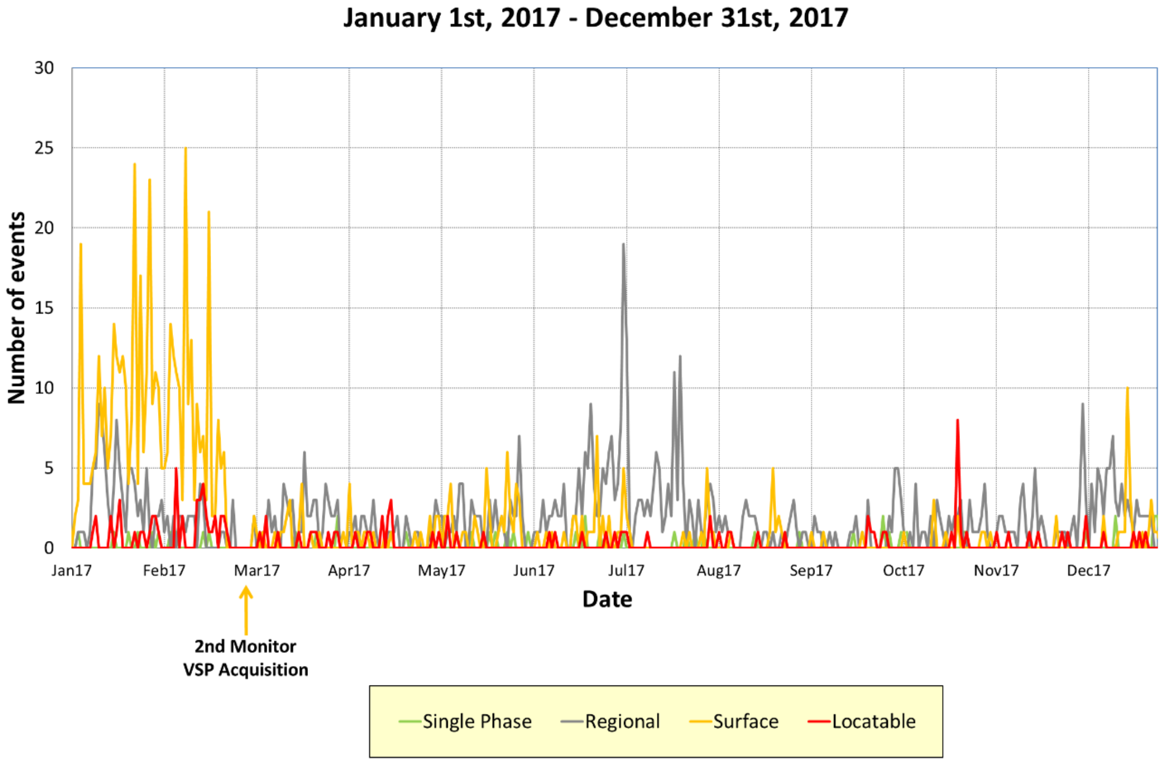


Figure 4-4: Daily event counts of microseismic categorized events in 2017.

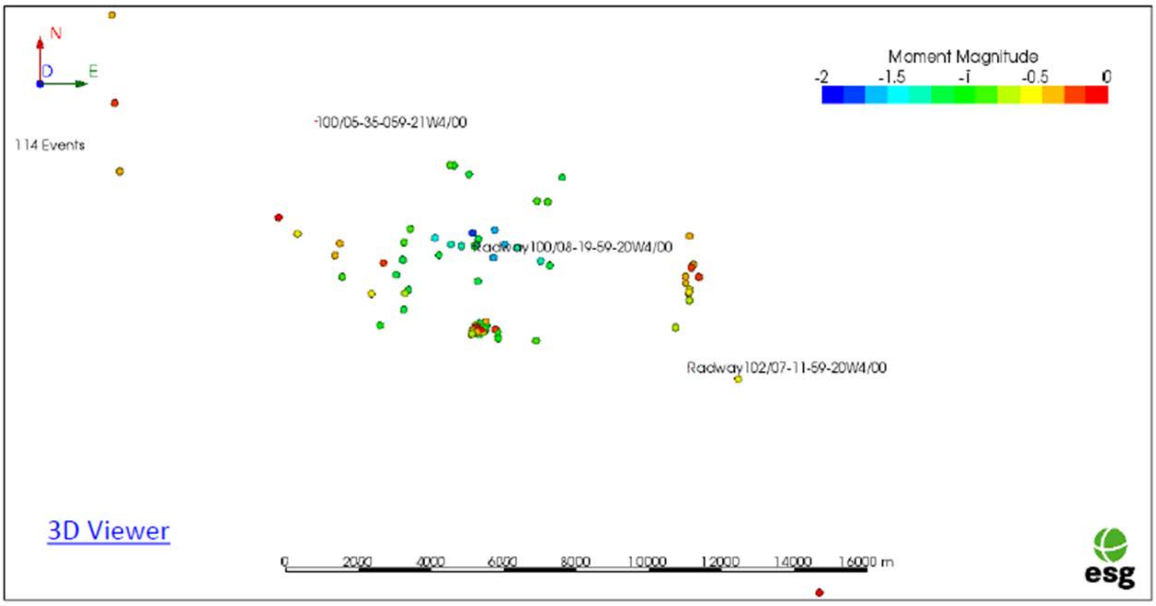


Figure 4-5: Plan view of the locatable events recorded 2015-7. All events were located in the Precambrian formation, below the injection zone.

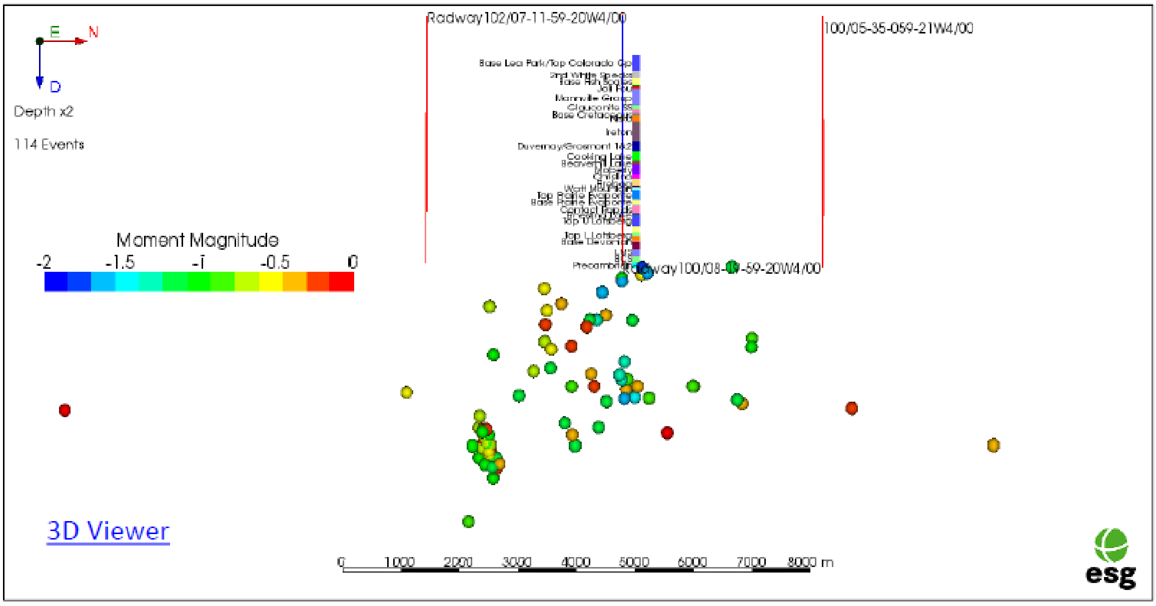


Figure 4-6: Depth view of all locatable events 2015-17. All events were located in the Precambrian formation, below the injection zone.

Since January 2017, sustained low level, small magnitude microseismic activity has been observed within the Quest area of review (AOR) . All these events have been located in the Precambrian basement, with the majority clustered in a small area roughly 3km away from the 8-19 injection site and 1 km below the bottom of the injection reservoir (Figure 4-5, Figure 4-6) . The events show a normal distribution, have an average magnitude of -0.7, a maximum magnitude of 0.1 and have a typical occurrence rate of 1-2 events per week. The events appear to follow the Gutenberg-Richter law with a standard b value close to 1 (Figure 4-7).

While the number of locatable events detected in 2017 is larger than in 2016, all events were located below the injection formation in the Precambrian basement, and event timing shows no correlation to injection pressure variations. None of these events present any to risk to CO_2 containment.

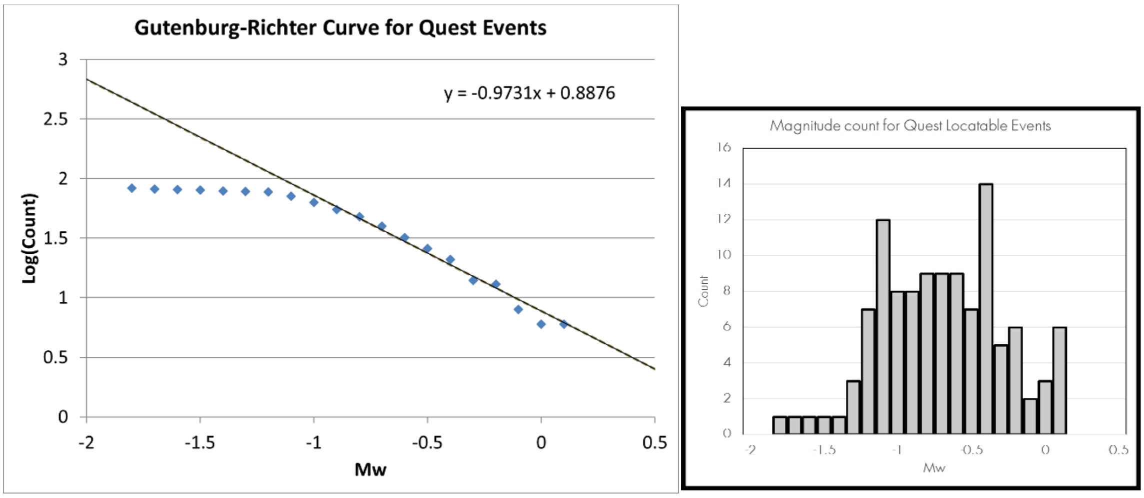


Figure 4-7: (Left) Gutenburg-Richter curve and (right) histogram of magnitude of Quest locatable microseismic events 2015-2017.

4.3.4. DTS

The DTS data collected from the injection wells are behaving as expected. The temperature changes are consistent with the thermal effects of 'cooling' due to injection, and normal geothermal warming when injection stops. This is illustrated in Figure 4-8 which provides an example of heatmaps for downhole temperature measured within IW 7-11 and the derivative of temperature versus time (dT/dt). As well, the corresponding data on flow to IW 7-11 are shown. Changes observed in the dT/dt heatmap correspond to changes in flow to the injection well, as illustrated for data covering Q4 2017. Note that the change is seen along the entire well section that is monitored by the DTS fibre. Figure 4-9 and Figure 4-10 provide an overview of all the DTS data collected during 2017 at IW 8-19 and IW 7-11, respectively.

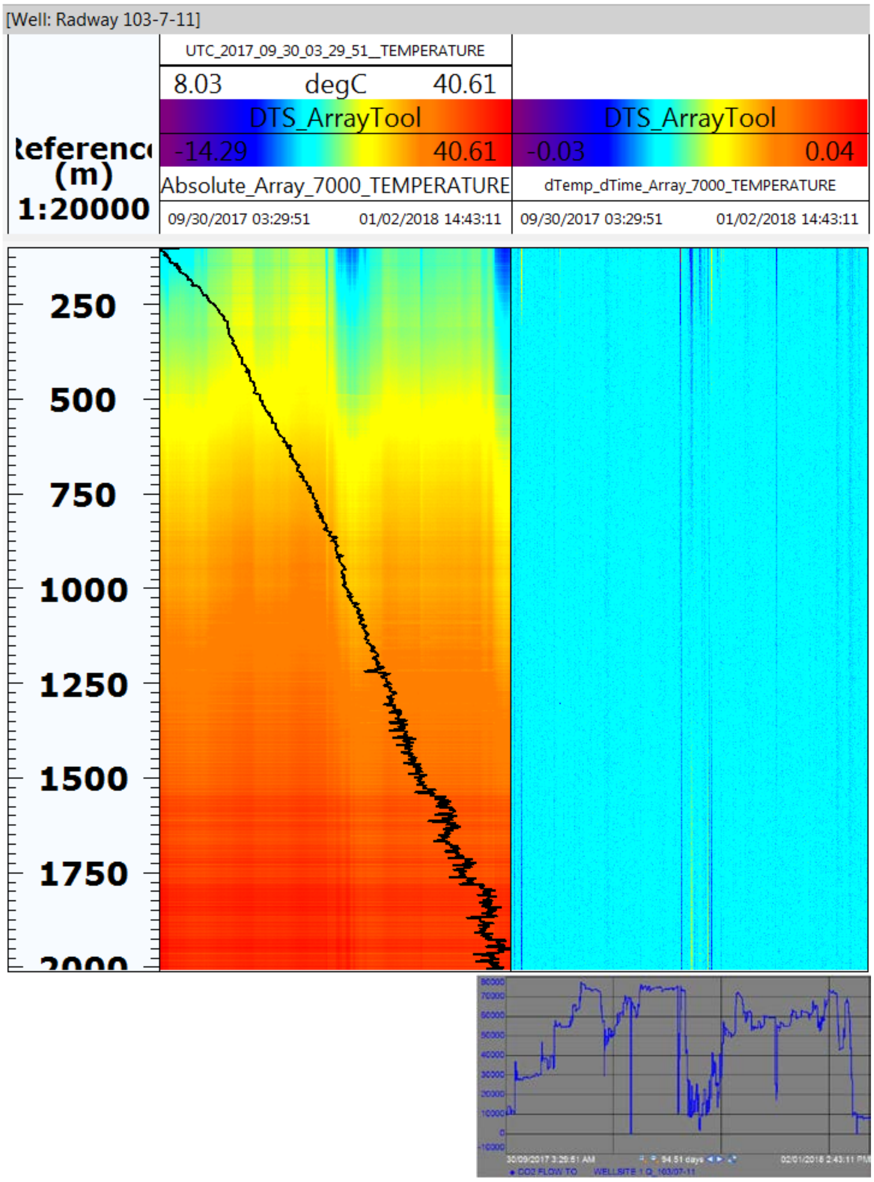


Figure 4-8: Heatmap for IW 7-11 DTS data recorded from October to April December (top left plot), and corresponding dT/dt heatmap and flow (kh/hr) into the well.

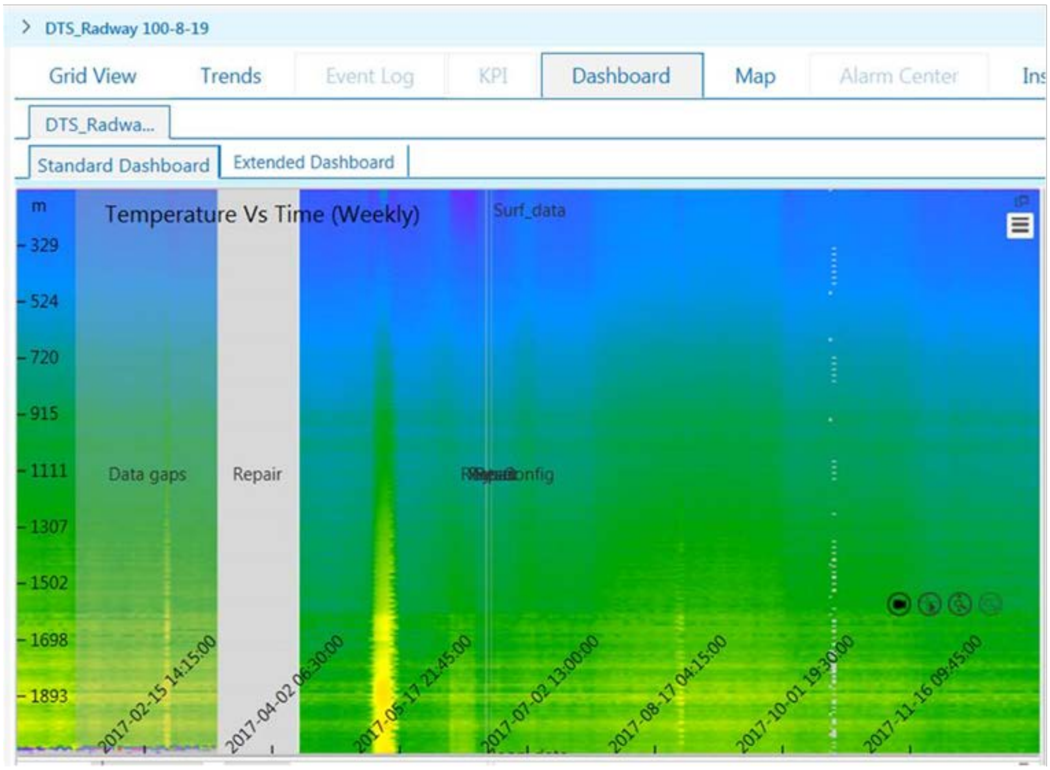


Figure 4-9: Injection well 8-19: heatmap of DTS data collected during 2017.

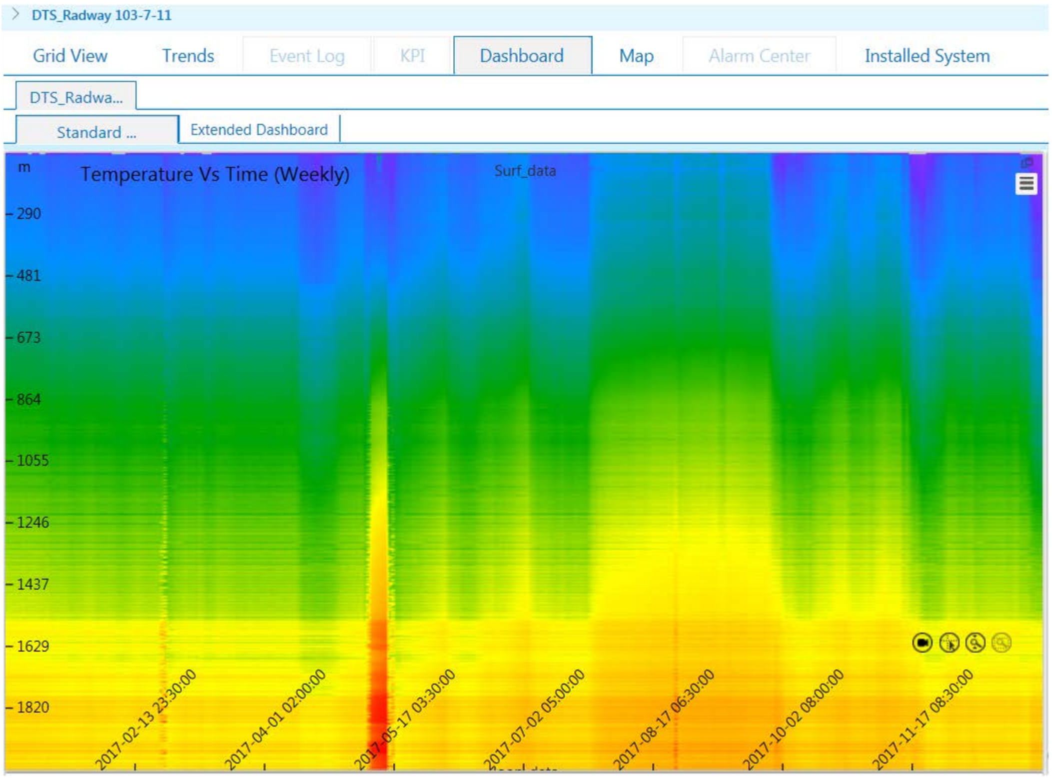


Figure 4-10: Injection well 7-11: heatmap of DTS data collected during 2017.

4.3.5. Pulsed Neutron log

A pulsed neutron log (PNX) was run May 8-9 at IW 7-11 and May 9-10 at IW 8-19.

Figure 4-11 and Figure 4-12 show the interpretations for the two injection wells. The findings indicate that the BCS is hydraulically isolated from over- and under-laying units. The following observations can be made:

Track 5 (T5) shows three year formation sigma log overlay (2015 – 2017)

- Green shading indicates the change in reservoir saturation with injection
- Changes are confined to perforated intervals (red interval in T5)

Track 6 compares the PNX sigma log from 2016 & 2017 → no change

- No change to near-wellbore reservoir saturation with an additional year of CO_2 injection
- No changes in the under- & over-laying reservoirs → hydraulic isolation confirmed

Further details on the PNX logging can be found in Appendix B.

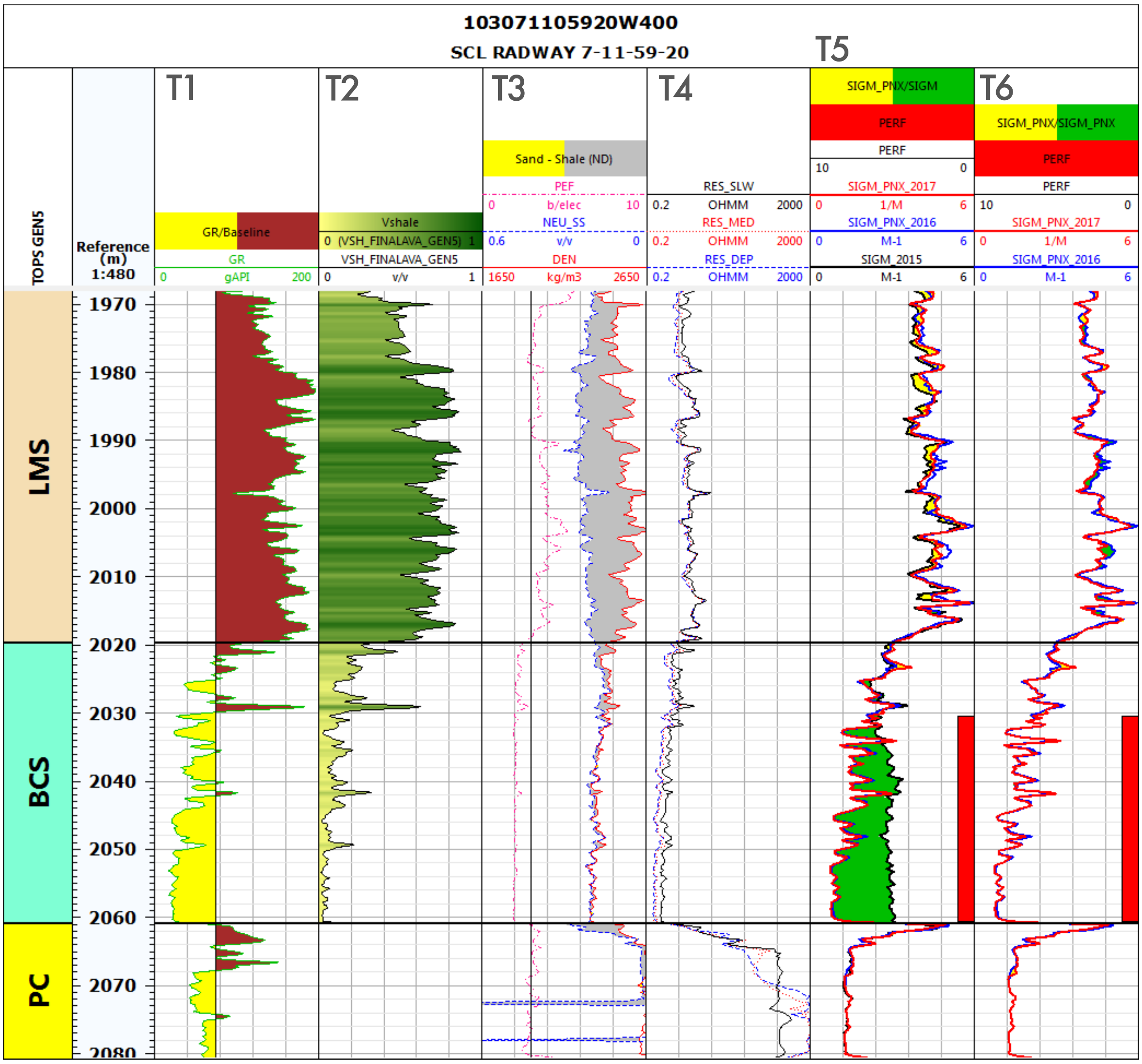


Figure 4-11: PNX logging for injection well IW 7-11. Track T5 shows three year formation sigma log overlay (2015 – 2017). Track T6 compares the PNX sigma log from 2016 and 2017 (no change observed). Tracks T1 to T4 show other logs, such as gamma ray (GR) or density (DEN) logs, T2 shows Vshale. Note that IW 8-19 DTS recording unit was removed for servicing mid-March and re-installed mid-April.

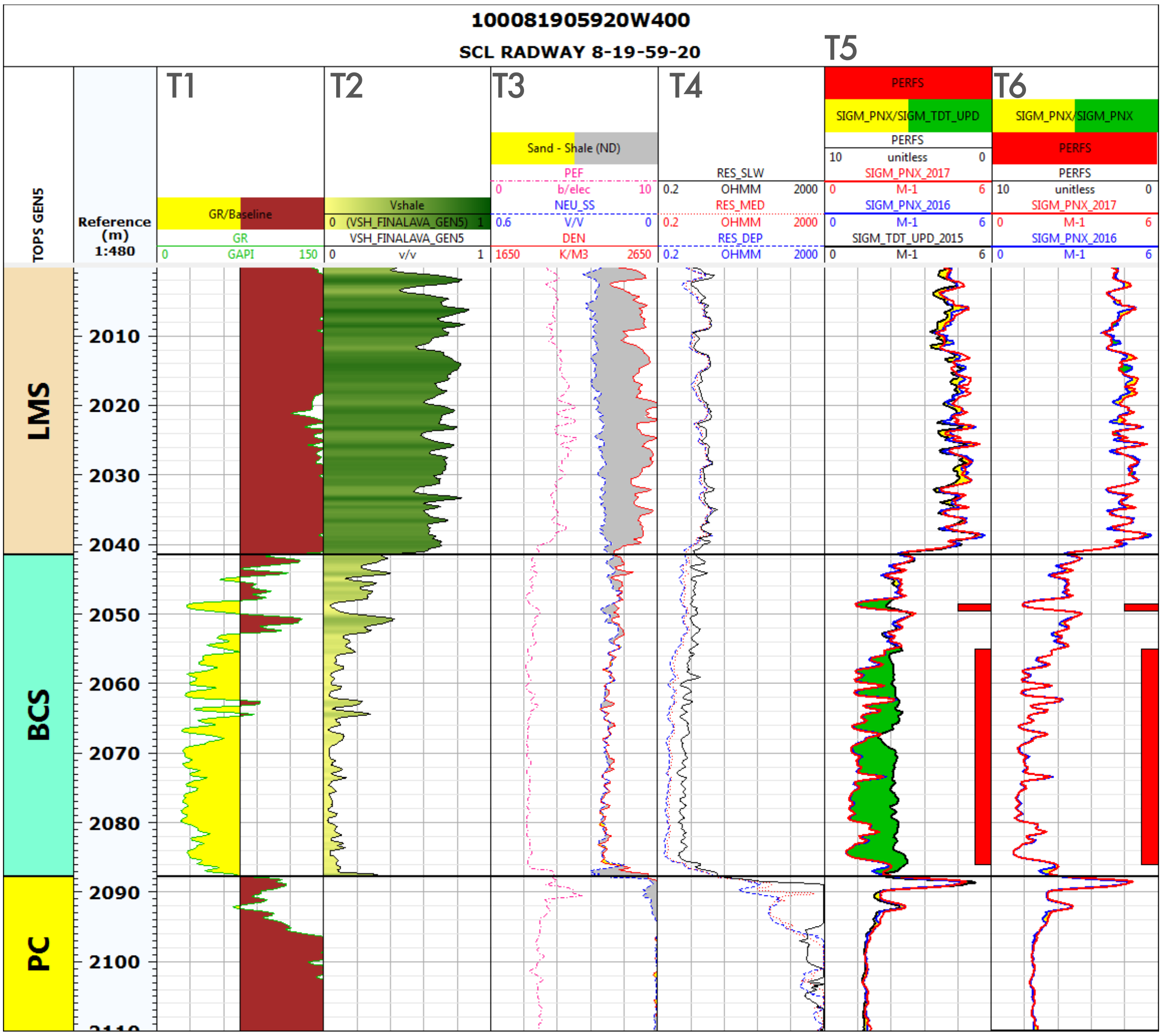


Figure 4-12: PNX logging for injection well IW 8-19. Track T5 shows three year formation sigma log overlay (2015 – 2017). Track T6 compares the PNX sigma log from 2016 and 2017 (no change observed). Tracks T1 to T4 show other logs, such as gamma ray (GR) or density (DEN) logs, T2 shows Vshale. Note that IW 8-19 DTS recording unit was removed for servicing mid-March and re-installed mid-April.

4.3.6. VSP2D

Please refer to Section 4.4.

4.3.7. SEIS3D, SEIS2D

Not applicable yet for SEIS3D.

In Q1, a baseline SEIS2D was acquired alongside the 2DVSP. Results are expected in 2018.

4.3.8. SCVF

A SCVF sample for laboratory analyses was obtained from IW 7-11 in June 2017. No gas sample was obtained at IW 8-19, due to no flow. The compositional results indicate that the SCVF gas at IW 7-11 is predominately methane, with a CH_4 concentration of 98.4% for IW 7-11. The isotopic results from the June 2017 SCVF – GM gas sampling campaign are comparable to findings from previous years (Figure 4-13).

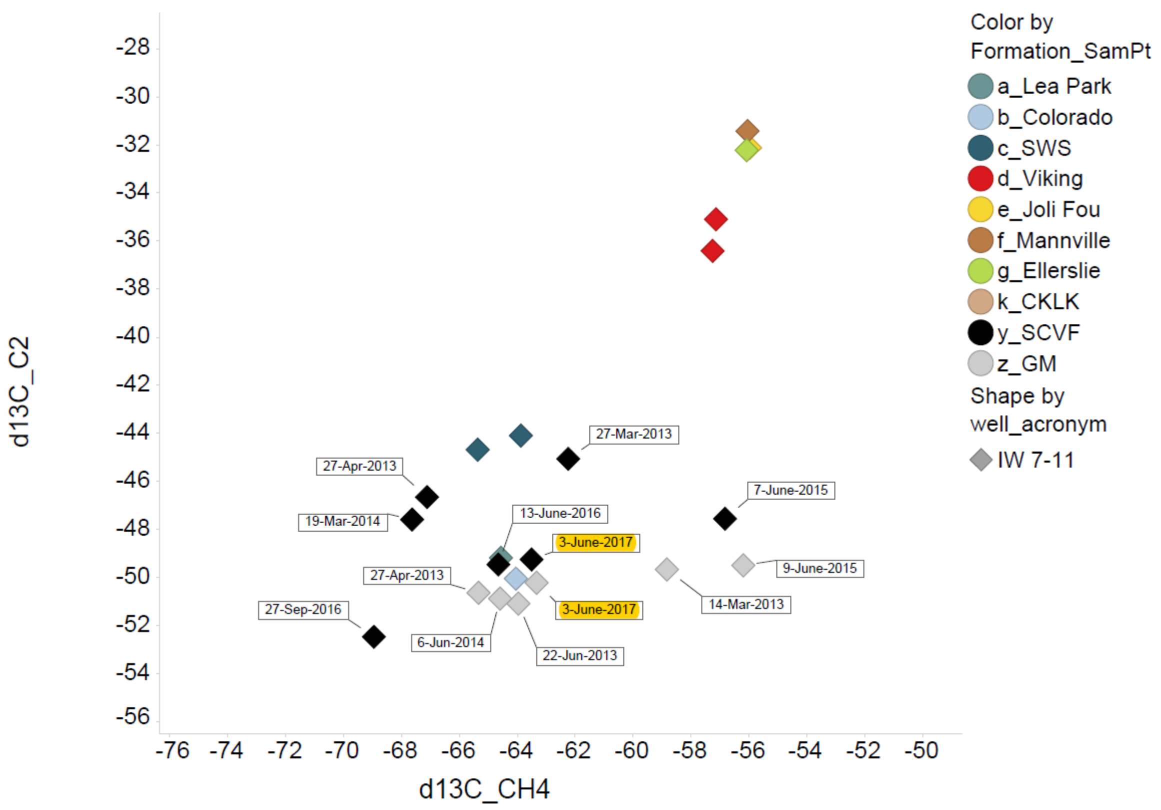


Figure 4-13: δ^{13}C-C2 versus δ^{13}C-CH_4 plot for SCVF (black diamonds) samples collected at IW 7-11. Also shown are formation specific data based on isotube measurements collected during drilling of IW 7-11, and gas migration samples (gray diamonds).

4.4. Assessment of MMV objective 'Conformance'

4.4.1. Time-lapse seismic data

The first monitor DAS VSP was acquired in 2016 and the second monitor VSP in 2017. Both surveys were shot in Q1 to allow for the same weather and ground conditions as the baseline DAS VSP acquired in Q1 2015 and to maximize repeatability. Eight walk-away VSP lines were again acquired at each injection well location. An ODH3i light source box was used to remain consistent with equipment used for the baseline survey. Additionally, an ODH4 light source box was used for recording to allow for this new technology to be used in future surveys. Both light boxes were used again in 2017 since the 2016 ODH4 results were not conclusive regarding its repeatability compared to 2015 ODH3i. Results from 2017 show that data from the ODH4 light box is repeatable compared to ODH3i.

VSP 2015 (Baseline) and VSP 2017 (Monitor 2) were subject to the same processing workflow to optimize the time-lapse signal, and VSP 2016 (Monitor 1) was re-processed to be consistent with Monitor 2. The results continue to demonstrate a clear time-lapse signal present in the difference between the Baseline and Monitor data for each vintage (Figure 4-14 and Figure 4-15). The maximum distance illuminated by the VSP continues to be approximately 800 meters away from each well.

Using the same interpretation workflow implemented in 2016, the CO_2 plume extent was interpreted using the straight calculated difference, along with additional 4D attributes, such as the dRMS (Baseline_RMS – Monitor_RMS) and the RMS of the difference (Figure 4-16 and Figure 4-17). Following interpolation between the 2D lines to create a 3D grid, the shape of the plume was approximated using an ellipse, and variations in the 4D attributes were used to define the lateral uncertainties associated with the edge of the time-lapse anomaly (Figure 4-16 and Figure 4-17).These values are contained in Table 4-4.

Measurement uncertainty in the exact plume dimensions arises from several sources: the attribute cut-off values at the anomaly edges, the varied responses of different 4D attributes, and from geometrical positioning uncertainties arising from the VSP surface geometry. The current interpretation indicates that the there is a larger uncertainty than previously assumed in 2016 due to a larger range observed in all time-lapse attributes. Nevertheless, this larger uncertainty still falls within the expected range for the plume based on the reservoir model (Section 3.4 Reservoir Modelling).

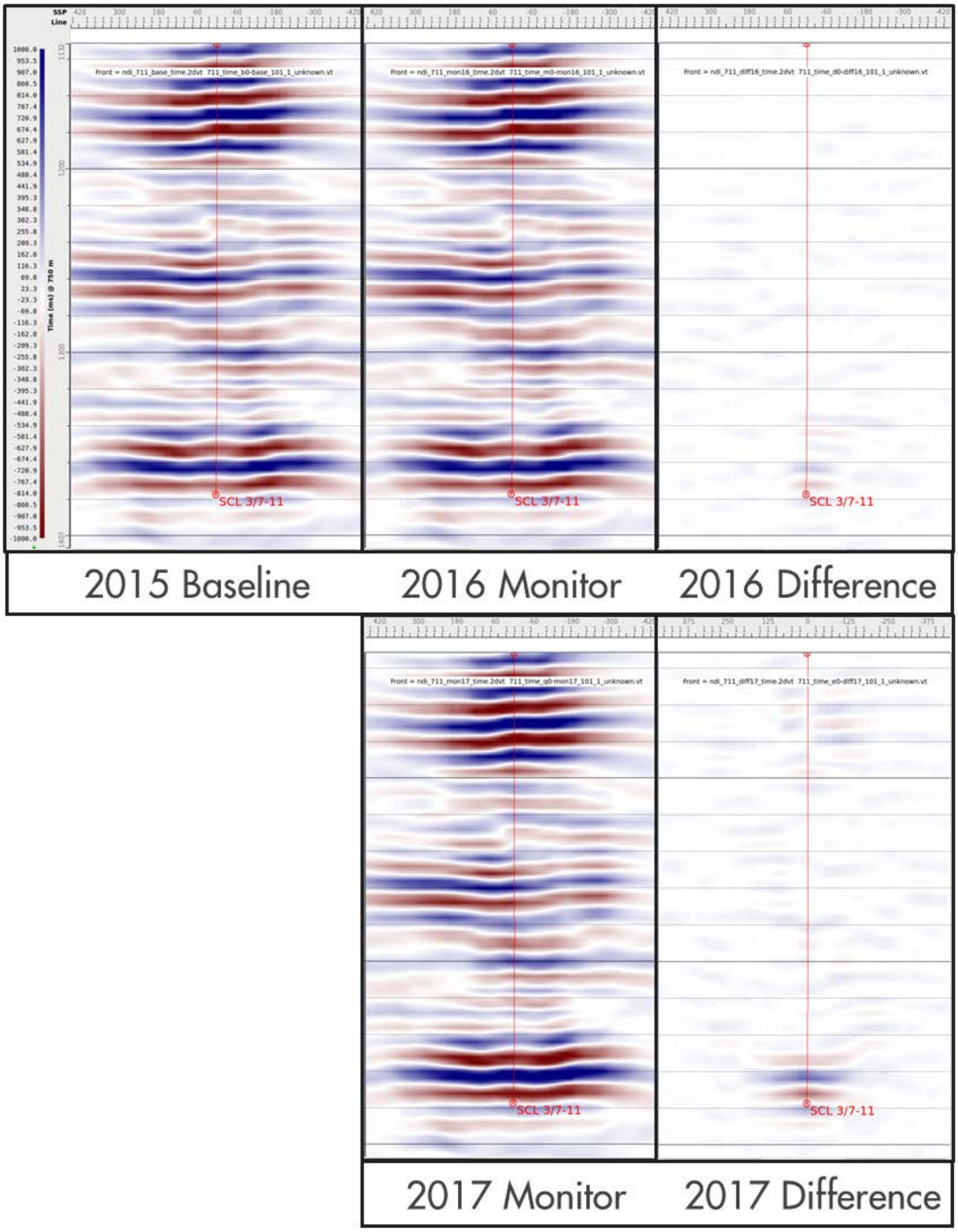


Figure 4-14: Baseline, 2016 Monitor 1, 2017 Monitor 2 and each difference for IW 7-11.

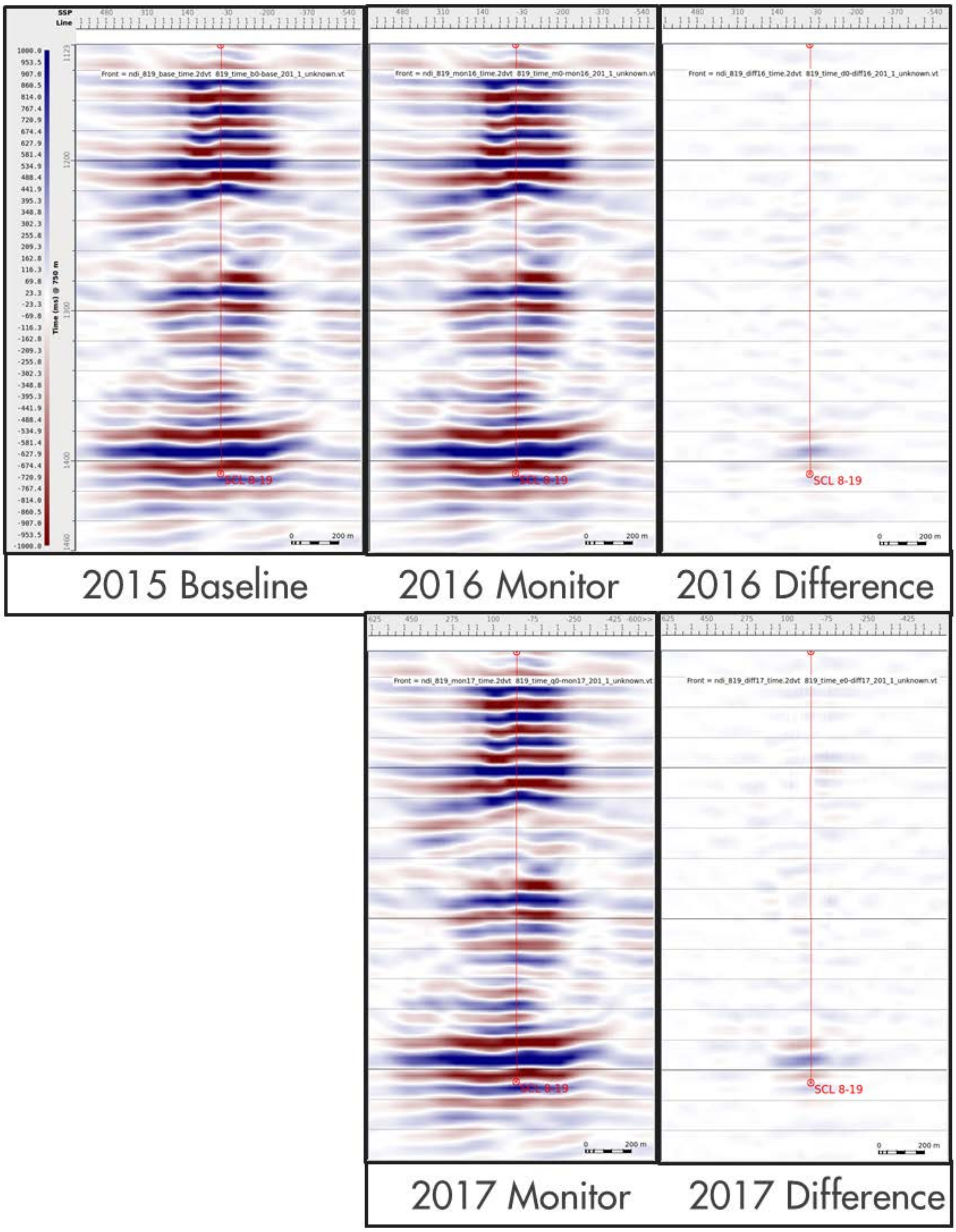


Figure 4-15: Baseline, 2016 Monitor 1, 2017 Monitor 2 and each difference for IW 8-19.

Table 4-4: Dimensions of the ellipsoidal approximation of the time-lapse signal for wells IW 7-11 and IW 8-19.

	Ellipse Short Axis	Ellipse Long Axis
2016 Monitor 1 - IW 7-11	285 m ± 230 m	494 m ± 230 m
2016 Monitor 1 - IW 8-19	401 m ± 240 m	413 m ± 240 m
2017 Monitor 2 - IW 7-11	488 m ± 260 m	668 m ± 260 m
2017 Monitor 2 - IW 8-19	487 m ± 330 m	576 m ± 330 m

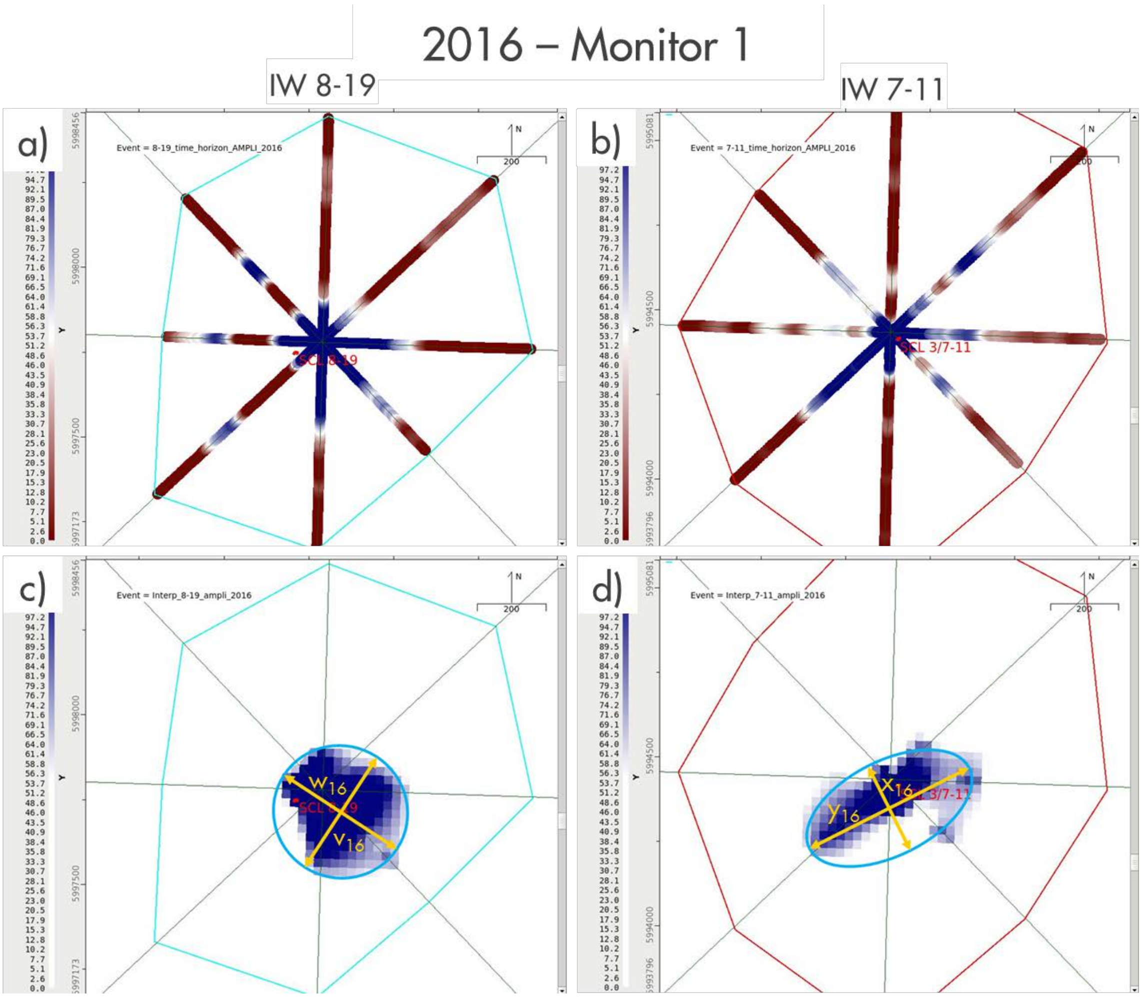


Figure 4-16: a) and b) Amplitude extraction of the time lapse signal for 2016 Monitor 1 wells IW 7-11 and IW 8-19 respectively. c) and d) Extrapolation of the time lapse signal to infill each walkaway line.

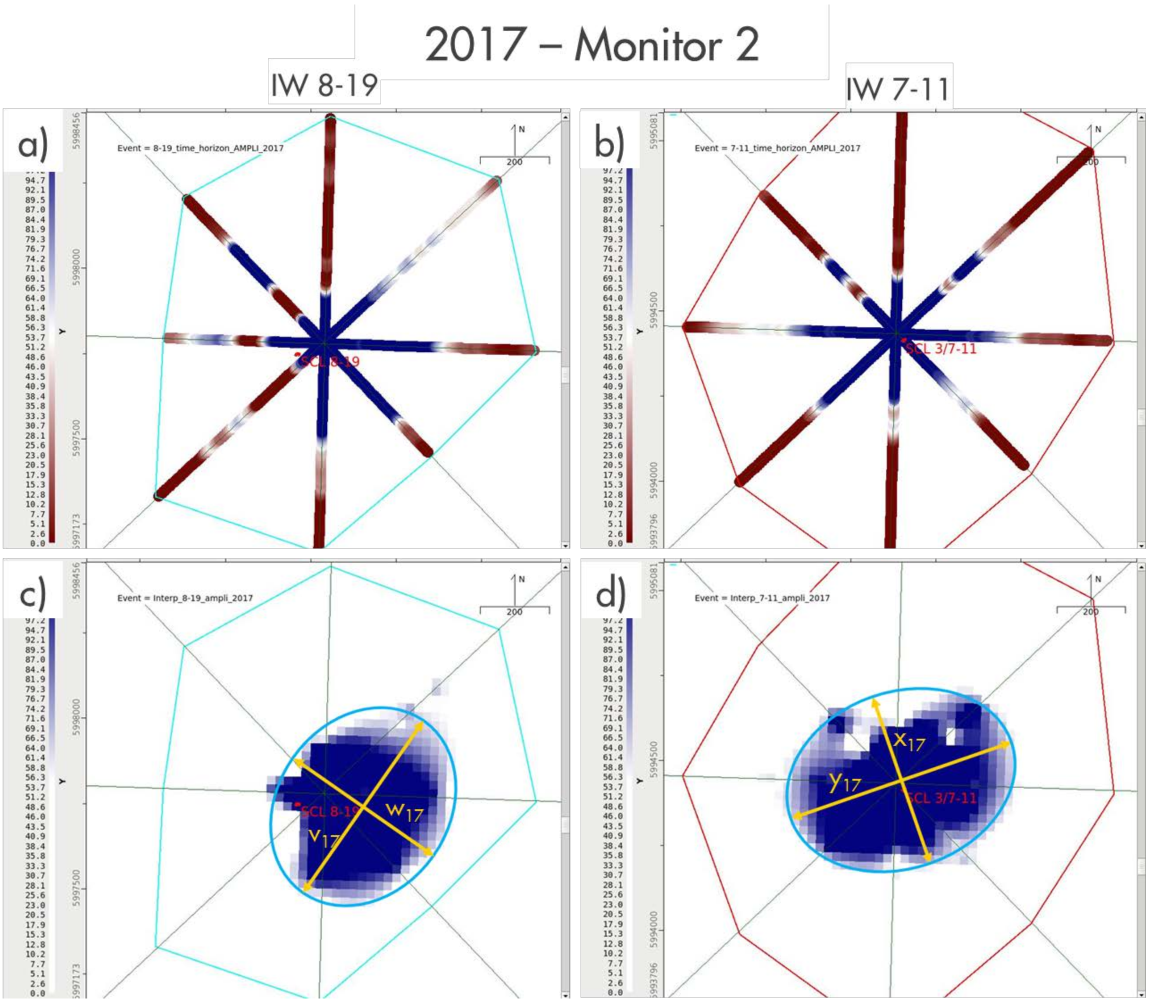


Figure 4-17: a) and b) Amplitude extraction of the time lapse signal for 2017 monitor 2 wells IW 7-11 and IW 8-19 respectively. c) and d) Extrapolation of the time lapse signal to infill each walkaway line.

Section 6.5.1.2 of the Quest Gen-4 Report contains a series of charts illustrating the range of uncertainty of the maximum plume length, where the plume "edge" is defined as 10% CO_2 saturation [4]. Figure 4-18 uses the P10, P50 and P90 "during injection" values to assess the expected plume length versus the amount of CO_2 injected in each well. Additionally, a "theoretical minimum" plume size is calculated assuming a cylindrical propagation of the CO_2 in the entire BCS pore space using 100% CO_2 saturations. The calculated dimensions from the interpretation of the 2016 monitor 1 VSP and 2017 monitor 2 VSP were plotted according to the cumulative CO_2 volumes injected into each well at the time of the VSP acquisition (Table 4-5).

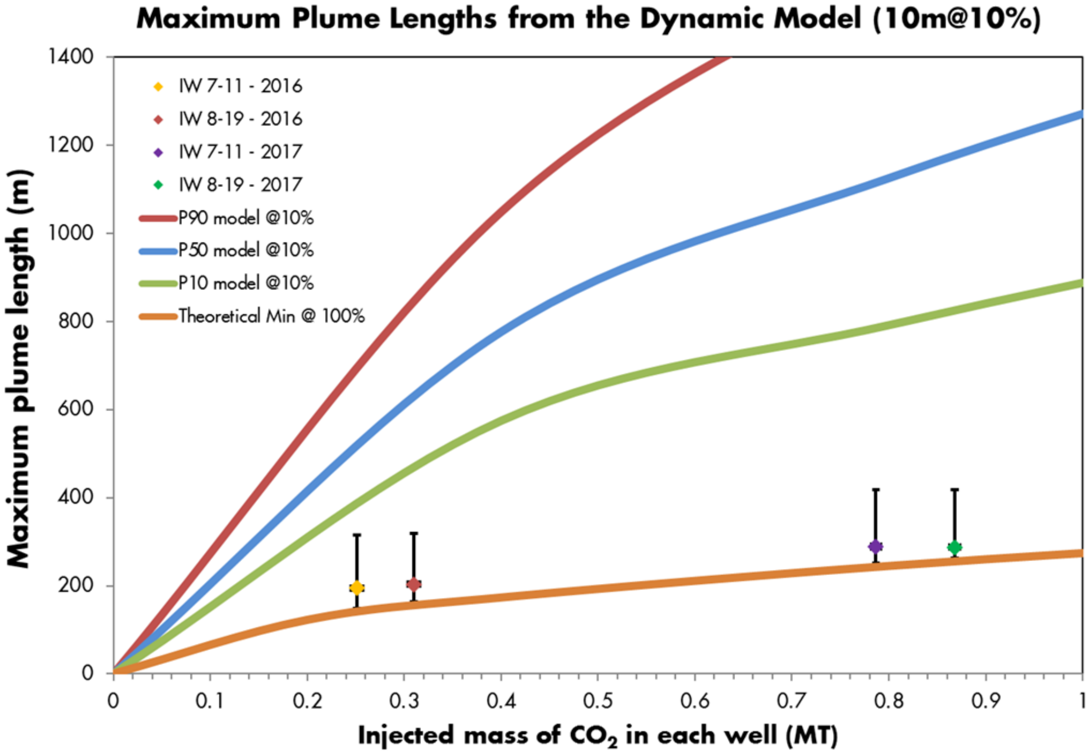


Figure 4-18: Maximum plume length scenarios from the Gen 4 report and the theoretical minimum are compared to the measured plume size from the 2016 monitor 1 VSP and 2017 monitor 2 VSP. Notice that the Plume length from both vintages is close to the theoretical minimum. This could be interpreted as the reservoir having higher CO_2 saturations than initially modelled and that the CO_2 is more effectively filling the pore space.

Table 4-5: Relation of plume sizes measured from the 2016 Monitor 1, the 2017 Monitor 2 and the amount of CO_2 injected in each well between the VSP data acquisitions.

Vintage	Well	Mass of CO_2 injected (MT)[1]	Injection error due to date (MT)	Maximum plume size on VSP (meters)	Upper size error from seismic (meters)	Lower size error from seismic (meters)
2016	7-11	0.251	0.006	194	120	45
2016	8-19	0.310	0.006	203	115	40
2017	7-11	0.787	0.006	289	130	40
2017	8-19	0.868	0.006	287	165	25

[1] Value of mass of CO_2 injected is averaged over the duration of seismic acquisition.

As noted in the 2016 AER report, a key result of the time-lapse seismic monitoring is that the size of the CO_2 plumes, as measured by the 2016 Monitor 1 and 2017 Monitor 2, is much smaller than the maximum plume lengths predicted from the Gen 4 model and it is closer to the theoretical minimum. This is another indication that the reservoir is behaving better than expected, and that the displacement of brine by the CO_2 may be more effective than the initial modelling predicted.

4.4.2. Downhole Pressure Temperature Gauges

Assessment of the pressure data indicates that the reservoir has more than enough capacity for the full life of this project. Pressures are behaving as expected as discussed in Section 3:Injection Well Performance.

4.4.3. InSAR

During 2017, monthly collection of Radarsat-2 satellite images continued; however, the data were not processed.

In 2017, a special report was submitted on InSAR efficacy [6] as per Condition 16 of AER Approval 11837C [1]. The conclusion of this report states that InSAR is a viable technology for assessing unexpected surface heave, although its value is limited for continuous monitoring given the site-specific characteristics at Quest. Based on the observed and modelled pressure build-up within the BCS, dilation within the BCS storage complex will be small. The resulting surface uplift will likely fall within the noise levels of the measured ground displacement. As a result, InSAR has limited value as a continuous monitoring technology for unexpected containment issues at Quest.

The current MMV Plan [8] now reflects this conclusion in that InSAR technology is considered a contingency monitoring technology with a focus on the AOR (area of review) of the Quest SLA (sequestration lease area). As such InSAR will be used in the event of another MMV technology or observation indicating the need for further investigation.

4.5. MMV Performance and Plan Issues

- A new MMV plan was submitted for review in February 2017 and approved on 11 May 2017 [8]. The 2017 MMV plan is in effect until 11 May 2020.
- The 5th Annual Status report indicated that some work remained to facilitate fully automated on-line DTS data access/retrieval [6]. This work has been completed.
- The DTS lightbox at pad 8-19 needed to be serviced.
- The 5th Annual Status report [6] indicated that additional work was required to assess why some of the pH values were 'less stable' after replacement of the groundwater well gauges. This work has been completed.

5. FUTURE MMV ACTIVTIES

- Pursue opportunities to optimize 2017 MMV plan as they arise.
- Complete work to optimize data transmission of the LightSource system.

The timing of all future time-lapse seismic acquisition is detailed in the 2017 MMV Plan, and is evaluated yearly based on plume growth, reservoir performance and findings from any recent acquisition [8]. The decision for 2019 acquisition will be made in Q3/2018.

5.1. Changes to approved 2017 MMV Plan

There are currently no changes to the approved MMV Plan.

5.2. Monitoring Wells

Need for Monitoring Wells Near Periphery of Pressure Build-up

Approval No. 11837C Condition 10i, requires that each annual status report address the need for additional monitoring wells towards the periphery of the pressure build-up area later in the project life.

Shell considers the current pressure monitoring program adequate. There has been no change since submission of the 2013 First Annual Report [2]. At this time, Shell considers additional monitoring wells (BCS wells, deep monitoring wells, or groundwater wells) situated towards the periphery of the pressure build-up zone and near legacy wells unnecessary. There is no indication from injection or well data that BCS pressure will increase to levels that would provide a threat to containment (Section 3.4.2: Pressure Prediction).

Need for Additional Monitoring Wells Near Legacy Wells

Currently, additional monitoring wells near the legacy wells are considered unnecessary, as there is no indication from injection and well data that BCS pressure will increase to levels that would provide a threat to containment near the legacy wells (Section 3.4.3: Plume Prediction).

Monitoring at Injection Wells

In accordance with the Approval, Shell will use each of the three injection wells as pressure monitoring wells when feasible. IW 5-35 has been monitoring pressures in the BCS throughout 2017. The permanent downhole pressure gauges will opportunistically capture BCS Formation fall-off shut-in reservoir pressures whenever a facility outage occurs. For example, as detailed in Section 3, stabilized reservoir pressures were achieved in both of the injection wells during an unplanned shut-in that occurred in December 2016.

6. STAKEHOLDER ENGAGEMENTS

Upon start-up of the Quest CCS facility, stakeholder engagement focused on two streams: community relations and CCS knowledge sharing/public awareness.

Community Relations

Community stakeholder engagement activities for Quest in 2017 fell into the following categories:

1) Updates to municipal governments
2) Working to resolve public concerns
3) Participation in the Community Advisory Panel (CAP)
4) Community events/Public information sessions

Municipal Government Updates

Annual updates were given to town and county authorities at their council sessions to provide the most recent project progress information. Specifically, updates were provided to the following municipalities:

- January 24, 2017 – Strathcona County
- February 28, 2017 – Fort Saskatchewan

Shell's updates to the above councils were well received. No major issues were raised specific to the Quest facility and questions were answered immediately at the council sessions.

Public Concerns

Shell has a comprehensive public concerns process that is designed to encourage community feedback. It does not take a formal complaint for a concern to be entered into the process. A concern or query from an informal conversation would still be captured to help Shell understand the pulse of the concerns from the community. These concerns can range from impact from our operations – both real and perceived – all the way to inquiries that are not attributable to Shell. In 2017, Shell recorded 26 concerns related to the Quest facility. This represents the total number of queries/complaints – not the number of individuals.

Most of the concerns from 2017 were related to soil quality due to pipeline construction and water runoff from the 5-35 well pad.

Shell responded to all of the individuals who raised concerns and put in action plans to address any issues that were identified.

Participation on Community Advisory Panel (CAP)

To involve the public in the development of the MMV plan, a Community Advisory Panel (CAP) was formed in 2012. The CAP comprises local community members including educators, business owners, emergency responders, and medical professionals as well as academics and AER representation. The mandate of the panel is to provide input to the Quest Project on the design and implementation of the MMV Plan on behalf of the broader community and to help ensure that results from the program are communicated in a clear and transparent manner. In 2017, the CAP met on May 11 to review the latest MMV data.

Public Information Session

An open house was held in Thorhild County on February 27, 2017 to give community members the opportunity to meet with Shell, learn more about the project, and ask questions about Quest. The open house was held at Thorhild Central School with it open to students from 1-2:30 p.m. and open to the community from 4-8 p.m.

7. CONSTRUCTION AND IMPLEMENTATION TEST RESULTS

Capture and pipeline construction was completed in 2015, and on 29th September 2015, the commercial operations certificate for Quest was issued [5].

There are no anticipated updates to this section.

REFERENCES

[1] Carbon Dioxide Disposal Approval No. 11837C, AER, May 12th, 2015.

[2] Shell Quest Carbon Capture and Storage Project: First Annual Status Report. Submitted to AER January 31, 2013.

[3] Shell Quest Carbon Capture and Storage Project: Second Annual Status Report. Submitted to AER January 31, 2014.

[4] Shell Quest Carbon Capture and Storage Project: Third Annual Status Report. Submitted to AER January 31, 2015.

[5] Shell Quest Carbon Capture and Storage Project: Fourth Annual Status Report. Submitted to AER March 31, 2016.

[6] Shell Quest Carbon Capture and Storage Project: Fifth Annual Status Report. Submitted to AER March 31, 2017.

[7] Special report on InSAR efficacy as per Condition 16 of AER Approval 11837C, submitted to AER March 31, 2017.

[8] Shell Quest Carbon Capture and Storage Project, AER Approval No. 11837C, February, 2017 MMV Plan Update.

[9] Quest Carbon Capture and Storage Project Injection Well Integrity Study, Schlumberger, submitted to AER 2014.

[10] Shell Quest Carbon Capture and Storage Project: 2011 Carbon Capture and Storage Detailed Reports, Capacity Risk and Uncertainty Review. Submitted to Alberta Energy, 2011.

APPENDIX A: REPORT ON 2017 HMP SAMPLING PROGRAM

February 22, 2018

2017 HMP SUMMARY REPORT

Shell Quest Hydrosphere Monitoring Program

Submitted to:
Shell Canada Limited
400 4th Avenue SW
Calgary, AB
T2P 2H5

REPORT

Report Number: 1543144-4000

Distribution:

Shell - 1 ecopy
Golder - 1 ecopy

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APPENDICES

1.0 INTRODUCTION

The purpose of the Shell Canada Limited (Shell) Quest Carbon Capture and Storage (CCS) Project is to capture more than one million tonnes of carbon dioxide (CO_2) per year from the Scotford Upgrader and permanently store it deep underground. The injection and storage facility is located near Thorhild, Alberta.

The 2017 Hydrosphere Monitoring Program (HMP) described in this report was conducted as part of Shell Quest's Measurement, Monitoring and Verification (MMV) Plan. The HMP involves collecting and analyzing groundwater and gas samples from private Landowner wells located within the Shell Quest sequestration lease area, and from nine purpose-built groundwater monitoring wells (referred to as the Project wells) installed by Shell in the proximity to three well sites.

This report outlines the field activities, sampling methods and analytical results from the HMP completed in 2017.

2.0 HYDROSPHERE MONITORING PROGRAM

The 2017 HMP included the following activities:

- Completing four quarterly groundwater and gas sampling events (Q1 to Q4). The Q1 to Q4 2017 events were conducted in January/February, May, August, and October/November 2017, respectively. Groundwater and gas sampling was conducted on all nine Project wells and Landowner wells identified within a radius of about 1 km of the three well sites.
- Completing additional sampling and flow-testing at designated Landowner wells before and after Shell's 2017 Vertical Seismic Profile (VSP) program, which took place in February 2017. Pre VSP sampling/flow-testing was completed in conjunction with the Q1 HMP sampling event to avoid duplicate samples within the same month/quarter. Post VSP sampling/flow-testing was completed in March 2017. The select VSP Landowner wells included eight wells in the vicinity of the 07-11 and 08-19 well sites.
- Performing maintenance checks on In-Situ® Multi-Parameter data loggers AquaTROLL 600 (installed in the Project wells) on a quarterly basis, and downloading pressure and basic water quality data.

The following sections provide a summary of field activities and analytical results from the 2017 HMP.

2.1 Monitoring Well Network

2.1.1 Landowner Wells

Landowner wells sampled in 2017 included privately owned wells located within a radius of about 1 kilometer (km) of a well site and/or any other additional well identified by Shell for sampling/testing. Of the 16 previously-identified Landowner wells, the sampling frequency for five of them was optimized from quarterly to biannual in 2017 based on the results from a concentration trend evaluation completed in Q1.

2.1.2 Project Wells

The Project wells are nine Shell-owned groundwater monitoring wells installed at the three well sites:

- Two project wells at 07-11-059-20 W4M (07-11);
- Five Project wells at 08-19-059-20 W4M (08-19); and
- Two Project wells at 05-35-059-21 W4M (05-35).

2.2 Laboratory Analysis

2.2.1 Groundwater Analysis

Laboratory analysis of groundwater samples collected in 2017 are listed in Table 2.2-1 below. Analyses included routine parameters and dissolved metals (Tier 1 & 2 analytes) and isotopes (Tier 3 analytes). Routine chemistry and metals analyses were performed by AGAT Laboratories (AGAT). Isotope analyses were performed by the University of Calgary.

Table 2.2-1: 2017 Laboratory Analyses – Groundwater

Analysis Type	Laboratory	Method
Tier 1 & 2 (Q1 to Q4)		
Routine water[a]	AGAT	Various
Dissolved arsenic	AGAT	ICP-MS, ICP-OES, or CVAA[c]
Tier 3 – Isotopes (Q1 to Q4)		
$\delta^{13}C$-dissolved inorganic carbon	University of Calgary	Isotope-Ratio Mass Spectrometry
VSP Chemistry		
Routine water[a]	AGAT	Various
Dissolved arsenic	AGAT	ICP-MS, ICP-OES, or CVAA[c]
Total iron and microbial parameters[b]	AGAT	Incubator

Notes:

[a] Routine water included: pH; alkalinity; bicarbonate; carbonate; hydroxide; electrical conductivity (EC); dissolved calcium, iron, magnesium, manganese, potassium and sodium; chloride; fluoride; nitrate; nitrite; sulphate; sodium adsorption ratio (SAR); calculated total dissolved solids (TDS); hardness; ion balance; and dissolved inorganic carbon (DIC).

[b] Microbial parameters included total and fecal coliforms.

[c] Inductively Coupled Plasma Mass Spectrometry (ICP-MS), Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) or Cold Vapour Atomic Absorption (CVAA) depending upon analyte.

2.2.2 Gas Analyses

Free gas in groundwater (gas that readily comes out of solution at atmospheric pressure) was collected during well purging using a flow-through (FT) gas separator (refer to Section 2.4.3).

Laboratory analyses of gas samples collected in 2017 are listed in Table 2.2-2 below. Gas sample analyses included gas compositional parameters and isotopes. Compositional analyses were conducted by AGAT. Isotope analyses were performed by the University of Alberta.

Table 2.2-2: 2017 Laboratory Analyses – Free Gas

Analysis Type	Laboratory	Method
Composition: Helium (He), hydrogen (H_2), oxygen (O_2), nitrogen (N_2), carbon dioxide (CO_2), hydrogen sulphide (H_2S), methane (C_1), ethane (C_2), propane (C_3), i-butane (iC_4), n-butane (nC_4), i-pentane (iC_5), n-pentane (nC_5), hexanes (C_6), heptanes (C_7), Octanes (C_8), Nonanes (C_9) and Decanes+ (C_{10}+)	AGAT	GC-TCD-FID[a]
Isotopes $\delta^{13}C_{CH4}$, $\delta^{13}C_{C2}$, $\delta^{13}C_{CO2}$	University of Alberta	GC-C-IRMS[b]

Notes:

[a] Gas Chromatography-Thermal Conduction Detector-Flame Ionization Detector

[b] Gas Chromatography–Combustion–Isotope Ratio Mass Spectrometry

2.3 2017 Sampling Schedule

The planned 2017 groundwater and gas sampling schedule is presented in Table 2.3-1 below. A total of four quarterly sampling events were conducted in 2017, along with the VSP program in Q1. Where possible, both groundwater and free gas samples from scheduled Landowner and Project wells were collected during each sampling event.

Table 2.3-1: 2017 Planned Groundwater and Free Gas Sampling Schedule

Sampling Quarter	Dates	Planned Sampling	Number of Planned Wells	
			Landowner Wells	Project Wells
Q1	January 23 to February 8	Pre-VSP	8	0
		Groundwater and Gas	16	9
	March 13 to 18	Post-VSP	8	0
Q2	May 15 to 26	Groundwater and Gas	12	9
Q3	August 14 to 24	Groundwater and Gas	16	9
Q4	October 30 to November 10	Groundwater and Gas	13	9

In Q1 2017, designated Landowner wells were sampled and flow tested before and after the VSP program. Pre-seismic testing was performed in January/February 2017, in conjunction with the planned Q1 HMP sampling. Post-seismic testing was performed in March 2017. Chemical analyses for pre- and post-VSP were similar to those conducted for the routine HMP sampling, with the addition of total iron and coliform bacteria.

As much as possible, samples were collected from all planned Landowner and Project wells in each given quarter. However, in some circumstances (e.g., Landowner absence), it was not always possible to collect the total number of samples indicated in Table 2.3-1 during a given quarter.

2.4 Methodology

2.4.1 Water Quality Data Loggers

Data loggers installed in each of the nine Project wells provide in-situ monitoring of downhole pressure and select hydrochemical parameters. The In-Situ® Multi-Parameter AquaTROLL 600s were used to collect pressures and basic water chemistry (pH, temperature, conductivity and oxidation-reduction potential [ORP]) from the Project wells on a daily basis. Data downloading and data logger maintenance (i.e., calibration and sensor inspection) were performed quarterly by Golder. Due to sensor and/or calibration challenges, some of the Aqua TROLL 600s were returned to Rice Engineering & Operating Ltd (Rice) and In-Situ® (In-Situ) for further checks and repairs.

2.4.2 Groundwater Sampling

2.4.2.1 Project Wells

Groundwater samples from the nine Project wells were collected using a portable bladder pump, following a low-flow sampling protocol. Low-flow sampling is an alternative approach to traditional sampling that reduces the need for large purge volumes by minimizing mixing and dilution within the wellbore, thereby minimizing alteration in water chemistry during the sampling process (Puls and Barcelona 1996). Before conducting the low-flow groundwater sampling, the water level in the wells was manually measured, after which the data loggers were removed and the data downloaded.

The Project wells were purged at a low-flow rate (between 0.1 to 0.5 litres per minute), with the water intake placed at the approximate mid-point of the well screen. Field parameters and water levels were monitored and recorded during purging. Once field parameters had stabilized, indicating representative groundwater conditions, water samples were collected directly into laboratory-supplied bottles using industry-standard sampling protocols, including, where appropriate, field filtration and the addition of chemical preservatives.

The samples were placed in an ice-filled cooler and submitted under chain-of-custody to AGAT in Edmonton for analysis. As much as possible, samples were collected and delivered to the laboratory on the same day of sampling. In certain cases, same-day delivery was not possible due to scheduling, availability of Edmonton staff and/or weather conditions. In cases where same-day delivery was not possible, samples were submitted the following day of sampling.

2.4.2.2 Landowner Wells

Prior to starting each quarterly sampling event, Landowners were contacted for permission to access their property and conduct groundwater and gas sampling.

Groundwater samples from Landowner wells were collected via a raw water sampling outlet (e.g., an outdoor spigot or kitchen tap), upstream of any known water treatment or softening systems. The water was first run through the tap for approximately 25 to 30 minutes. Field parameters (pH, conductivity, temperature and dissolved oxygen) were monitored and recorded during the purge time. Once parameters stabilized, indicating representative groundwater conditions, water samples were collected directly into laboratory-supplied bottles using industry-standard sampling protocols, including, where appropriate, field filtration and the addition of chemical preservatives.

Similar to Project well samples, Landowner well samples were placed in an ice-filled cooler and submitted under chain-of-custody to AGAT in Edmonton for analysis. As much as possible, samples were collected and delivered to the laboratory on the same day of sampling. In cases where same-day delivery was not possible due to scheduling, availability of Edmonton staff and/or weather conditions, samples were submitted the following day of sampling.

2.4.3 Gas Sampling

Gas sampling was attempted at all Landowner and Project wells scheduled for 2017. Gas samples were collected for compositional and isotopic analysis.

Gas samples were collected consecutively with groundwater samples using a flow-through (FT) gas separator. The FT gas separator operates by capturing free phase gas bubbles that enter the separator or are released from solution within the separator. The detailed protocol adopted for flow-through sampling is described by Jones et al. (2009).

Although gas collection was attempted at all planned Landowner and Project wells in 2017, samples could not always be collected, particularly in shallower and unconfined wells, where gas concentrations were minimal or the pressure differential was insufficient to allow gas to build up above the surface saturation levels.

For each Project well, the FT was connected to the outlet of the pump and left connected. For Landowner wells, the FT was connected to a tap or spigot and allowed to collect gas. The FT was allowed to collect gas for a minimum of 30 minutes in order to obtain sufficient volume for both compositional and isotopic analysis. For wells producing a sufficient quantity of gas for sampling, two Tedlar® bags were typically filled and submitted for compositional and isotopic analysis.

Tedlar® bags were placed in a cooler and submitted under chain-of-custody to AGAT in Edmonton. As much as possible, samples were collected and delivered to the laboratory on the same day of sampling. In cases where same-day delivery was not possible, samples were submitted the following day.

2.4.4 Vertical Seismic Profile Sampling

In addition to the Q1 HMP sampling, select Landowner wells were sampled and flow tested before and after Shell's 2017 VSP program, which took place in February 2017. Pre-seismic testing was performed in conjunction with the planned Q1 HMP sampling in January/February 2017 to avoid duplicate samples within the same month/quarter. Post-seismic testing was performed in March 2017.

Note that some of the selected VSP landowner wells in the vicinity of the 07-11 and 08-19 well sites could not be flow tested.

Flow testing was conducted to determine drawdown and recharge rates before and after the VSP program. Testing consisted of opening a tap (pumping the well) at a constant rate for approximately 60 minutes; followed by a recovery period of 60 minutes. During pumping and recovery, water level data were recorded both manually and using a pressure transducer to log continuous data. Water quality parameters were also recorded during testing. Prior to the completion of pumping, a water and gas sample were collected and submitted to AGAT for analysis.

2.4.5 Quality Assurance/Quality Control

Industry-standard methods and equipment were used in the sampling process to ensure representative samples were collected. The Groundwater Quality Assurance/Quality Control (QA/QC) program consisted of collecting duplicate groundwater and gas samples, along with groundwater field and equipment blanks, during each quarterly sampling event.

Field duplicates were collected to assess the reliability of field sampling procedures. One duplicate was collected for every 10 to 12 regular samples and submitted with the regular samples for laboratory analysis. The measure of the reproducibility or precision of the groundwater and gas chemistry duplicate analysis was quantified by calculating the Relative Percent Difference (RPD) between parameter concentrations of select samples and the corresponding field duplicate samples.

Field and equipment blanks were collected to assess potential contamination resulting from field and ambient conditions during sampling. Theoretically, sample concentrations in blank samples should be below the laboratory Reportable Detection Limits (RDLs). The blank samples were generated in the field using laboratory-supplied distilled water.

2.5 Results

2.5.1 Data Logger Results

Daily pressure and water quality data collected from the In-Situ® Multi-Parameter AquaTROLL 600s installed in the nine Project wells were downloaded during each quarterly sampling event.

Data currently available for 2017 extends from January 1 to November 6, 2017. Total number of water pressure data points collected during this time period are summarized in Table 2.5-1 below. Data from the remainder of 2017 will be downloaded in the upcoming 2018 Q1 event.

Table 2.5-1: 2017 Data Logger Summary

Project Well-ID	2017 Date Range [(a)]	2017 Data Points Collected [(b)]
1F1-08-19-059-20W4	January 01 to August 24, 2017	34
UL1-08-19-059-20W4	January 25 to November 03, 2017	240
UL2-08-19-059-20W4	January 01 to November 03, 2017	255
UL3-08-19-059-20W4	January 25 to October 31, 2017	172
UL4-08-19-059-20W4	January 26 to October 31, 2017	228
1F1-05-35-059-21W4	January 01 to November 06, 2017	153
UL1-05-35-059-21W4	January 27 to November 06, 2017	281
1F1-07-11-059-20W4	January 01 to October 23, 2017	321
UL1-07-11-059-20W4	January 28 to November 02, 2017	278

Notes:
[(a)] 2017 data range from January 1 to November 6, 2017. The remaining 2017 data will be downloaded in Q1 of 2018.
[(b)] Represents number of water pressure data points collected for the specified date range. Number of data points for remaining water quality parameters (temperature, pH, ORP, conductivity) will vary.

On-site calibration and equipment/sensor inspections on the data loggers were performed quarterly. Additional maintenance and calibration was completed off-site by the manufacturer.

Sensor and/or calibration issues were identified in 2017, which required some of the data loggers to be returned to the manufacturer for repairs. A spare Troll unit was available for deployment in case that a dedicated unit needed to be temporarily removed for service.

2.5.2 Groundwater Sampling and Analytical Results

Number of wells sampled/tested in 2017 are summarized in Table 2.5-2. Quarterly samples were collected from all nine Project wells in 2017. Samples from Landowner wells varied between quarters, primarily due to Landowner availability (i.e., well access) and/or sampling frequency.

Table 2.5-2: 2017 Groundwater Samples Collected

Sampling Quarter	Groundwater Analysis	Number of Wells Sampled/Tested		
		Landowner Wells	Project Wells	Flow Testing[b]
Q1	Pre-VSP and Q1 Chemistry[a] (Tier 1 & 2 / Tier 3)	15	9	6
	Post-VSP Chemistry (Tier 1 & 2 / Tier 3)	8	0	6
Q2	Tier 1 & 2 / Tier 3	12	9	0
Q3	Tier 1 & 2 / Tier 3	13	9	0
Q4	Tier 1 & 2 / Tier 3	13	9	0

Notes:

[a] Pre-VSP sampling/flow testing of Landowner wells was conducted concurrently with Q1 HMP sampling.

[b] Flow testing conducted on select Landowner wells only as part of pre- and post-VSP.

The analytical results from groundwater samples collected in 2017 are summarized in Table 2.5-3 of Appendix A. The table includes: minimum, maximum and average observed concentrations above the RDL for each analyte; total number of samples; and total number of samples above the RDL. The data are shown separated by sampling quarter (Q1 to Q4) with Project and Landowner wells combined. Sample blanks have not been included in the summary table.

Table 2.5-3: 2017 Groundwater Chemical Analysis Summary (refer to Appendix A)

2.5.3 Gas Sampling and Analytical Results

Gas samples collected during the 2017 sampling events are summarized in Table 2.5-4. As noted previously, gas sampling was attempted at all Project and Landowner wells in 2017; however, samples could not always be collected at all wells, particularly in shallower and unconfined wells.

Table 2.5-4: 2017 Gas Sampling Summary

Sampling Quarter	Gas Analysis	Number of Wells Sampled	
		Landowner Wells	Project Wells
Pre-VSP, Q1	Composition	1	3
	Isotopes	1	3
Post-VSP	Composition	1	0
	Isotopes	1	0
Q2	Composition	0	4
	Isotopes	0	4
Q3	Composition	1	3
	Isotopes	1	3
Q4	Composition	0	4
	Isotopes	0	4

The gas composition and isotope results from samples collected in 2017are summarized in Table 2.5-5 and Table 2.5-6, respectively, in Appendix A. The tables list minimum, maximum and total number of samples. The data are shown separated by sampling quarter (Q1 to Q4) with Project and Landowner wells combined.

Table 2.5-5: 2017 Gas Chemical Analysis Summary (refer to Appendix A)
Table 2.5-6: 2017 Gas Isotope Analysis Summary (refer to Appendix A)

2.5.4 Sampling/Flow Testing for VSP Program

Note that some of the selected VSP landowner wells in the vicinity of the 07-11 and 08-19 well sites could not be flow tested. Of the six Landowner wells that were flow tested, none produced sufficient gas for sampling in both pre- and post VSP.

The groundwater analytical results are included with the Q1 2017 results in Table 2.5-3 in Appendix A.

2.5.5 Quality Assurance/Quality Control

Duplicate groundwater and gas samples, along with groundwater equipment and field blanks, were collected during each sampling event to assess precision of field sampling procedures and the quality of reported analytical results.

The QA/QC samples collected in 2017 are summarized in Table 2.5-7. A total of 10 groundwater duplicates, 7 gas duplicates and 13 groundwater blanks were collected in 2017.

Table 2.5-7: 2017 Quality Assurance/Quality Control Sampling

Sampling Quarter	Analysis	Number of QA/QC Samples Collected					
		Groundwater QA/QC			Gas QA/QC		
		Duplicate Samples	Field Blanks	Equipment Blank	Duplicate Samples	Field Blanks	Equipment Blank
Pre-VSP, Q1	Chemical	2	2	1	2	0	0
	Isotopes						
Post-VSP	Chemical	2	1	0	1	0	0
	Isotopes						
Q2	Chemical	2	2	1	1	0	0
	Isotopes						
Q3	Chemical	2	2	1	2	0	0
	Isotopes						
Q4	Chemical	2	2	1	1	0	0

Relative percent differences and alert limit exceedances were noted for select analytes in 2017, as outlined in Table 2.5-8.

Table 2.5-8: 2017 QA/QC Result Summary

Sampling Quarter	RPD Exceedances		Alert Limit Exceedances for Blank Water Samples
	Groundwater Samples	Gas Samples	
Q1	One for chloride	One for hydrogen	Four for ion balance
Q2	None	None	Three for ion balance
Q3	One from chloride One for various routine parameters	One for hydrogen One for oxygen	Three for ion balance
Q4	None	One for helium, oxygen and nitrogen	Three for ion balance Two for electrical conductivity

3.0 REFERENCES

Jones, D., S. Gordon, B. Mayer, M. Hitz, and A. Blyth. 2009. The Free Gas Sampling Standard Operating Procedure for Baseline Water Well Testing. Prepared by Alberta Research Council Inc. for Alberta Environment and Sustainable Resource Development, March 31, 2009, 13 p.

Puls, R.W. and M.J. Barcelona. 1996. Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures. USEPA, Reston, Virginia.

Report Signature Page

GOLDER ASSOCIATES LTD.

Prepared by:

PROFESSIONAL ENGINEER ALBERTA
JULIO HENRIQUEZ

Feb 22, 2018

Julio Henriquez, M.A.Sc., P.Eng.,
Environmental Engineer

Reviewed by:

N G B

Neil Barnsdall, M.Sc.
Environmental Scientist, Project Manager

PROFESSIONAL ENGINEER ALBERTA
JILLIAN MITTON

M. Jillian Mitton

Feb 22, 2018

Jillian Mitton, M.Sc., P.Eng.
Principal, Senior Environmental Engineer

APEGA PERMIT TO PRACTICE P5122

APPENDIX A

Summary of 2017 Groundwater and Gas Analytical Results

Table 2.5-3
2017 Groundwater Analytical Results Summary
Shell Quest Carbon Capture and Storage Hydrosphere Monitoring Program
Shell Canada Limited

Parameter	Unit	2017 Results Summary																			
		Q1-2017					Q2-2017					Q3-2017					Q4-2017				
		Mean*	Min*	Max*	Number of Samples	Samples Above RDL	Mean*	Min*	Max*	Number of Samples	Samples Above RDL	Mean*	Min*	Max*	Number of Samples	Samples Above RDL	Mean*	Min*	Max*	Number of Samples	Samples Above RDL
Field Parameters																					
pH	-	7.94	7.08	11.91	35	35	8.10	7.22	11.19	23	23	7.87	7.00	10.82	24	24	7.97	7.00	10.94	24	24
Temperature of Water	degC	4.62	2.70	7.3	35	35	6.91	4.6	10.2	23	23	8.7	4.8	15.9	24	24	5.3	3.6	7.8	24	24
Dissolved Oxygen (O2)	mg/L	0.93	0.00	6.9	35	35	0.80	-0.330	6.41	23	23	0.94	0.26	3.69	24	24	0.85	0.19	2.56	24	24
Oxidation Reduction Potential	mV	-55.7	-348	169	35	35	-100	-262	173	23	23	-56.2	-240	151	24	24	-93.0	-220	72	24	24
Turbidity	NTU	144.7	-0.60	850	13	13	49.19	1.0	450	20	20	9.64	-0.20	76.3	24	24	10.42	-0.60	55.7	24	24
Electrical Conductivity	uS/cm	3380	870	17418	35	35	3985	560	19668	23	23	4471	849	21139	24	24	3494	773	16905	24	24
Conventional Parameters																					
pH	-	7.87	7.09	10.4	35	35	8.03	7.17	10.0	23	23	7.99	7.27	10.2	24	24	8.14	7.58	9.69	24	24
Hardness	mg/L	288	9.0	1610	35	35	326	5	1400	23	23	353	6	1450	24	24	320	5	1310	24	24
Total Dissolved Solids	mg/L	3246	772	16700	35	35	3305	530	14800	23	23	3880	756	22600	24	24	3623	799	17100	24	24
Electrical Conductivity	uS/cm	jm	1294	28400	35	35	5829	920	27100	23	23	6330	1310	28200	24	24	5958	1290	29400	24	24
Alkalinity, total (as CaCO3)	mg/L	620	67	1080	35	35	585	47	910	23	23	633	64	1070	24	24	570	48	970	24	24
Alkalinity, phenolphthalein (as CaCO3)	mg/L	61.3	9.0	152	35	3	47	17	97	23	5	57	5	85	24	3	26.75	8	91	24	8
Dissolved Inorganic Carbon	mg/L	136	1.0	261	35	35	124	1.0	205	23	23	128	1.0	248	24	24	104	1.0	180	24	24
SAR	-	30.9	5.22	65.9	35	35	31.5	3.07	59.4	23	23	31.22	5.18	65.6	24	24	34.00	5.25	67.8	24	24
Major Ions																					
Dissolved Calcium (Ca)	mg/L	82.5	2.60	617	35	35	94.0	1.5	520	23	23	100	1.7	518	24	24	90	1.4	462	24	24
Dissolved Magnesium (Mg)	mg/L	19.81	0.50	125	35	35	22.2	0.4	95.8	23	23	24.9	0.4	80.6	24	24	23.2	0.3	115	24	24
Dissolved Potassium (K)	mg/L	9.10	1.40	56.4	35	35	11.0	1.7	58.1	23	23	11.1	1.5	73.7	24	24	10.7	2.2	65.3	24	24
Dissolved Sodium (Na)	mg/L	1071	245	6090	35	35	1066	103	5110	23	23	1166	208	5750	24	24	1162	240	5640	24	24
Bicarbonate (HCO3)	mg/L	769	82.0	1310	35	34	724	57	1110	23	22	791	78	1310	24	23	704	58	1180	24	23
Carbonate (CO3)	mg/L	23.3	10.0	32	35	3	39.4	20.0	72	23	5	32.75	6.0	97	24	4	29.5	9.0	109	24	8
Chloride (Cl)	mg/L	1260	2.0	9880	35	35	1480	8.0	9010	23	23	1645	13	10400	24	24	1615	2	10900	24	24
Fluoride (F)	mg/L	0.44	0.080	2.1	35	10	0.29	0.06	0.90	23	8	0.34	0.15	0.42	24	4	1.12	1.12	1.12	24	1
Sulphate (SO4)	mg/L	525	3.0	1120	35	25	432	51.0	1160	23	14	407	3	1150	24	18	526	2	1530	24	17
Hydroxide (OH)	mg/L	43	43	43	35	1	24	24	24	23	1	23	23	23	24	1	6	6	6	24	1
Ion Balance	%	93.17	80.3	106	35	35	87.9	82	98	23	23	85.5	79.0	95.0	24	24	94.1	80.0	107.0	24	24
Nutrients																					
Nitrate-N (NO3-N)	mg/L	3.81	0.090	27.8	35	9	14.8	0.68	47.4	23	5	7.15	0.56	16.5	24	6	14.91	3.59	35.2	24	3
Nitrate (NO3)	mg/L	16.87	0.40	123	35	9	65.4	3	210	23	5	31.7	2.5	73.2	24	6	66.1	15.9	156	24	3
Nitrite-N (NO2-N)	mg/L	0.040	0.040	0.040	35	2	nd	nd	nd	23	0	0.030	0.030	0.030	24	1	nd	nd	nd	24	0
Nitrite (NO2)	mg/L	0.135	0.13	0.14	35	2	nd	nd	nd	23	0	0.11	0.11	0.11	24	1	nd	nd	nd	24	0
Dissolved Metals																					
Dissolved Arsenic (As)	mg/L	0.0060	0.0010	0.020	35	9	0.0020	0.0010	0.0040	23	8	0.0018	0.0010	0.0030	24	4	0.0018	0.0010	0.0040	24	13
Dissolved Iron (Fe)	mg/L	0.82	0.10	2.5	35	14	4.28	0.10	33	23	13	0.38	0.10	1.60	24	6	0.88	0.20	3.80	24	6
Dissolved Manganese (Mn)	mg/L	0.10	0.007	0.32	35	35	0.12	0.01	0.45	23	21	0.12	0.008	0.39	24	23	0.12	0.006	0.51	24	21
Total Metals																					
Total Iron (Fe)	mg/L	4.6	0.10	26.8	25	21	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-
Biological Parameters																					
Total Coliform	CFU/100 mL	40.8	1.0	320	25	16	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-
Fecal Coliform	CFU/100 mL	nd	nd	nd	25	0	-	-	-	0	-	-	-	-	0	-	-	-	-	0	-
Carbon Isotope in Water																					
$\delta^{13}C_{-DIC}$	‰	-10.89	-18.81	10.87	34	34	-10.92	-18.27	11.29	23	22	-9.5	-17.5	12.73	23	23	-11.2	-18.5	11.5	23	23

Notes:
CFU - colony-forming unit
degC - degree Celsius
mL - millilitres
mg/L - milligrams per litre
mV - millivolts
nd = not detected; no concentrations observed above RDL
NTU - nephelometric turbidity unit
RDL = reportable detection limit

Table 2.5-5
2017 Gas Composition Analytical Results Summary
Shell Quest Carbon Capture and Storage Hydrosphere Monitoring Program
Shell Canada Limited

Parameter	Units	Q1-2017				Q2-2017				Q3-2017				Q4-2017			
		Min	Max	Number of Samples	Samples Above RDL	Min	Max	Number of Samples	Samples Above RDL	Min	Max	Number of Samples	Samples Above RDL	Min	Max	Number of Samples	Samples Above RDL
Helium	%	0.0093	0.0240	8	8	0.007	0.020	3	3	0.010	0.027	6	6	0.0070	0.2100	5	5
Hydrogen	%	0.0010	0.2992	8	8	0.001	0.816	3	3	0.003	0.876	6	6	0.3840	0.6396	5	3
Oxygen	%	0.4110	1.5564	8	8	0.990	1.811	3	3	0.28	2.2	6	6	0.3960	1.6440	5	5
Nitrogen	%	3.7630	6.3253	8	8	4.880	7.097	3	3	3.99	8.61	6	6	2.8120	7.2520	5	5
Carbon Dioxide	%	0.0020	0.1480	8	8	0.013	0.049	3	3	0.004	0.101	6	6	0.0200	0.0500	5	4
Hydrogen Sulphide	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
Methane	%	91.75	95.28	8	8	90.27	93.97	3	3	88.5	95.6	6	6	90.935	96.608	5	5
Ethane	%	0.0170	0.1030	8	8	0.035	0.049	3	3	0.032	0.109	6	6	0.0347	0.1080	5	5
Propane	%	0.0013	0.0060	8	2	0.089	0.089	3	1	0.0060	0.0060	6	1	0.0030	0.0050	5	2
i-Butane	%	nd	nd	8	0	nd	nd	3	0	0.0010	0.0010	6	1	0.0010	0.0010	5	2
n-Butane	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
i-Pentane	%	0.0016	0.0016	8	1	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
n-Pentane	%	0.0026	0.0026	8	1	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
n-Hexane	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
iso-Heptane (Mixed Isomers)	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
n-Octane	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
n-Nonane	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0
n-Decane	%	nd	nd	8	0	nd	nd	3	0	nd	nd	6	0	nd	nd	5	0

Notes:

nd= not detected; no concentrations observed above parameter RDL.

RDL = reportable detection limit

% - percent

Table 2.5-6
2017 Gas Isotopes Analytical Results Summary
Shell Quest Carbon Capture and Storage Hydrosphere Monitoring Program
Shell Canada Limited

Parameter	Isotope	Units	Q1-2017			Q2-2017			Q3-2017			Q4-2017		
			Minimum	Maximum	Number of Samples	Minimum	Maximum	Number of Samples	Minimum	Maximum	Number of Samples	Minimum	Maximum	Number of Samples
Delta 13 Carbon – methane	$\delta^{13}C_{C1}$	‰	-69.32	-63.75	8	-64.5	-62.01	5	-69.15	-61.76	6	-66.06	-64.01	5
Delta 13 Carbon - ethane	$\delta^{13}C_{C2}$	‰	-53.27	-50.69	8	-52.06	-50.39	5	-54.16	-50.7	6	-52.22	-51.06	5
Delta 13 Carbon - carbon dioxide	$\delta^{13}C_{CO2}$	‰	-56.33	-1.31	8	-28.93	-12.38	5	-25.49	-10.14	6	-31.24	-26.62	5

Notes:

‰ - permil

nd - not detected

'-' = no data

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Africa	+ 27 11 254 4800
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Europe	+ 44 1628 851851
North America	+ 1 800 275 3281
South America	+ 56 2 2616 2000

solutions@golder.com
www.golder.com

Golder Associates Ltd.
102, 2535 - 3rd Avenue S.E.
Calgary, Alberta, T2A 7W5
Canada
T: +1 (403) 299 5600

Golder Associates

APPENDIX B: RESULTS OF 2017 PNX LOGGING (HYDRAULIC ISOLATION LOGS)

Schlumberger

*Techlog Processed Interpretation

Analysis Behind Casing Pulsed Neutron eXtreme Tool(PNX)

* A Mark of Schlumberger

COMPANY:	SHELL CANADA ENERGY
WELL:	SCL RADWAY 8-19-59-20
FIELD:	RADWAY
PROVINCE:	ALBERTA
COUNTRY:	CANADA

Date Logged: 09-May-2017	Run No. 1	API Number: 0421182	
Location: 8-19-59-20W4		UWI: 100081905920W400	
Borehole Fluid Type: Air		Borehole Fluid Weight: 11.9826 kg/m3	
Elevations:	KB: 646.76 m	DF: 640.96 m	GL: 640.96 m
Top Log Interval: -999.25 m		Bottom Log Interval: -999.25 m	TD Logger: 2133.02 m
Casing Size: 177.8 mm @ 2132 m	Casing Weight: 38.69 kg/m		Casing Grade: L80
Bit Size: 222 mm			

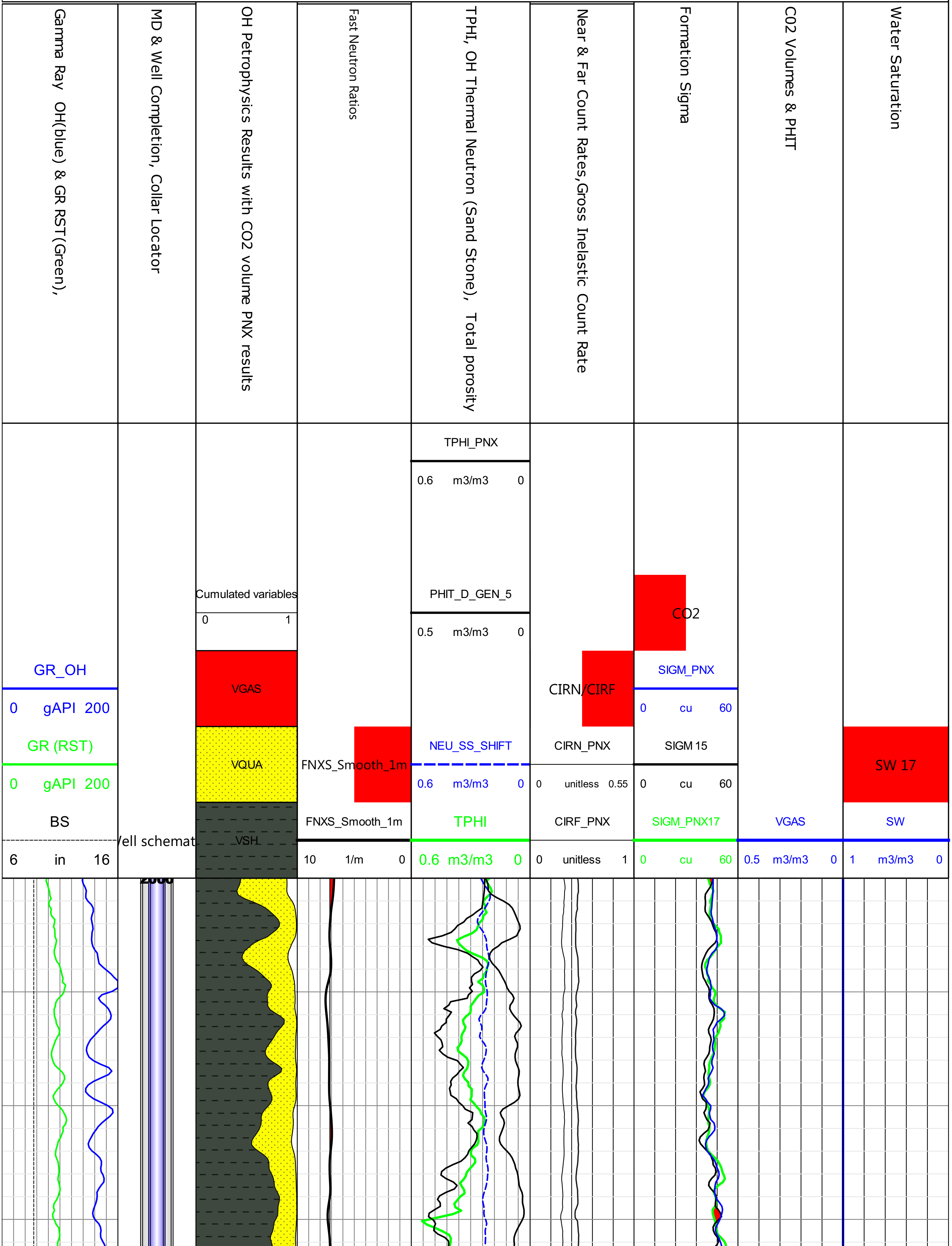
FOLD HERE: The well name, location and borehole reference data were furnished by the customer.

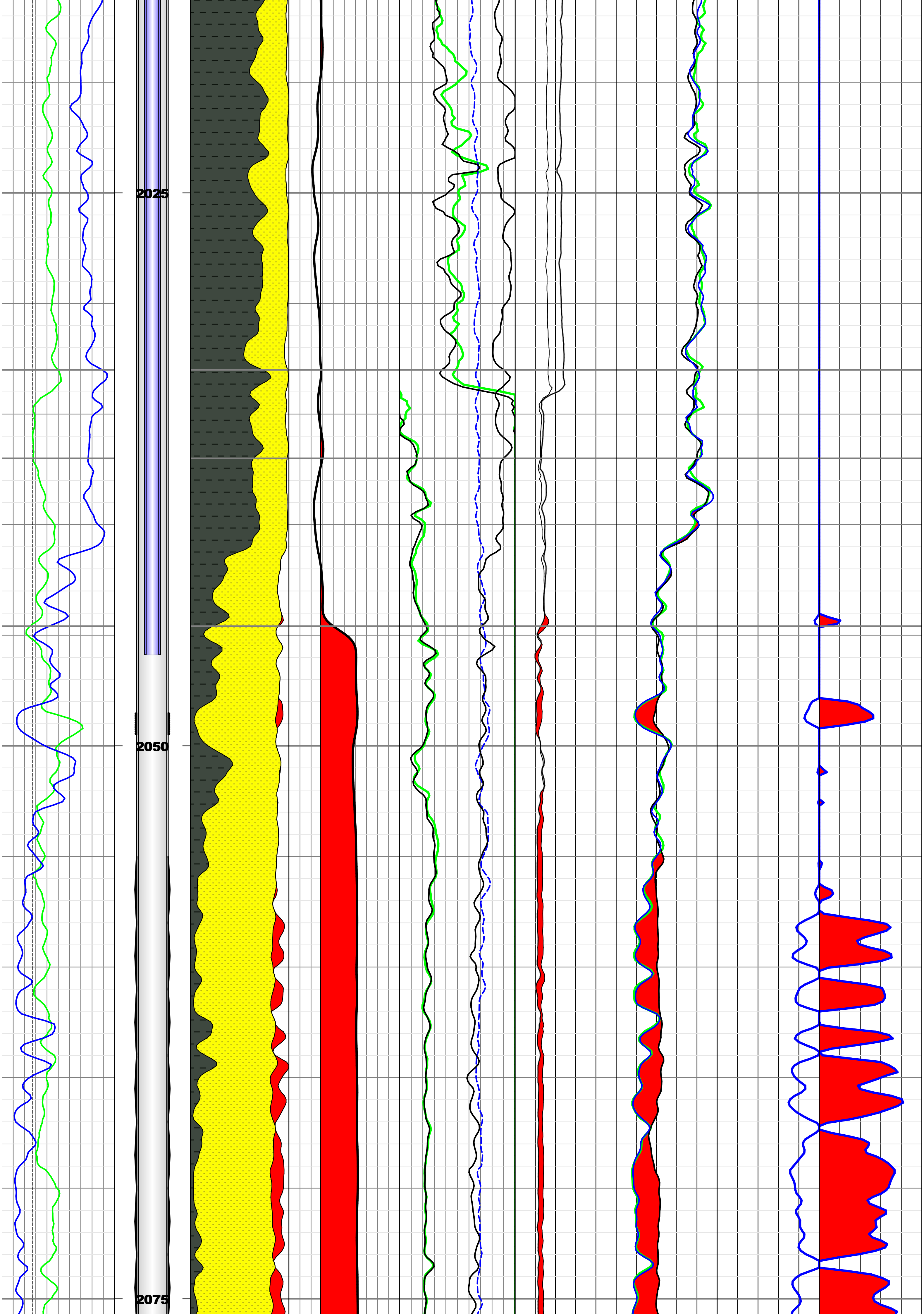
Svc. Order #: DE02-00147 Location: NISKU PS	Interpretation Center: Calgary Techlog Vers:2014.3	Analyst: Chris OKUKU Email: COkuku@slb.com	Process Date: 11 May 2017

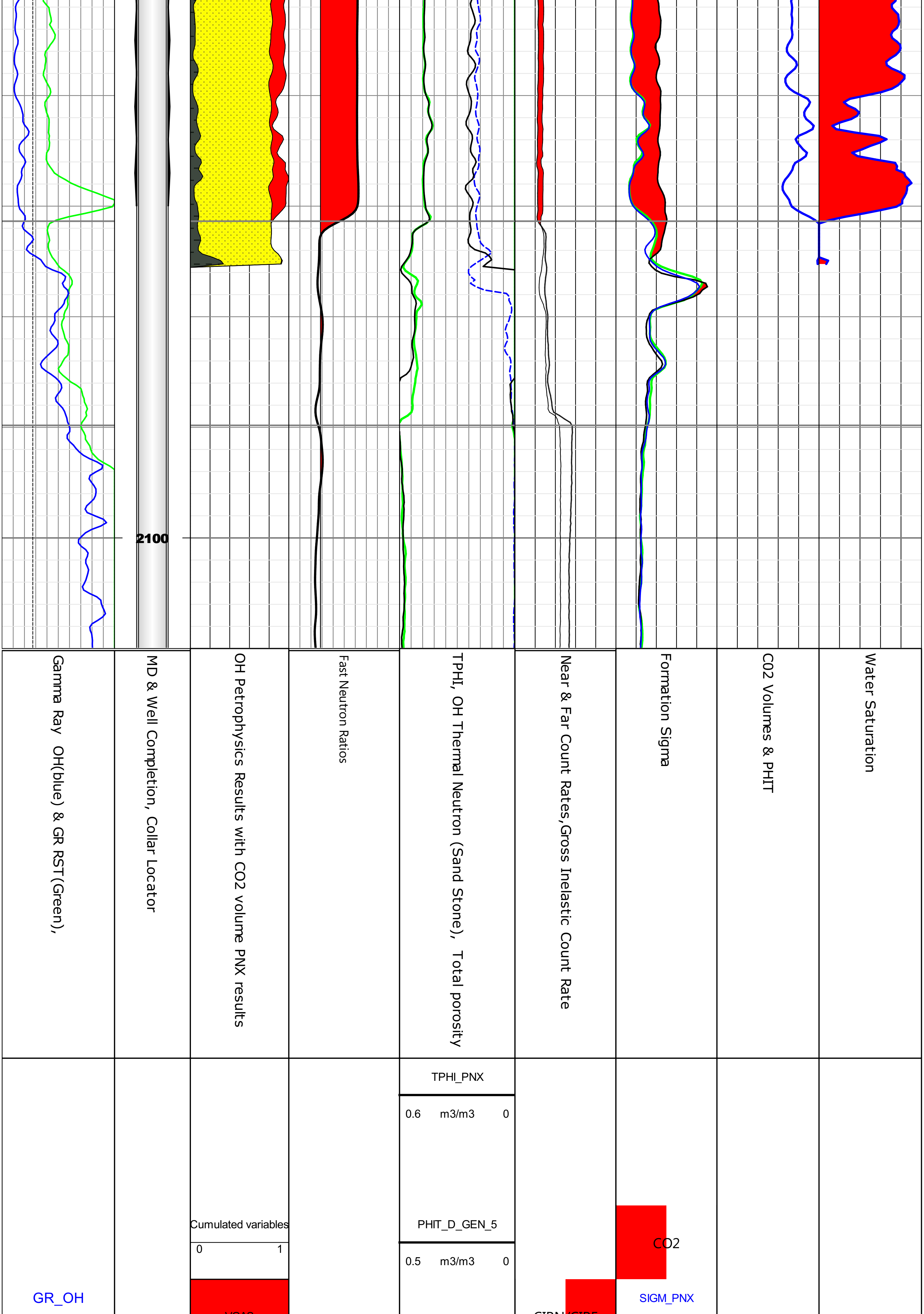
Remarks:

RST was logged as the first run in 2015 when the fluid was mainly water and PNX was logged after the CO2 injection started.
The PNX results was used to estimate the C02 volume and saturation in combination with the OH petrophysical interpretation. Excellent match was observed between PNX runs of 2016 & 2017 and also between PNX and RST results.

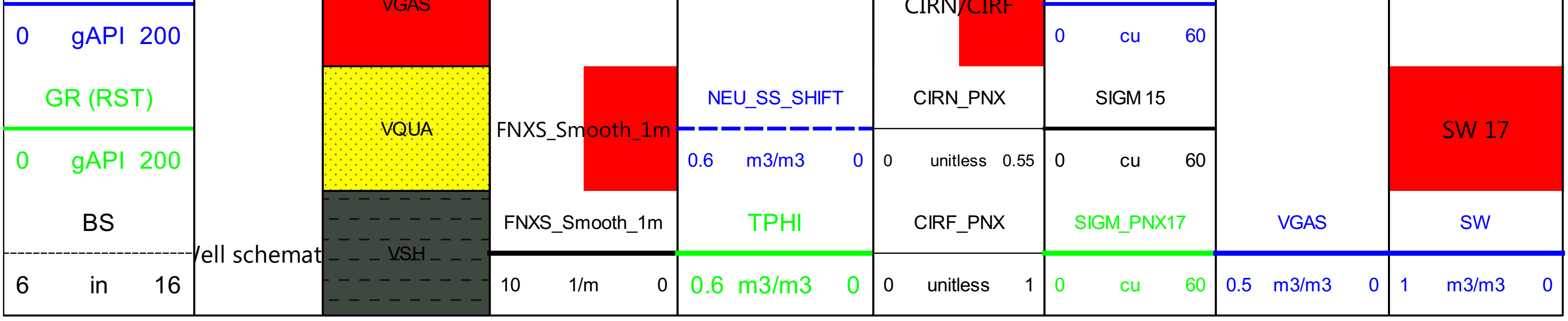
SCL RADWAY 8-19-59-20



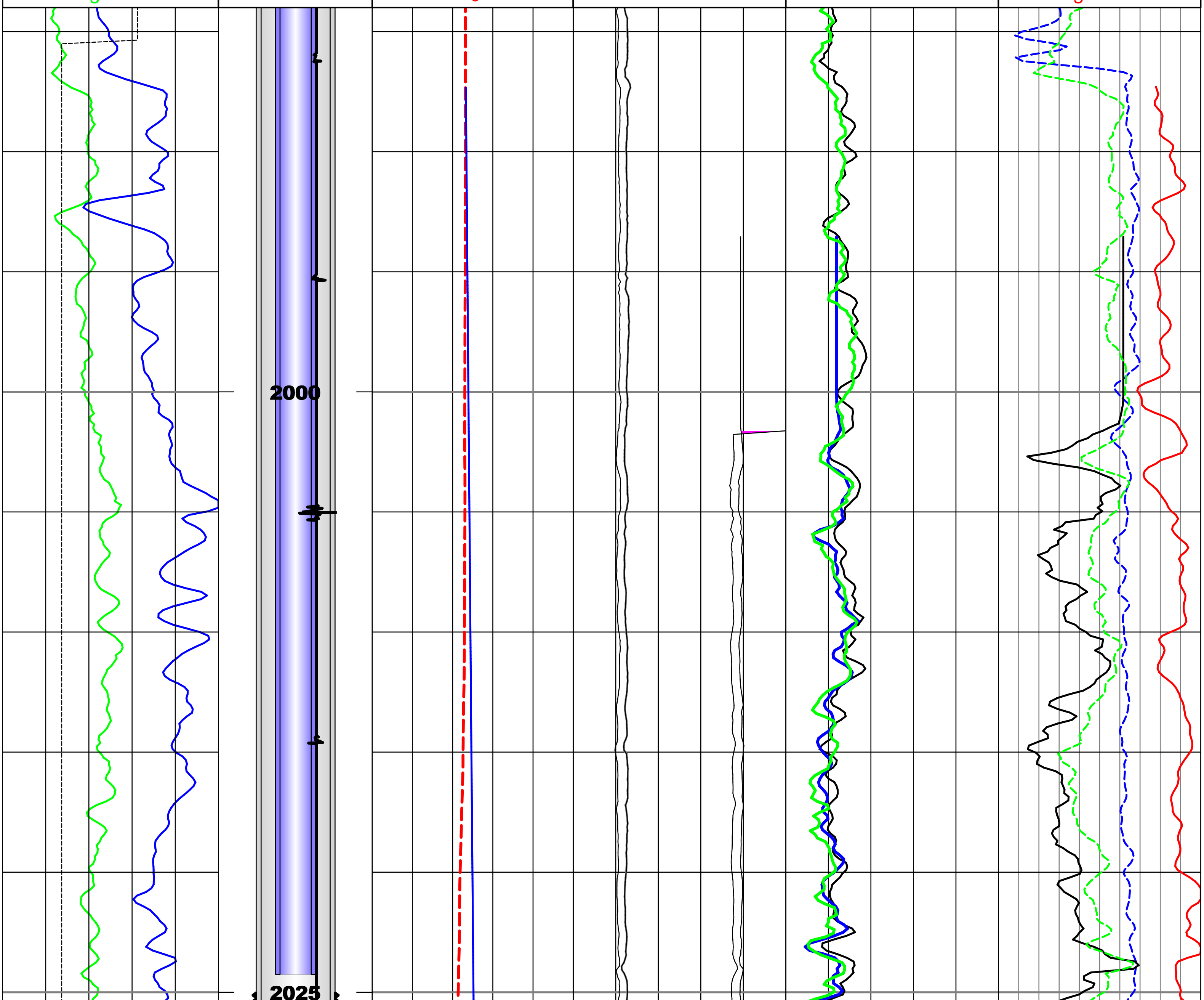

2025
2050
2075

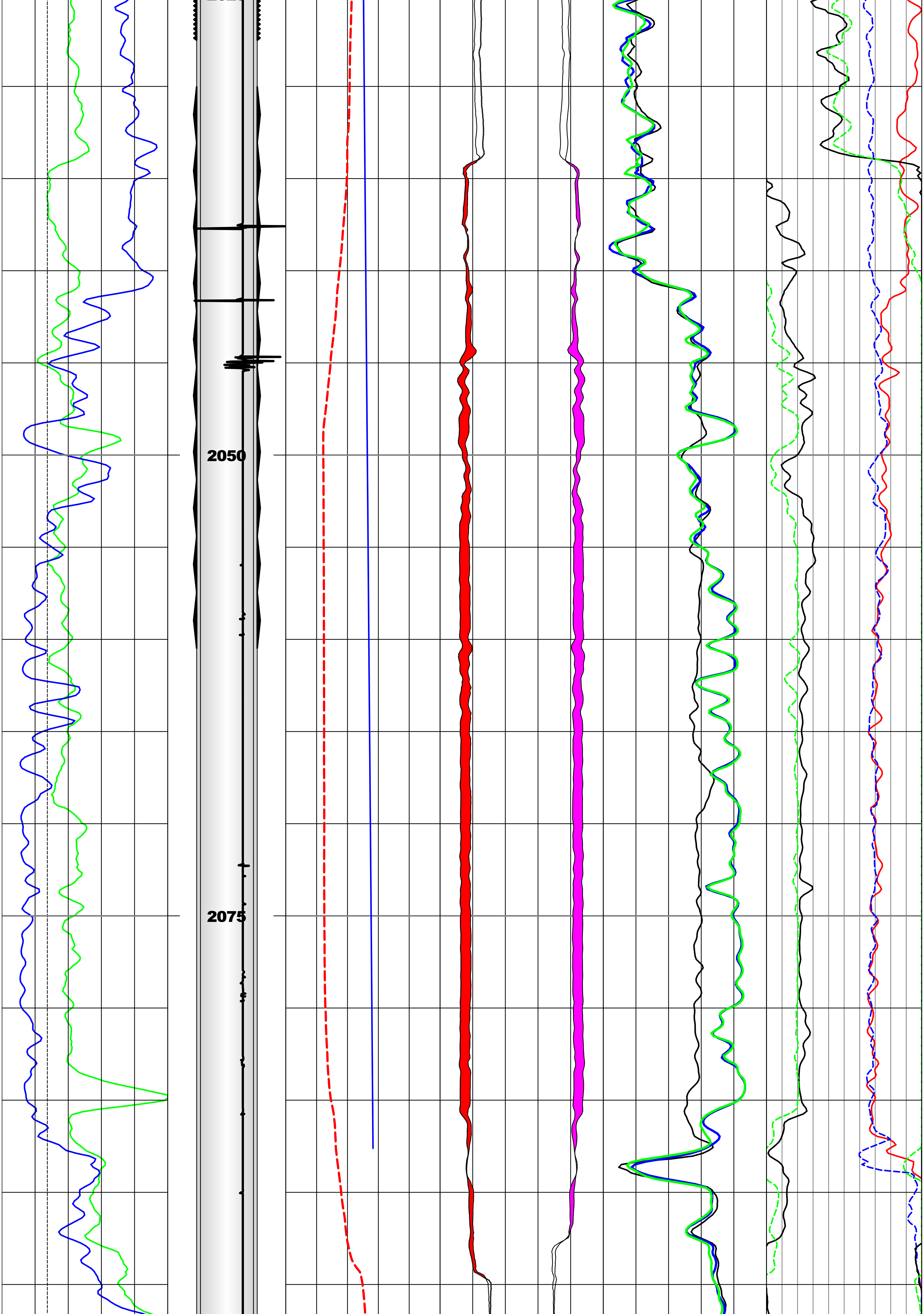


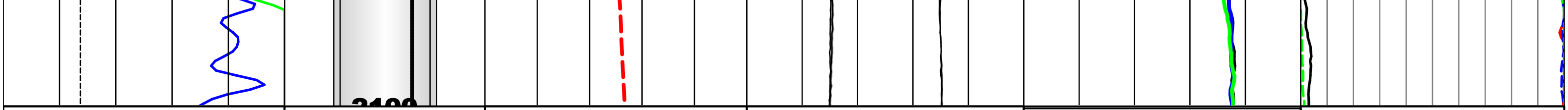
2100
Gamma Ray OH(blue) & GR RST(Green),
MD & Well Completion, Collar Locator
OH Petrophysics Results with CO2 volume PNX results
Fast Neutron Ratios
TPHI, OH Thermal Neutron (Sand Stone), Total porosity
Near & Far Count Rates,Gross Inelastic Count Rate
Formation Sigma
CO2 Volumes & PHIT
Water Saturation
TPHI_PNX
0.6 m3/m3 0
PHIT_D_GEN_5
0.5 m3/m3 0
Cumulated variables
0 1
CO2
SIGM_PNX
GR_OH


0 gAPI 200
GR (RST)
0 gAPI 200
BS
6 in 16
Well schemat
VGAS
VQUA
VSH
FNXS_Smooth_1m
FNXS_Smooth_1m
10 1/m 0
NEU_SS_SHIFT
0.6 m3/m3 0
TPHI
0.6 m3/m3 0
CIRN/CIRF
CIRN_PNX
0 unitless 0.55
CIRF_PNX
0 unitless 1
0 cu 60
SIGM 15
0 cu 60
SIGM_PNX17
0 cu 60
VGAS
0.5 m3/m3 0
SW 17
SW
1 m3/m3 0

Cased & Open Hole GR . Caliper & BS	MD, Collar locator, well schematics	Well Tempt, Pressure,Borehole Salinity & Borehole Sigma	Formation Sigma count rates from RST & PNX	Formation Sigma from RST & PNX Tools	Bulk Density, Cased hole Neutron and open hole neutron
	Well schematic		CIRN_PNX/CIRF_PNX 16		TPHI_PNX17
			CIRN/CIRF 17		0.6 m3/m3 0
					TPHI_PNX16
			CIRN_PNX	SIGM_PNX17	0.6 m3/m3 0
			1 unitless 0	60 cu 0	
BS	CCLD		CIRF_PNX	SIGM_PNX16	NEU_SS_SHIFT
6 in 16	-3.5 V 2		1.5 unitless 0	60 cu 0	0.6 m3/m3 0
GR_OH		WPRE	CIRN		
0 gAPI 200	**Reference (m)**	15000 kPa 25000	0 unitless 1		
GR		WTEP	CIRF_PNX	SIGM_TDT_UPD	DEN_SHIFT
0 gAPI 200	**1:240**	0 degC 100	0 unitless 1.5	60 cu 0	1.65 g/cm3 2.65




2050
2075



Cased & Open Hole GR . Caliper & BS	MD, Collar locator, well schematics	Well Tempt, Pressure,Borehole Salinity & Borehole Sigma	Formation Sigma count rates from RST & PNX	Formation Sigma from RST & PNX Tools	Bulk Density, Cased hole Neutron and open hole neutron
			CIRN_PNX/CIRF_PNX 16		TPHI_PNX17
					0.6 m3/m3 0
	Well schematic		CIRN/CIRF 17		TPHI_PNX16
					0.6 m3/m3 0
			CIRN_PNX	SIGM_PNX17	
			1 unitless 0	60 cu 0	
BS	CCLD		CIRF_PNX	SIGM_PNX16	NEU_SS_SHIFT
6 in 16	-3.5 V 2		1.5 unitless 0	60 cu 0	0.6 m3/m3 0
GR_OH		WPRE	CIRN		
0 gAPI 200	**Reference (m) 1:240**	15000 kPa 25000	0 unitless 1		
GR		WTEP	CIRF_PNX	SIGM_TDT_UPD	DEN_SHIFT
0 gAPI 200		0 degC 100	0 unitless 1.5	60 cu 0	1.65 g/cm3 2.65

Schlumberger

COMPANY: SHELL CANADA ENERGY

WELL: SCL RADWAY 8-19-59-20

PROVINCE: **MD**

FIELD: RADWAY

Analysis Behind Casing
Pulsed Neutron eXtreme Tool(PNX)

Schlumberger

*Techlog Processed Interpretation

Analysis Behind Casing Pulsed Neutron eXtreme Tool(PNX)

* A Mark of Schlumberger

COMPANY:	SHELL CANADA ENERGY
WELL:	SCL RADWAY 7-11-59-20
FIELD:	RADWAY
PROVINCE:	ALBERTA
COUNTRY:	CANADA

Date Logged: 08-May-2017	Run No. 1	API Number: 0448521	
Location: LSD(SURFACE)_7-11-059-20W4M		UWI: 103071105920W400	
Borehole Fluid Type: Air		Borehole Fluid Weight: 11.9826 kg/m3	
Elevations:	KB: 641.9 m	DF: 636.2 m	GL: 636.2 m
Top Log Interval: -999.25 m	Bottom Log Interval: -999.25 m		TD Logger: 2105 m
Casing Size: 177.8 mm @ 2105 m	Casing Weight: 36.84 kg/m		Casing Grade: L80
Bit Size: 222 mm			

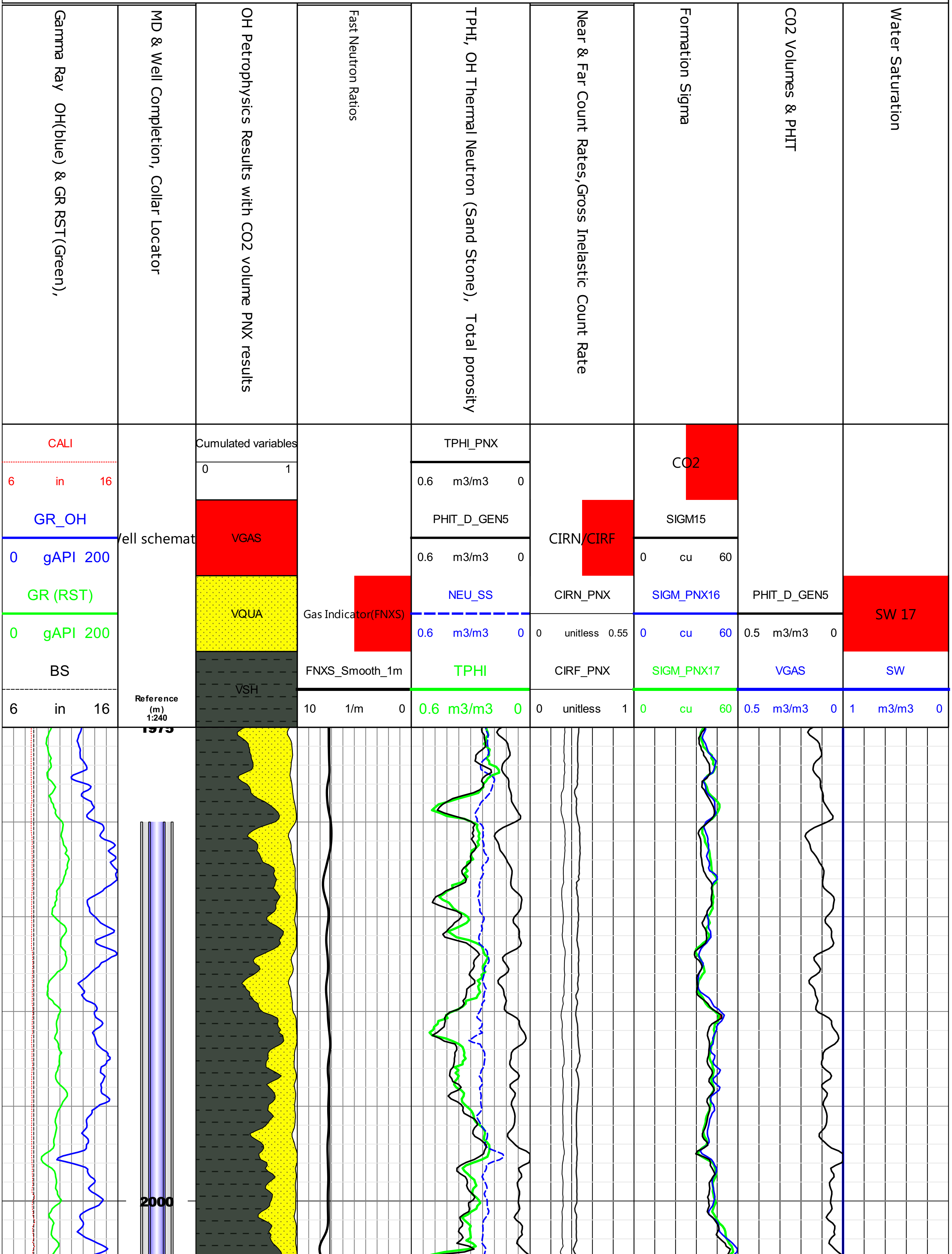
FOLD HERE: The well name, location and borehole reference data were furnished by the customer.

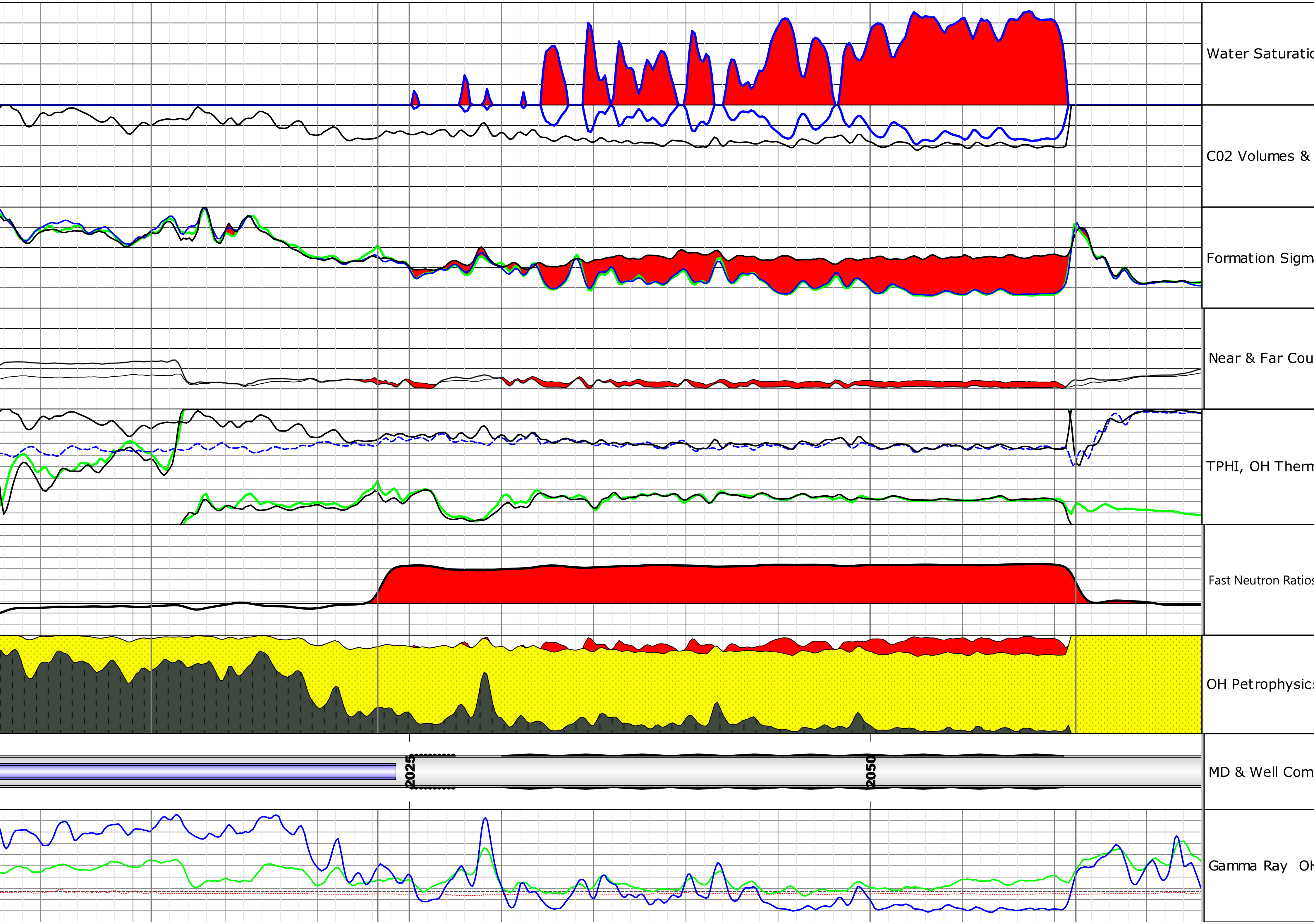
Svc. Order #: DE02-00146 Location: NISKU PS	Interpretation Center: Calgary Techlog Vers:2014.3	Analyst: Chris OKUKU Email: COkuku@slb.com	Process Date: 11 May 2017

Remarks:

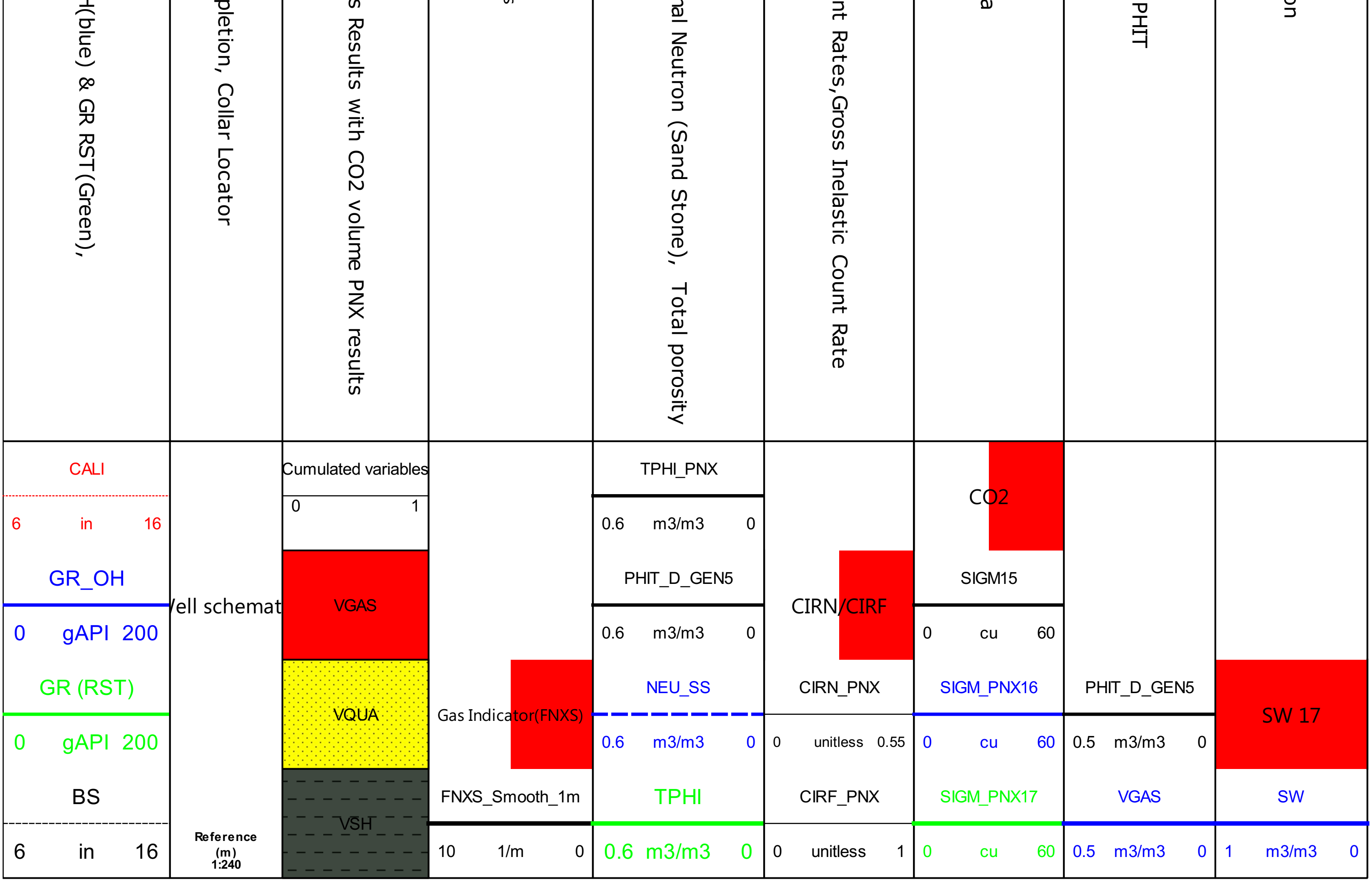
The PNX results was used to estimate the C02 volume ans saturation in combination with the OH petrophysical interpretation. Excellent match was observed between PNX runs of 2016 & 2017 and also between PNX and RST results.

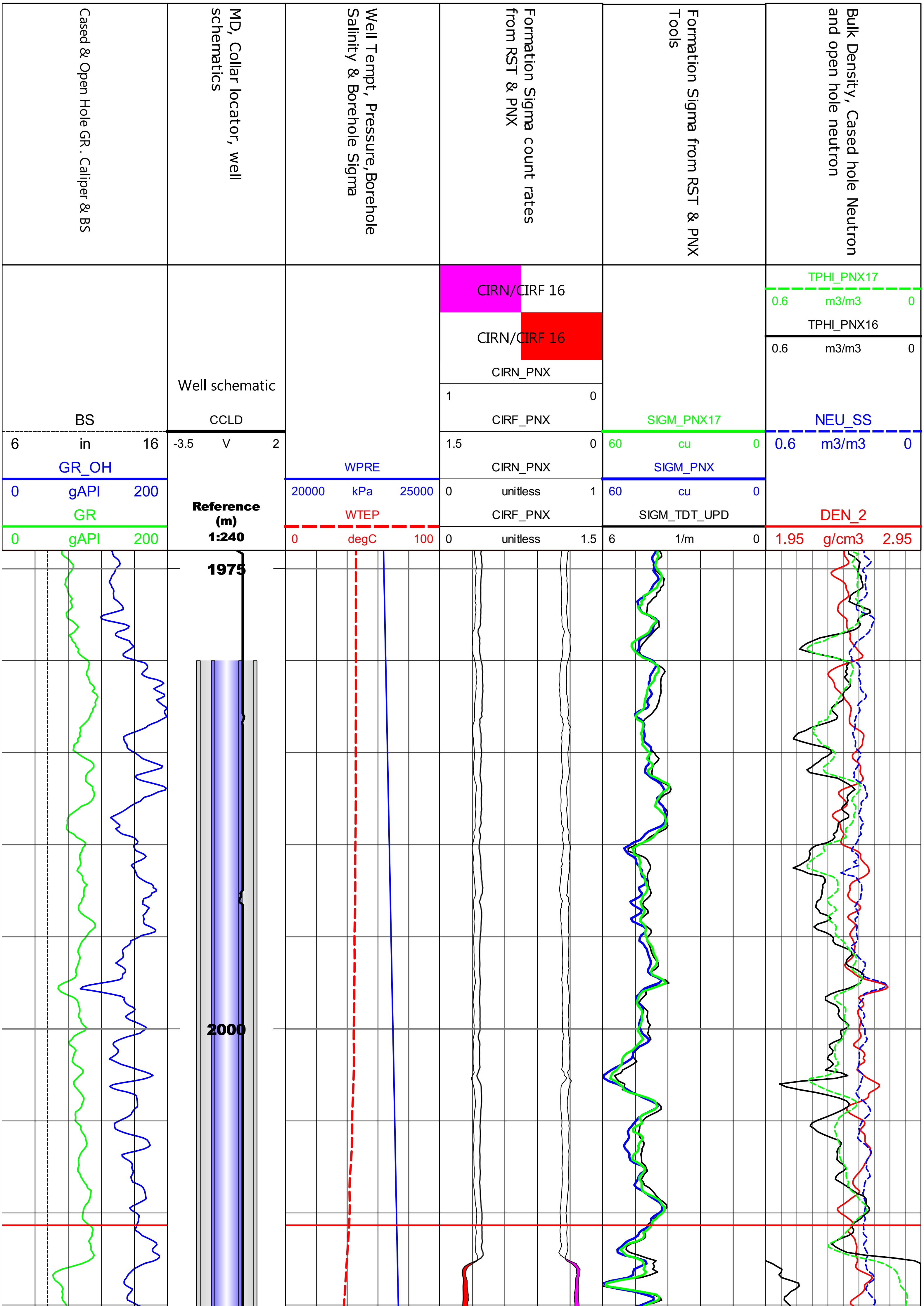
SCL RADWAY 7-11-59-20

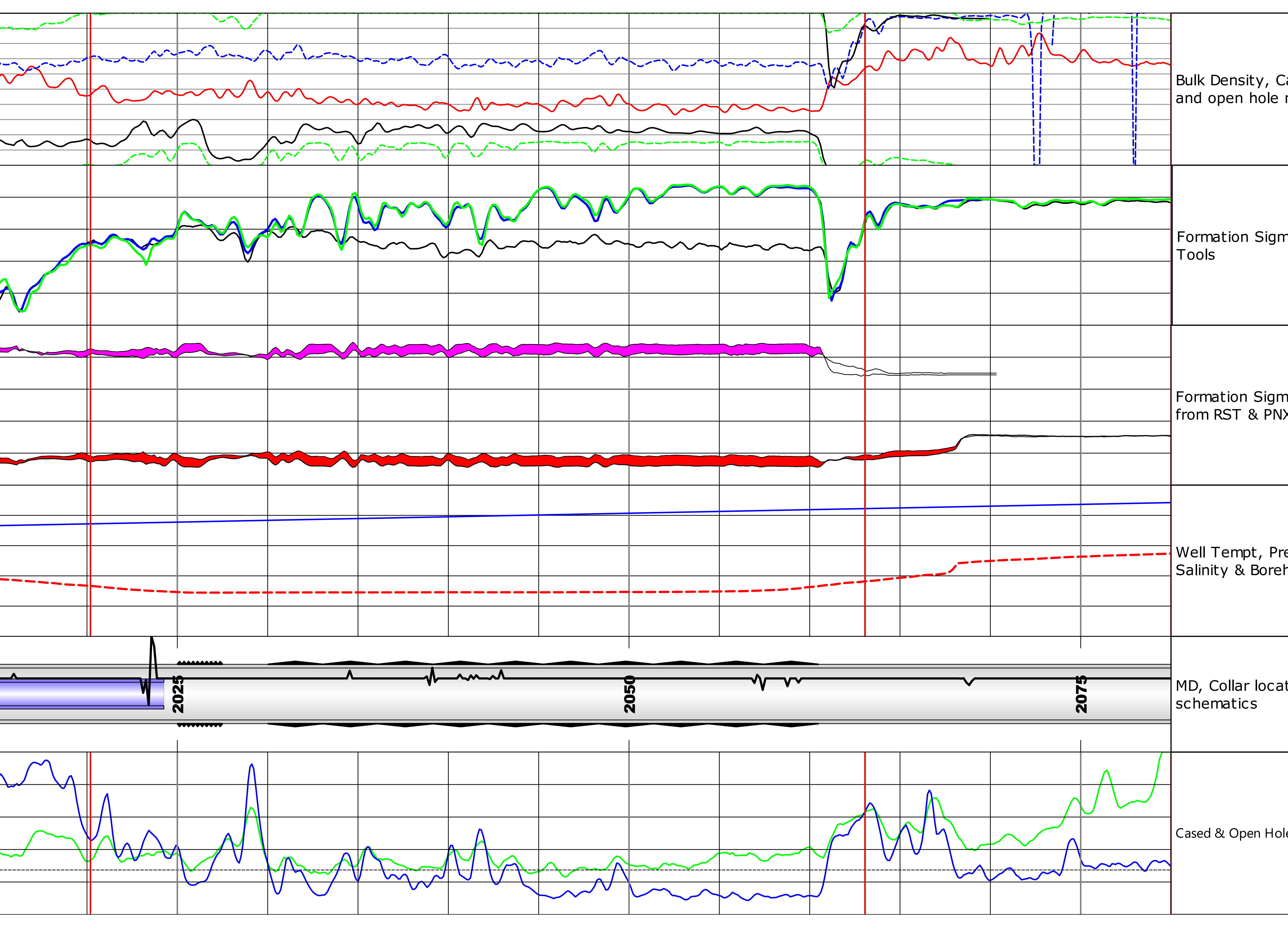




Water Saturatio
C02 Volumes &
Formation Sigm
Near & Far Cou
TPHI, OH Therm
Fast Neutron Ratios
OH Petrophysics
MD & Well Com
2025
2050
Gamma Ray OH


H(blue) & GR RST(Green),
pletion, Collar Locator
s Results with CO2 volume PNX results
al Neutron (Sand Stone), Total porosity
nt Rates,Gross Inelastic Count Rate
PHIT
CALI
6 in 16
GR_OH
0 gAPI 200
GR (RST)
0 gAPI 200
BS
6 in 16
Vell schemat
Reference (m) 1:240
Cumulated variables
0 1
VGAS
VQUA
VSH
Gas Indicator(FNXS)
FNXS_Smooth_1m
10 1/m 0
TPHI_PNX
0.6 m3/m3 0
PHIT_D_GEN5
0.6 m3/m3 0
NEU_SS
0.6 m3/m3 0
TPHI
0.6 m3/m3 0
CIRN/CIRF
CIRN_PNX
0 unitless 0.55
CIRF_PNX
0 unitless 1
CO2
SIGM15
0 cu 60
SIGM_PNX16
0 cu 60
SIGM_PNX17
0 cu 60
PHIT_D_GEN5
0.5 m3/m3 0
VGAS
0.5 m3/m3 0
SW 17
SW
1 m3/m3 0


Cased & Open Hole GR . Caliper & BS
MD, Collar locator, well schematics
Well Tempt, Pressure,Borehole Salinity & Borehole Sigma
Formation Sigma count rates from RST & PNX
Formation Sigma from RST & PNX Tools
Bulk Density, Cased hole Neutron and open hole neutron
BS
6 in 16
GR_OH
0 gAPI 200
GR
0 gAPI 200
Well schematic
CCLD
-3.5 V 2
Reference (m) 1:240
WPRE
20000 kPa 25000
WTEP
0 degC 100
CIRN/CIRF 16
CIRN/CIRF 16
CIRN_PNX
1 0
CIRF_PNX
1.5 0
CIRN_PNX
0 unitless 1
CIRF_PNX
0 unitless 1.5
SIGM_PNX17
60 cu 0
SIGM_PNX
60 cu 0
SIGM_TDT_UPD
6 1/m 0
TPHI_PNX17
0.6 m3/m3 0
TPHI_PNX16
0.6 m3/m3 0
NEU_SS
0.6 m3/m3 0
DEN_2
1.95 g/cm3 2.95
1975
2000


Bulk Density, Ca
and open hole r
Formation Sigm
Tools
Formation Sigm
from RST & PNX
Well Tempt, Pre
Salinity & Boreh
2025
2050
2075
MD, Collar locat
schematics
Cased & Open Hole

e GR. Caliper & BS	or, well	essure, Borehole hole Sigma	a count rates X	a from RST & PNX	ased hole Neutron neutron
			CIRN/CIRF 16		TPHI_PNX17
					0.6 m3/m3 0
			CIRN/CIRF 16		TPHI_PNX16
					0.6 m3/m3 0
			CIRN_PNX		
	Well schematic		1 0		
BS	CCLD		CIRF_PNX	SIGM_PNX17	NEU_SS
6 in 16	-3.5 V 2		1.5 0	60 cu 0	0.6 m3/m3 0
GR_OH		WPRE	CIRN_PNX	SIGM_PNX	
0 gAPI 200	**Reference (m) 1:240**	20000 kPa 25000	0 unitless 1	60 cu 0	
GR		WTEP	CIRF_PNX	SIGM_TDT_UPD	DEN_2
0 gAPI 200		0 degC 100	0 unitless 1.5	6 1/m 0	1.95 g/cm3 2.95

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COMPANY: SHELL CANADA ENERGY

WELL: SCL RADWAY 7-11-59-20

PROVINCE: **MD**

FIELD: RADWAY

Analysis Behind Casing
Pulsed Neutron eXtreme Tool(PNX)

APPENDIX C: 2017 MICROSEISMIC LOCATABLE EVENTS

Location, time and magnitude for the locatable events detected in 2017. All events do not constitute an MMV trigger and were located in the Precambrian basement. The event magnitudes are small (less than moment magnitude of 0.1 for locatable events in the AOR).
For reference, the BCS injection zone is located at approximately 1430m TVDSS.

Event	Date	Time	TVDss (m)	Northing (m)	Easting (m)	Moment Magnitude	Formation
1	08/01/2017	0:01:06	2753	5995322	370696	-0.7	Precambrian
2	09/01/2017	14:57:57	3121	5995558	370794	-0.7	Precambrian
3	09/01/2017	18:21:41	3038	5995488	370960	-0.6	Precambrian
4	14/01/2017	6:17:30	3108	5995470	370777	-1	Precambrian
5	14/01/2017	20:01:45	2853	5995307	370676	-0.7	Precambrian
6	16/01/2017	14:13:57	3071	5995482	370970	-0.6	Precambrian
7	17/01/2017	15:46:12	3003	5995457	370832	-1	Precambrian
8	17/01/2017	17:01:08	2601	5998196	369001	-0.8	Precambrian
9	17/01/2017	21:00:46	2953	5995410	370716	-0.4	Precambrian
10	22/01/2017	4:22:30	3047	5995506	370834	-0.4	Precambrian
11	24/01/2017	16:26:59	3113	5995521	370937	-1	Precambrian
12	25/01/2017	22:36:47	3100	5995606	370925	-1.1	Precambrian
13	27/01/2017	19:07:11	3268	5995545	370798	-1.1	Precambrian
14	28/01/2017	1:28:50	2897	5995384	370968	-0.5	Precambrian
15	28/01/2017	23:02:49	1581	5997734	370764	-1.1	Precambrian
16	29/01/2017	0:18:30	1607	5997738	370792	-1.7	Precambrian
17	29/01/2017	13:34:18	3088	5995548	370885	-1.1	Precambrian
18	30/01/2017	13:18:09	2980	5995445	370926	-0.6	Precambrian
19	05/02/2017	0:24:26	2992	5995489	370811	0.1	Precambrian
20	05/02/2017	1:01:46	2999	5995480	370786	-0.2	Precambrian
21	05/02/2017	1:02:08	2863	5995377	370842	-0.4	Precambrian
22	05/02/2017	1:04:21	2889	5995359	370762	-0.4	Precambrian
23	05/02/2017	23:32:27	3079	5995523	370880	-0.2	Precambrian
24	07/02/2017	1:29:53	3020	5995498	370890	0.1	Precambrian
25	07/02/2017	13:49:45	2850	5997346	368787	-1.1	Precambrian
26	12/02/2017	0:33:14	3005	5995501	370968	-0.5	Precambrian
27	12/02/2017	17:13:42	2869	5995398	370985	0.1	Precambrian
28	12/02/2017	17:15:35	2987	5995483	370983	-0.8	Precambrian
29	13/02/2017	8:04:57	2989	5995488	370963	-0.9	Precambrian
30	13/02/2017	8:23:39	2950	5995444	370842	-0.9	Precambrian
31	13/02/2017	18:52:53	2980	5995443	371004	-0.6	Precambrian
32	14/02/2017	1:14:58	2946	5995456	370981	-0.5	Precambrian
33	14/02/2017	7:01:27	2956	5995413	370974	-0.7	Precambrian
34	14/02/2017	7:43:12	3169	5995615	370906	-1	Precambrian

Event	Date	Time	TVDss (m)	Northing (m)	Easting (m)	Moment Magnitude	Formation
35	14/02/2017	21:34:33	3031	5995492	370978	-0.3	Precambrian
36	15/02/2017	6:29:05	2968	5995419	370764	-1.2	Precambrian
37	15/02/2017	17:44:52	2987	5995458	371003	-0.9	Precambrian
38	16/02/2017	11:30:38	2878	5995368	371000	-0.7	Precambrian
39	17/02/2017	11:33:07	2961	5995441	370965	-0.8	Precambrian
40	18/02/2017	19:36:08	2968	5995391	370964	-0.1	Precambrian
41	18/02/2017	19:42:37	3009	5995441	370982	-0.4	Precambrian
42	20/02/2017	13:15:39	3014	5995365	370958	-0.7	Precambrian
43	20/02/2017	13:15:43	3013	5995451	370978	-0.8	Precambrian
44	21/02/2017	10:17:11	2919	5995388	371011	-0.7	Precambrian
45	21/02/2017	21:18:10	3014	5995458	370963	-0.9	Precambrian
46	22/02/2017	19:30:15	2940	5995445	370960	0.1	Precambrian
47	05/03/2017	14:22:54	2992	5995499	370989	-0.7	Precambrian
48	07/03/2017	1:44:41	2997	5995415	370957	-0.8	Precambrian
49	07/03/2017	8:19:57	3638	5995129	372452	-0.8	Precambrian
50	11/03/2017	8:54:00	3177	5995527	371085	-1.2	Precambrian
51	18/03/2017	17:54:29	3148	5995661	371069	-0.4	Precambrian
52	22/03/2017	8:31:44	2648	5999780	361029	-0.4	Precambrian
53	23/03/2017	3:38:19	2957	5995441	370912	-1.2	Precambrian
54	24/03/2017	16:27:12	2605	5997779	371601	-1.6	Precambrian
55	28/03/2017	10:22:50	3017	5995471	370918	-0.5	Precambrian
56	30/03/2017	21:16:16	3042	5995487	370912	-1	Precambrian
57	06/04/2017	15:58:04	1552	5998070	365907	-0.5	Precambrian
58	11/04/2017	1:35:50	2915	5995475	371042	-1	Precambrian
59	15/04/2017	12:45:33	2869	5995436	371327	-0.2	Precambrian
60	15/04/2017	18:05:51	2594	5997955	369672	-1.4	Precambrian
61	17/04/2017	7:35:19	3045	5995475	371002	-0.5	Precambrian
62	17/04/2017	18:24:44	2953	5995399	370883	0.1	Precambrian
63	18/04/2017	0:14:46	3181	5995613	370911	-0.2	Precambrian
64	18/04/2017	3:32:06	3009	5995476	370929	-0.5	Precambrian
65	18/04/2017	12:39:32	3130	5995577	370900	-0.6	Precambrian
66	02/05/2017	23:05:52	2995	6001652	360891	-0.4	Precambrian
67	07/05/2017	0:32:49	2888	5995365	371391	-0.9	Precambrian
68	07/05/2017	18:00:15	2164	5999939	370197	-1	Precambrian
69	19/05/2017	8:08:40	2914	5996897	376547	-0.4	Precambrian
70	10/06/2017	13:12:04	2896	5998512	365385	-0.1	Precambrian
71	12/06/2017	0:06:02	3155	5995408	371049	-1.1	Precambrian
72	21/06/2017	2:01:16	2441	5997833	368821	-0.9	Precambrian
73	29/06/2017	1:42:45	2616	5999699	370610	-1.2	Precambrian
74	02/07/2017	22:19:02	1941	5997919	370872	-1.1	Precambrian
75	04/07/2017	22:42:12	3096	5995310	370889	-1	Precambrian
76	05/07/2017	4:19:55	2631	5997477	369784	-1.2	Precambrian
77	06/07/2017	15:35:45	2501	5996886	367136	-0.8	Precambrian
78	13/07/2017	21:44:08	1937	5997191	372822	-1.2	Precambrian

Event	Date	Time	TVDss (m)	Northing (m)	Easting (m)	Moment Magnitude	Formation
79	03/08/2017	0:49:20	2501	5997267	368263	-0.2	Precambrian
80	03/08/2017	7:01:02	2500	5998961	372477	-0.9	Precambrian
81	06/08/2017	8:12:58	2500	5998944	372768	-0.8	Precambrian
82	09/08/2017	16:59:55	2812	5996764	370858	-1.1	Precambrian
83	10/08/2017	20:35:57	2893	5995430	370873	0.1	Precambrian
84	19/08/2017	0:45:19	1702	5997405	371276	-1.5	Precambrian
85	28/08/2017	16:21:14	2527	5997804	367059	-0.5	Precambrian
86	25/09/2017	2:54:21	2996	5996942	368611	-1.1	Precambrian
87	25/09/2017	13:39:56	2500	5998006	376660	-0.4	Precambrian
88	26/09/2017	20:29:04	2686	6001652	360891	-0.2	Precambrian
89	27/09/2017	9:03:53	2704	5988267	380218	0	Precambrian
90	30/09/2017	19:41:14	1897	5997466	366935	-0.3	Precambrian
91	01/10/2017	11:58:18	2292	5997783	370114	-1.3	Precambrian
92	23/10/2017	2:20:33	2581	5995986	368814	-1.1	Precambrian
93	25/10/2017	20:59:14	1800	5996710	376553	-0.4	Precambrian
94	25/10/2017	21:54:48	1976	5996438	376637	-0.3	Precambrian
95	25/10/2017	21:57:08	2394	5997216	376758	-0.4	Precambrian
96	25/10/2017	22:00:10	1997	5997138	376706	-0.3	Precambrian
97	25/10/2017	22:23:45	1856	5996465	376645	-0.6	Precambrian
98	25/10/2017	22:27:57	1824	5995488	376270	-0.6	Precambrian
99	25/10/2017	22:30:37	2372	5996239	376658	-0.8	Precambrian
100	25/10/2017	22:55:59	2159	5996882	376913	-0.3	Precambrian
101	26/10/2017	22:24:59	2185	5996532	376659	-0.5	Precambrian
102	28/10/2017	18:48:16	2233	5995549	368173	-1.1	Precambrian
103	11/11/2017	19:53:14	2555	5994078	377987	-0.6	Precambrian
104	18/11/2017	19:27:40	2121	5996426	368847	-0.7	Precambrian
105	21/11/2017	7:30:19	2346	5996522	368949	-1.2	Precambrian
106	01/12/2017	6:51:35	3000	5995196	371405	-1.1	Precambrian
107	07/12/2017	0:56:41	2402	5997697	371943	-1.3	Precambrian
108	07/12/2017	17:04:18	2094	5999947	370091	-0.9	Precambrian
109	13/12/2017	4:47:44	1538	5998169	371309	-1.7	Precambrian
110	25/12/2017	7:25:37	1486	5999608	373166	-1.2	Precambrian
111	27/12/2017	14:36:47	2446	5997735	370396	-1.3	Precambrian