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July 6, 2017

via email only: [ThermalInsitu@aer.ca](mailto:ThermalInsitu@aer.ca)

Alberta Energy Regulator  
Suite 1000, 250 – 5<sup>th</sup> Street SW  
Calgary, Alberta  
T2P 0R4  
Attention: Lindsay Kopf, P.Eng. Manager Industry Relations

Dear Ms. Kopf,

Re: Nexen Long Lake – Revision 2 Biennial Report of Upgrader Operations 2015 and 2016

Please find attached a revised copy of Nexen Energy ULC's (Nexen's) Long Lake Biennial Report of Upgrader Operations for 2015 and 2016 in response to your clarification questions and errata dated June 19, 2017. This report is being submitted pursuant to Clause 20 as stated in the Alberta Energy Regulator Scheme Approval 9485, as amended.

Should you have any questions or concerns please do not hesitate to contact [deepa.thomas@nexencnoocld.com](mailto:deepa.thomas@nexencnoocld.com) or 403-699-5115.

Sincerely,

A handwritten signature in blue ink that reads 'Deepa Thomas'. The signature is written in a cursive, flowing style.

Deepa Thomas, Regulatory Specialist



**Nexen Energy ULC Long Lake Upgrader  
Biennial Report of Operations for 2015 and 2016  
Revised**

**AER Approval No. 9485 (as amended)**

**Submitted to: Alberta Energy Regulator  
July 2017**

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## 1.0 INTRODUCTION

Nexen Energy ULC's (Nexen) Long Lake is situated approximately 45 km southeast of Fort McMurray in the Regional Municipality of Wood Buffalo in northeastern Alberta (Figure 1.1). Project approval is granted by the Alberta Energy Regulator (AER) Approval No. 9485, as amended, for the recovery and upgrading of bitumen. Specifically, the Approval states:

*Clause (6) Unless otherwise stipulated by the AER, the production of bitumen from the project areas identified in Appendix A shall not exceed 33,600 m<sup>3</sup>/d on an annual average basis*

*Clause (7) Unless otherwise stipulated by the AER, the bitumen feed into the upgraders shall not exceed 22,400 m<sup>3</sup>/d on an annual average basis.*

As required in Long Lake's AER Scheme Approval No 9485 as amended, this report provides a summary of the 2015 and 2016 Long Lake Upgrader performance. This is specifically to fulfill the requirement of Clause 20:

*The Operator shall file with the AER on or before February 28 of the year following start-up of the upgrader facilities and every second year thereafter, or on such date or frequency as the AER may stipulate, a report summarizing:*

*a) The performance of the upgrading facilities, which shall include as a minimum:*

*i) a discussion of the product yields and qualities and energy efficiency as compared with the design expectation,*

*ii) the results of any studies undertaken to identify opportunities for improved yield and energy efficiency, and*

*iii) a description of any modifications made to improve yield and energy efficiency.*

*b) The schedule to add facilities to convert the upgrader product (A-fuel) to sweet syngas for use as a replacement for natural gas in the scheme.*

*c) The performance of the A-fuel gasification facilities and comparison with design expectations.*

## 2.0 OVERVIEW

The Long Lake Facility (Long Lake) consists of an Upgrader and SAGD Facilities. The Upgrader includes an Air Separation Unit (ASU), OrCrude™ Unit, Asphaltene Gasification Unit (AGU), Hydrocracker Unit (HCU), Sulphur Recovery Unit (SRU) and Utilities and Offsites (U&O). The primary SAGD facility is comprised of a Central Processing Facility (CPF), which includes Inlet Separation and De-Oiling, a Water Treatment Plant, Steam Generation and 2 Cogeneration Units, 15 wellpads, pipelines, and a network of disposal and source water wells. Long Lake is located in Section 31, Township 85, Range 6, W4M, which is approximately 40 km southeast of Fort McMurray, AB and approximately 8 km southeast of Anzac, AB (see Figure 1 - Long Lake Location). In 2014 Nexen brought the Kinosis 1A (K1A) facility on line, to provide additional bitumen and improve Upgrader yields. This facility is comprised of a Steam Generation Facility (SGF) with 4 Once Through Steam Generators (OTSGs), 37 well pairs on 2 well pads, and associated pipelines. K1A is located (Section 35, Township 84, Range 7, W4M), approximately 55km southeast of Fort McMurray, AB and approximately 15 km south of Anzac, AB.

Long Lake began steam injection in mid-April 2007. Startup of the Upgrader and production of first Premium Synthetic Crude (PSC) was announced on January 22, 2009. K1A began steam injection in August of 2014 and

by the end of 2014, well pairs at Kinosis Phase 1A's Well Pad 1 and Well Pad 2 were in the circulation phase.

In 2015, the Upgrader continued to increase its processing capabilities but has yet to reach design capacity processing. On July 15, 2015, Nexen discovered an emulsion line leak at K1A which resulted in an issuance of Environmental Protection Order. The pipeline and K1A remain shut-in.

On January 15, 2016 there was an explosion, at the Hydrocracker Unit Compressor Building, in the Upgrader area of Nexen's Long Lake Facility. This incident resulted in the shut-in of the Upgrader. In addition to the shut-in of the Upgrader, the Fort McMurray wildfire (Wildfire) also impacted operations at Long Lake in May and June, 2016. The Wildfire caused a forced evacuation of Fort McMurray on May 3, 2016 and a complete evacuation and shut down of Long Lake on May 4, 2016. Some units in the Upgrader were brought back online in June 2016 to support SAGD operations while others remain shut-in. Winterization of the Upgrader was completed in September 2016. The Upgrader will remain shut-in until decisions on the repair and start-up are made.

The following sections provide a detailed update on the Long Lake Upgrader for the period extending from January 1, 2015 to December 31, 2016.

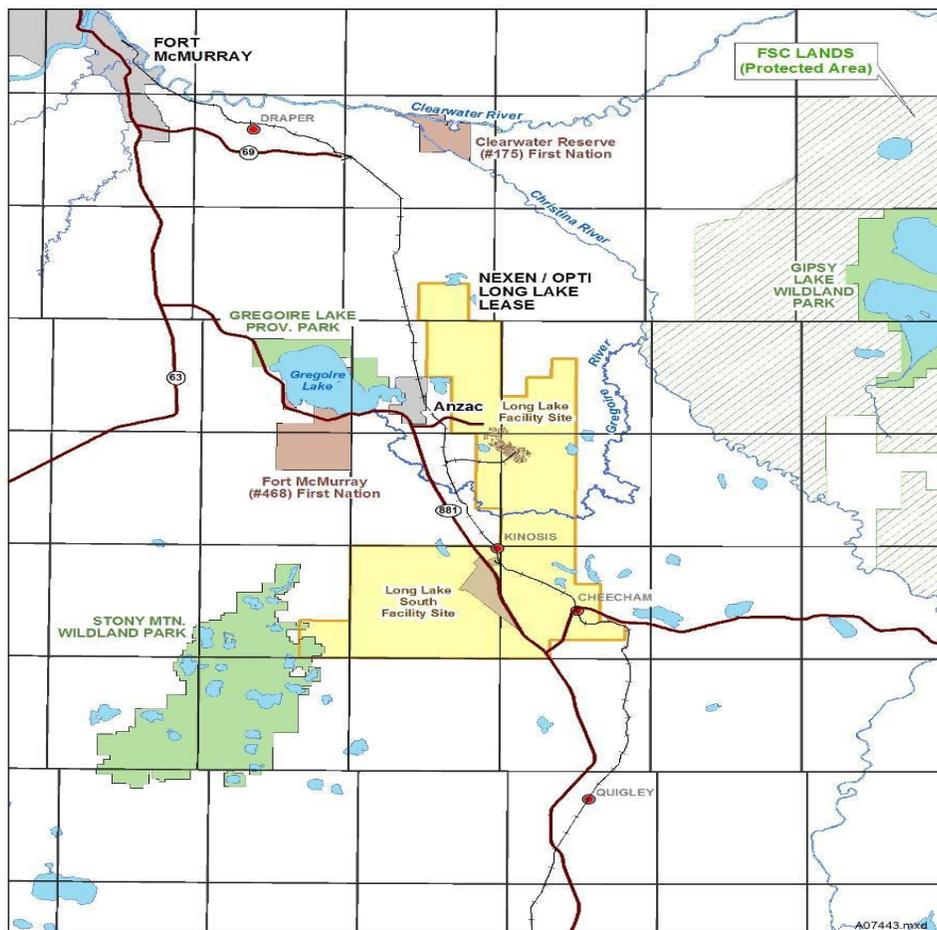


Figure 1.1 - Long Lake Location Map

### **3.0 PRODUCTION SUMMARY**

The production summary for the Upgrader for January 2015 to December 2016 is presented in Tables 3.1 to Tables 3.4. These are annual compilations of the performance data submitted to the AER in the S-23 Monthly Oil Sands Processing Plant Statements.

**Table 3.1 - 2015 Upgrader Production Summary**

2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
<b>Bitumen (m<sup>3</sup>)</b>													
Total Receipts	188,388.6	134,776.5	227,122.9	235,949.0	222,867.7	578.4	162,805.3	251,476.6	234,045.7	252,797.3	103,829.7	112,966.9	2,127,604.6
Further Processing	188,317.1	134,775.7	227,101.3	235,945.1	222,753.5	578.4	162,804.9	251,476.2	234,043.5	252,757.3	103,827.2	112,966.9	2,127,347.1
Total Deliveries	71.5	0.8	21.6	3.9	114.2	0.0	0.4	0.4	2.2	40.0	2.5	0.0	257.5
<b>Diluent (m<sup>3</sup>)</b>													
Total Receipts	97,674.1	80,869.7	117,169.1	114,426.7	113,893.6	634.5	101,442.8	131,308.5	112,108.6	131,753.4	66,767.4	62,799.8	1,130,848.2
Further Processing	17,070.6	59,084.5	21,646.9	1,526.6	16,422.9	634.5	22,948.7	2,478.6	4,236.5	2,840.5	11,161.3	9,295.0	169,346.6
Total Deliveries	80,603.5	21,785.2	95,522.2	112,900.1	97,470.7	0.0	78,494.1	128,829.9	107,872.1	128,912.9	55,606.1	53,504.8	961,501.6
<b>Intermediate Hydrocarbons (m<sup>3</sup>)</b>													
Opening Inventory	19,204.1	17,513.7	17,412.9	9,511.3	9,170.6	6,928.0	9,418.7	9,862.4	10,537.7	10,976.6	13,016.4	14,174.5	
Production	133,043.6	94,945.8	155,254.1	161,702.7	150,907.1	532.7	118,840.9	170,983.0	159,959.7	171,175.7	67,089.3	66,371.9	1,450,806.5
Further Processing	134,733.9	95,046.6	163,155.7	162,043.4	153,149.7	0.0	118,397.2	170,307.7	159,520.8	169,135.9	65,931.2	69,695.3	1,461,117.4
Measurement Difference	-0.1	0.0	0.0	0.0	0.0	-1,958.0	0.0	0.0	0.0	0.0	0.0	0.0	-1,958.1
Closing Inventory	17,513.7	17,412.9	9,511.3	9,170.6	6,928.0	9,418.7	9,862.4	10,537.7	10,976.6	13,016.4	14,174.5	10,851.1	
<b>Synthetic Crude Oil (m<sup>3</sup>)</b>													
Opening Inventory	3,471.3	9,367.2	8,837.3	8,873.2	9,371.7	10,452.4	9,137.2	8,770.8	9,235.7	8,879.9	9,191.7	8,942.7	
Total Receipts	8,738.3	23,174.5	3,965.9	0.0	203.9	32,185.7	45,117.1	203.7	204.6	0.0	38,724.0	38,798.8	191,316.5
Production	155,229.3	161,698.5	199,892.9	180,990.9	185,604.8	0.0	141,787.9	188,075.8	180,213.4	191,850.2	82,509.0	88,198.3	1,756,051.0
Deliveries to Enbridge	121,491.8	77,827.1	170,605.3	170,312.8	151,779.5	0.0	121,750.0	184,549.2	180,749.0	191,456.2	80,476.8	87,614.1	1,538,611.8
Deliveries to SAGD	36,579.9	107,795.6	33,217.6	10,179.6	32,948.5	33,064.5	65,301.5	3,265.4	24.8	82.2	41,005.2	39,703.5	403,168.3
Inventory adjustment	0.0	0.0	0.0	0.0	0.0	436.4	0.0	0.0	0.0	0.0	0.0	0.0	436.4
Closing Inventory	9,367.2	8,837.3	8,873.2	9,371.7	10,452.4	9,137.2	8,990.7	9,235.7	8,879.9	19,191.7	8,942.7	8,622.2	
<b>Process Gas Production (10<sup>3</sup> m<sup>3</sup>)</b>	179,358.0	127,094.3	209,205.1	211,280.2	213,173.0	3,745.4	153,753.0	234,908.7	218,556.6	243,574.4	106,536.8	122,288.7	2,023,474.2
<b>Natural Gas Purchased (10<sup>3</sup> m<sup>3</sup>)</b>	14,903.0	14,945.9	12,046.7	9,011.8	9,140.6	3,578.8	12,250.0	10,711.0	11,391.1	9,929.3	19,480.3	19,723.6	147,112.1
<b>Electricity (MWh)</b>													
Imported	70,312.0	63,875.0	72,203.0	71,155.0	72,574.0	33,294.0	68,232.0	77,746.0	72,736.0	71,943.0	62,725.0	68,994.0	805,789.0
Generation	1,144.2	112.8	120.6	0.0	0.0	0.0	110.0	118.0	110.0	2,344.0	1,968.0	120.0	6,147.6

**Table 3.2 - 2016 Upgrader Production Summary**

2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
<b>Bitumen (m<sup>3</sup>)</b>													0.0
Total Receipts	90,799.5	0.0	57.6	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90,905.1
Further Processing	90,799.5	0.0	57.6	48.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	90,905.1
Total Deliveries	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<b>Diluent (m<sup>3</sup>)</b>													
Total Receipts	48,752.2	0.0	41.6	35.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48,829.1
Further Processing	2,638.1	0.0	41.6	35.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2,715.0
Total Deliveries	46,114.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46,114.1
<b>Intermediate Hydrocarbons (m<sup>3</sup>)</b>													0.0
Opening Inventory	10,851.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	
Production	57,664.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57,664.9
Further Processing	59,220.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	59,220.3
Deliveries to SAGD	856.6							3,054.1					3,910.7
Measurement Difference	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Closing Inventory	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	8,439.2	
<b>Synthetic Crude Oil (m<sup>3</sup>)</b>													
Opening Inventory	8,622.2	11,126.8	10,665.2	9,856.7	10,825.0	8,145.3	8,133.8	9,927.6	10,847.9	10,552.8	9,657.3	12,101.5	
Total Receipts	51,466.6	96,524.6	102,964.4	93,296.9	9,996.5	0.0	114,170.0	178,666.8	167,606.5	191,697.5	197,597.3	222,775.8	1,426,762.9
Production	68,7315.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68,735.7
Deliveries to Enbridge	70,533.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70,533.2
Deliveries to SAGD	47,164.5	94,341.6	103,224.3	89,810.4	12,726.6	0.0	111,985.6	177,369.4	167,148.7	193,082.7	194,494.8	225,292.2	1,416,640.8
Inventory adjustment	0.0	2,644.6	548.6	2,518.2	-50.4	11.5	390.6	377.1	752.9	-489.7	658.3	1,833.7	9,195.4
Closing Inventory	11,126.8	10,665.2	9,856.7	10,825.0	8,145.3	8,133.8	9,927.6	10,847.9	10,552.8	9,657.3	12,101.5	7,751.4	
<b>Process Gas Production (10<sup>3</sup> m<sup>3</sup>)</b>	98,902.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98,902.1
<b>Natural Gas Purchased (10<sup>3</sup> m<sup>3</sup>)</b>	19,231.0	17,383.9	17,787.7	12,539.3	1,053.1	236.0	2,902.9	4,985.9	7,435.5	4,655.9	3,502.6	4,125.3	95,839.1
<b>Electricity (MWh)</b>													
Imported	56,942.0	34,333.0	36,689.0	35,507.0	3,062.0	7.0	2,649.0	27,558.0	22,986.0	3,967.0	4,054.0	4,243.0	231,997.0
Generation	89.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	134.0

**Table 3.3 - Upgrading Yields**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
<b>2015 Instantaneous Balanced Yield</b>	73	76	78	76	76	NA	73	74	75	75	69	70
<b>2016 Instantaneous Balanced Yield</b>	73	NA	NA	NA	NA							

The design yield objective for the Upgrader, as specified in the original application (OPTI 2000), is approximately 79% to 83% and was predicted to vary depending on feed quality. It was calculated as:

$$\text{(SCO production – Diluent for further processing) / Bitumen for further processing}$$

The upgrading yields shown in Table 3.3 are based on the OrCrude™ yield and Hydrocracker yield. The resulting product, named “instantaneous balanced yield” accounts for monthly inventory changes. The OrCrude™ yield and Hydrocracker yields are described in the S-23 Manual, approved by the AER, and are repeated below:

$$\text{OrCrude™ Yield} = H3/B5 * 100\%$$

$$HCU \text{ Yield} = \frac{SC3 - \left[ D5 \left( \frac{SC3}{D5 + H5} \right) \right]}{H5} \times 100\%$$

Throughout 2015, the average instantaneous balanced yield was an approximated 74%, while the yield prior to the shut-in was 73% in January 2016.

The Upgrader is integrated with the SAGD oil sands plant and electrical generation facility, resulting in several water streams flowing between these portions of Long Lake. Table 3.4 shows the demineralized water that the Upgrader receives and the Process Oily Water sent from Upgrader to the SAGD CPF. This reflects the water volumes for these streams reported to Petrinex for the SAGD facility and is not a complete water balance for the Upgrader.

**Table 3.4 –Upgrader Water Streams**

	Water Received into Upgrader (m <sup>3</sup> )		Process Oily Water from Upgrader (m <sup>3</sup> )	
	freshwater	water	freshwater	water
Jan-2015	117,378.0	86,290.4	33,071.0	26,845.1
Feb-2015	93,651.2	74,681.1	51,500.0	44,855.1
Mar-2015	109,379.3	89,857.0	56,927.3	50,012.0
Apr-2015	92,826.4	75,977.2	47,478.8	42,746.2
May-2015	98,550.5	78,272.0	47,020.8	42,505.6
Jun-2015	37,458.8	5,223.8	1,236.6	194.9
Jul-2015	98,041.5	73,105.5	40,756.9	34,352.3
Aug-2015	97,192.8	97,736.9	52,628.4	59,362.7
Sep-2015	95,101.2	100,113.3	50,269.8	62,338.9
Oct-2015	98,678.0	101,590.7	56,505.5	63,981.5
Nov-2015	98,131.3	73,888.1	51,827.9	43,215.3
Dec-2015	105,022.4	78,878.5	55,113.0	45,774.7
<b>Total</b>	<b>1,141,411.4</b>	<b>935,614.5</b>	<b>544,336.0</b>	<b>516,184.3</b>
Jan-2016	100,931.9	77,250.2	51,635.8	43,149.8
Feb-2016	67,218.7	42,218.3	24,749.3	16,867.2
Mar-2016	51,569.3	57,296.4	23,381.1	27,653.6
Apr-2016	40,985.6	37,822.5	11,527.2	10,989.0
May-2016	4,071.0	2,544.4		
Jun-2016				
Jul-2016	6,422.6	5,564.4		
Aug-2016	20,016.2	14,792.3		
Sep-2016	30,062.2	12,784.7		
Oct-2016	13,660.2	18,034.3		
Nov-2016	11,999.6	10,460.1		
Dec-2016	12,914.0	13,276.8		
<b>Total</b>	<b>359,851.3</b>	<b>292,044.4</b>	<b>111,293.4</b>	<b>98,659.6</b>

## 4.0 ENVIRONMENTAL MANAGEMENT

The environmental performance at Long Lake is managed in an integrated fashion with the performance of the Upgrader, SAGD facility, and electrical generation facility as components.

The Long Lake continuous air monitoring station is located approximately 35 km southeast of Fort McMurray on the northern edge of the hamlet of Anzac and is operated by the Wood Buffalo Environmental Association. The Anzac Station contains analyzers that continuously measure SO<sub>2</sub>, O<sub>3</sub>, TRS, THC, NO, NO<sub>2</sub>, NO<sub>x</sub>, PM 2.5, wind speed and direction, and temperature.

There were 8 events in 2015 and 20 events in 2016 which exceeded the Alberta Ambient Air Quality Objectives (AAAQO). All of these events were attributed to forest fires burning in the region and are summarized as Tables 4.4 and 4.5

**Table 4.5 - 2015 Ambient Air Monitoring Exceedance Table**

Date / Time	Parameter	Concentration (ppb or $\mu\text{g}/\text{m}^3$ )	Limit	Exceedance Period	AER Reference #
6/29/15 0:00	PM <sub>2.5</sub>	78 $\mu\text{g}/\text{m}^3$	30 $\mu\text{g}/\text{m}^3$ 24 hr avg	24hr	300127
6/30/15 0:00	PM <sub>2.5</sub>	81 $\mu\text{g}/\text{m}^3$		24hr	300199
7/1/15 0:00	PM <sub>2.5</sub>	58 $\mu\text{g}/\text{m}^3$		24hr	300242
7/2/15 0:00	PM <sub>2.5</sub>	38 $\mu\text{g}/\text{m}^3$		24hr	300293
7/3/15 0:00	PM <sub>2.5</sub>	108 $\mu\text{g}/\text{m}^3$		24hr	300350
7/4/15 0:00	PM <sub>2.5</sub>	85 $\mu\text{g}/\text{m}^3$		24hr	300386
7/11/15 0:00	PM <sub>2.5</sub>	146 $\mu\text{g}/\text{m}^3$		24hr	300736
7/12/15 0:00	PM <sub>2.5</sub>	143 $\mu\text{g}/\text{m}^3$		24hr	300782

**Table 4.6 - 2016 Ambient Air Monitoring Exceedance Table**

Date / Time	Parameter	Concentration (ppb or $\mu\text{g}/\text{m}^3$ )	Limit	Exceedance Period	AER Reference #	
5/5/16 23:00	O <sub>3</sub>	138.0		1hr	311081	
5/6/16 0:00	PM <sub>2.5</sub>	223.0	30 $\mu\text{g}/\text{m}^3$ 24 hr avg	24hr	311080	
5/14/16 0:00	PM <sub>2.5</sub>	267.0		24hr	311658	
5/15/16 0:00	PM <sub>2.5</sub>	267.0		24hr	311441	
5/16/16 0:00	PM <sub>2.5</sub>	42.0		24hr	311492	
5/17/16 0:00	PM <sub>2.5</sub>	52.0		24hr	311552	
5/18/16 0:00	PM <sub>2.5</sub>	67.0		24hr	311608	
5/19/16 0:00	PM <sub>2.5</sub>	50.0		24hr	311680	
5/20/16 0:00	PM <sub>2.5</sub>	40.0		24hr	311731	
5/21/16 0:00	PM <sub>2.5</sub>	46.0		24hr	311748	
5/22/16 0:00	PM <sub>2.5</sub>	60.0		24hr	311825	
5/23/16 0:00	PM <sub>2.5</sub>	73.0		24hr	311877	
5/24/16 0:00	PM <sub>2.5</sub>	84.0		24hr	311926	
5/5/16 22:00	TRS	42.0			1hr	311080
5/5/16 23:00	TRS	12.0			1hr	311080
5/15/16 0:00	TRS	4.1		24hr	311422	
5/15/16 3:00	TRS	11.0		1hr	311422	
5/15/16 4:00	TRS	12.0		1hr	311422	
5/15/16 5:00	TRS	15.0		1hr	311422	
5/6/16 22:00	NO <sub>2</sub>	291.0		1hr	311080	

Air emissions, specifically sulphur dioxide (SO<sub>2</sub>) emissions, are managed through stack specific and site-wide emission limits. Potential impacts to the environment are monitored at various air monitoring locations. A summary table (Table 4.6) and map of the monitoring locations (Figure 4.2) are included below.

Figures 4.3 through to Figure 4.6 illustrate the ambient concentrations observed during the reporting period for this report.

The Annual Performance Presentations for 2015 and 2016 submitted to the AER also include a complete description of the SO<sub>2</sub> emissions, monitoring and regulatory compliance from the Long Lake Project for the reporting period.

**Table 4.7 - Passive Air Monitoring Locations**

Station Number	Station Location	Status
1	SAGD Pilot Site SE- near Pilot flare stack	Discontinued in December 2010
2	SAGD Pilot Site NW Rear of the Pilot	Discontinued in December 2010
3	02-32-085-06 W4M Source Well	Active
4	01-21-085-06 W4M Source Well	Active
5	13-31-085-06 W4M Source Well	Active
6	Nexen Tower	Active
7	Well Pad 9	Discontinued in January 2010
8	Well Pad 7	Active
9	Electrical Substation	Discontinued in December 2010
10	Beside Tankyard	Discontinued in December 2010
11	Near Kinosis Drilling Camp	Active
12	Anzac	Active
13	Gregoire Estates	Active
14	Mark Amy Centre	Active
15	Well Pad 11	Active
16	Sucker Lake	Active
17	Long Lake Sign	Active
18	02-12-85-06 W4M Source Well	Discontinued in May 2014

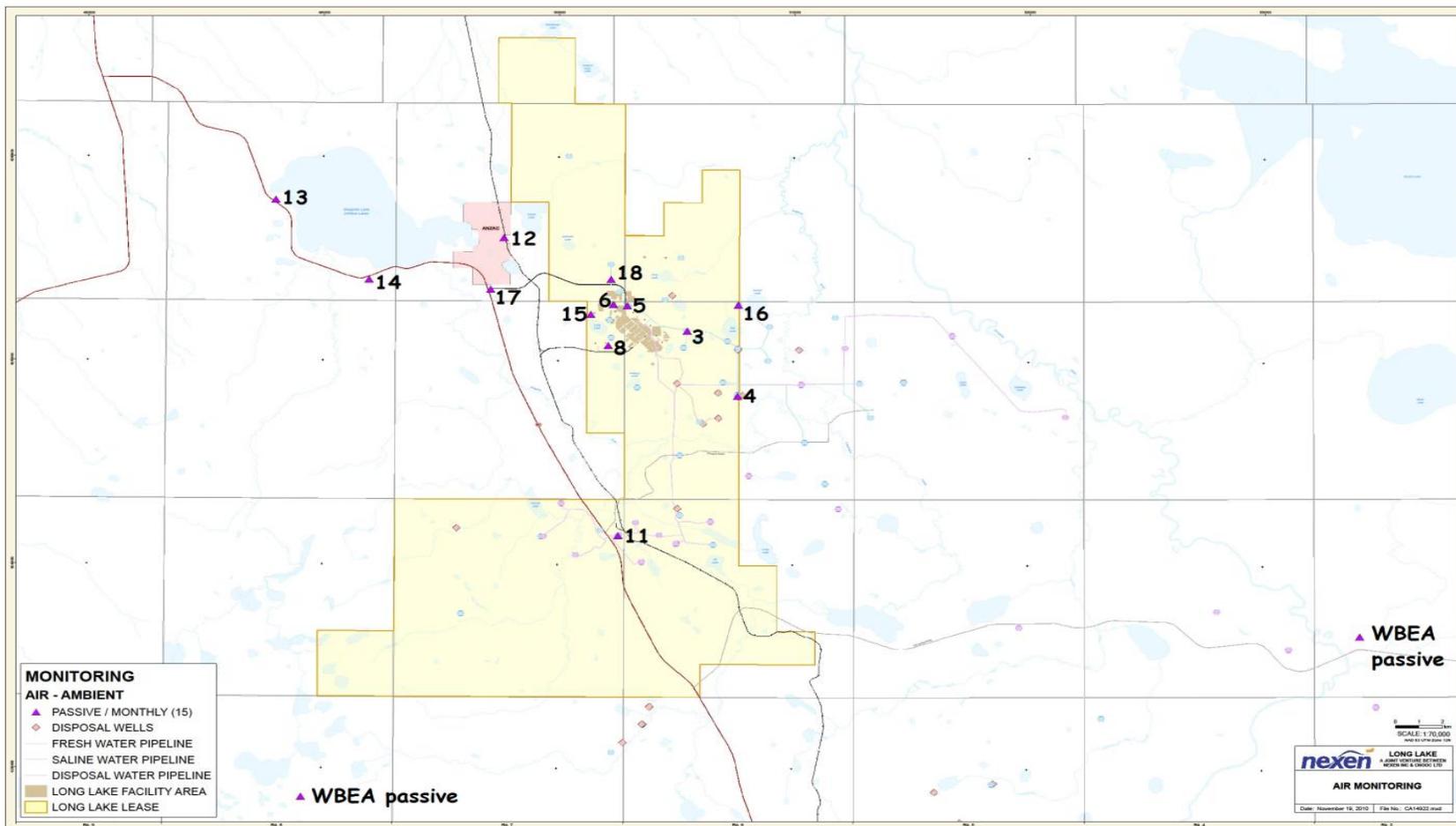


Figure 4.2 - Passive Air Monitoring Locations

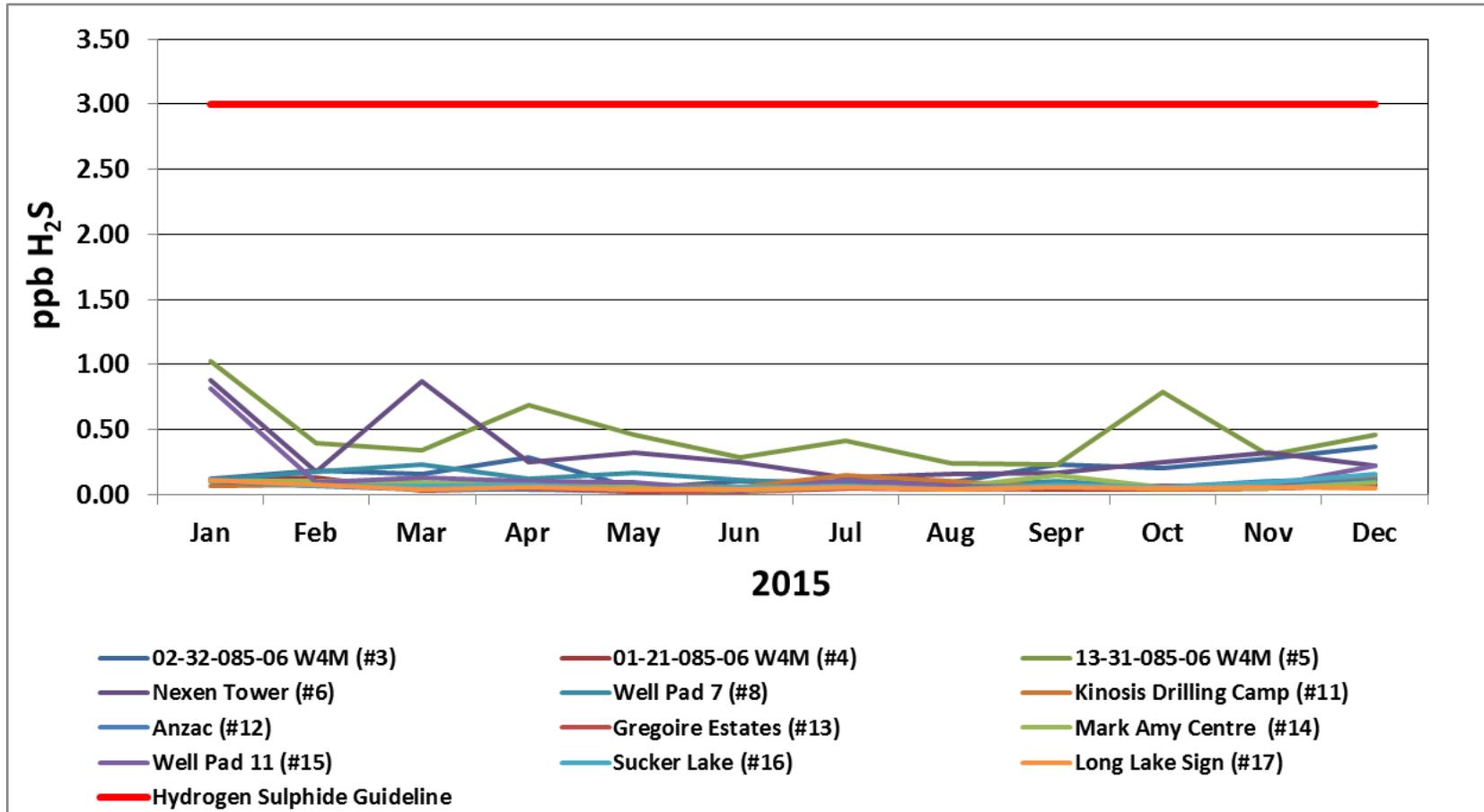


Figure 4.3 - 2015 Passive Air Monitoring Results for H<sub>2</sub>S

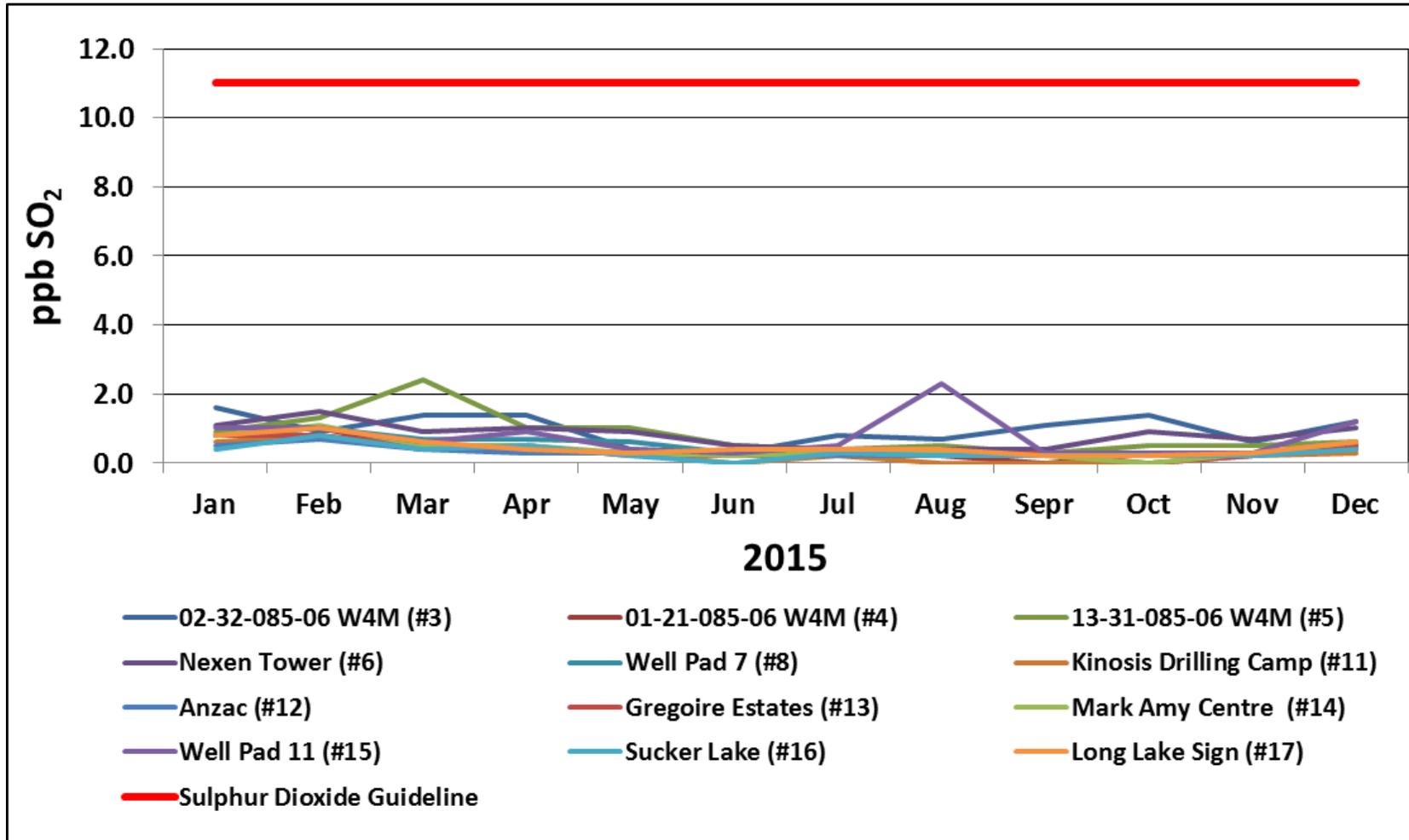


Figure 4.4 – 2015 Passive Monitoring Results for SO<sub>2</sub>

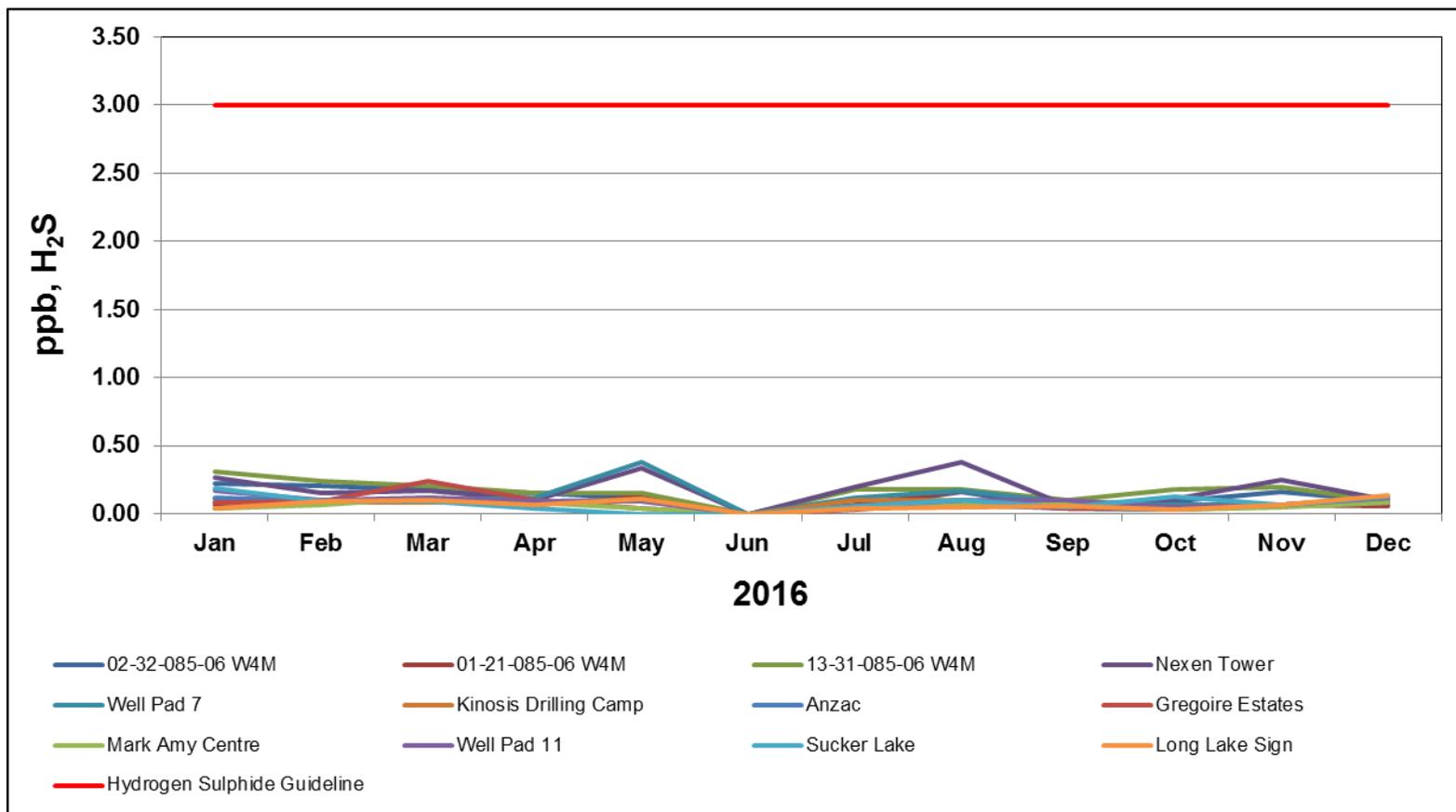


Figure 4.5 - 2016 Passive Monitoring for H<sub>2</sub>S

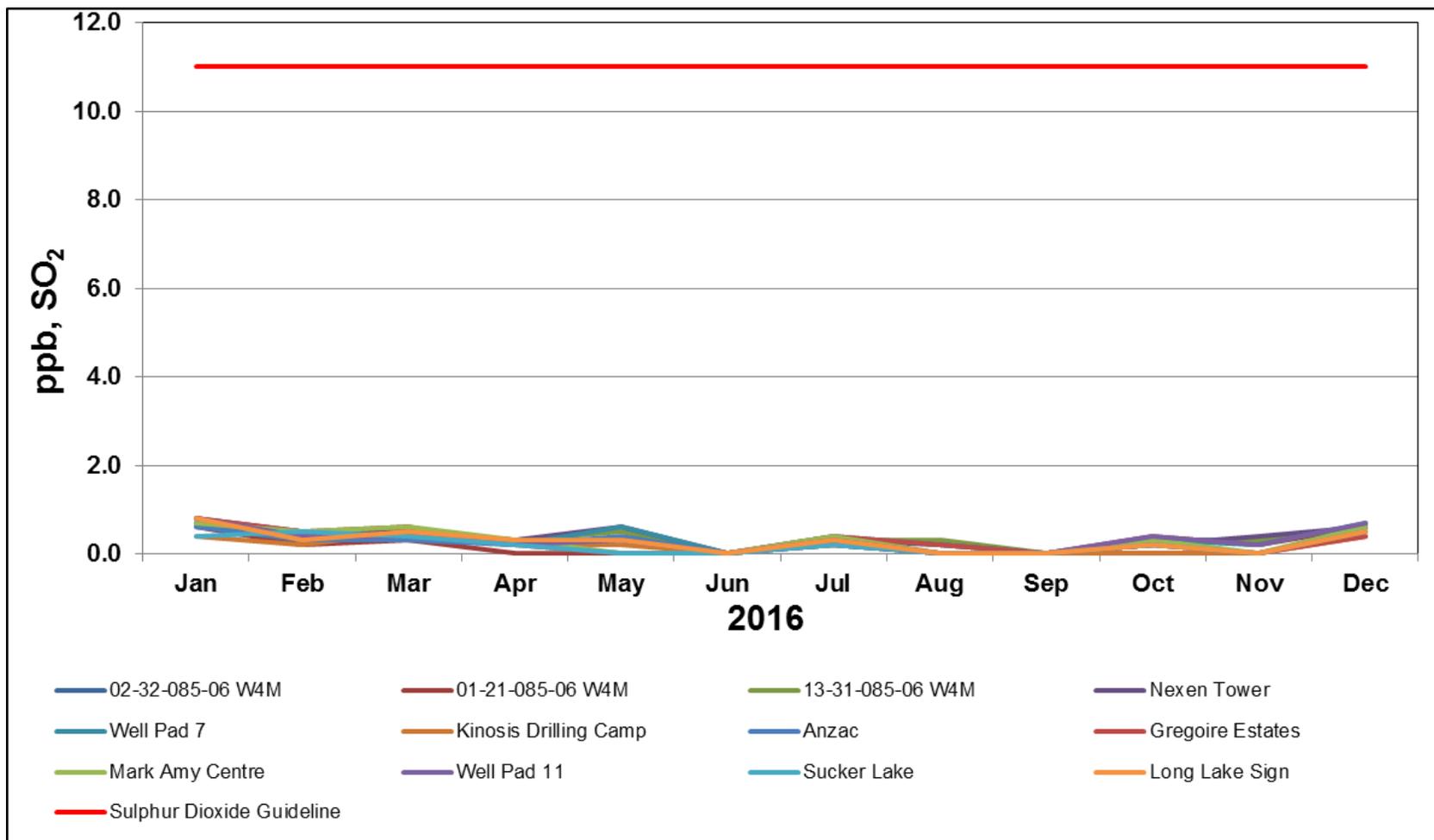


Figure 4.6 - 2016 Passive Monitoring Results for SO<sub>2</sub>

## 5.0 ENERGY MANAGEMENT

Energy management at Long Lake is continually being optimized to maximize energy efficiencies and plant reliability. Tables 5.9 and 5.10 provide the annual Upgrader energy balance for 2015 and 2016. Tables 5.11 and 5.12 provide the monthly summary of fuel and electricity use for 2015 and 2016.

Nexen continued to evaluate process modifications and examine engineering studies to improve energy efficiency and product yield at the Long Lake Project. As an example, during the reporting period the Diluent Recovery Unit (DRU) project was completed and put in service to segregate the cracked naphtha (diluent) produced in the Thermal Crackers and the straight run diluent in the dilbit feed.

Before the DRU project, the cracked naphtha produced in the Upgrader was sent to the SAGD facility as diluent to be mixed with bitumen for further processing in the Upgrader. However, when the Upgrader was not available, the plant was limited to exporting bitumen from SAGD in the form of synbit (bitumen diluted with PSC) because the bitumen once combined with cracked naphtha could not be put into the sales pipeline. With the DRU project, SAGD and Upgrader were decoupled and cracked material did not enter the SAGD facility, allowing thus import / export of dilbit.

**Table 5.8 - 2015 Upgrader Energy Balance**

		Input	GJ
<b>Energy In</b>	GJ		<b>321,422,643</b>
<b>Opening Inventory</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	19,204	733,611
Synthetic Crude Oil	m <sup>3</sup>	3,471	132,606
Sulphur	tonnes	1,009	9,243
<b>Imports</b>			
Bitumen Received	m <sup>3</sup>	2,127,605	91,465,264
Synthetic Crude Oil	m <sup>3</sup>	191,317	7,308,432
Diluent Imported	m <sup>3</sup>	1,130,848	39,738,572
Electricity Imported	MWH	805,789	2,900,840
NG Imported	10 <sup>3</sup> m <sup>3</sup>	147,112	4,967,976
<b>Production</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	1,450,807	55,421,886
Synthetic Crude Oil	m <sup>3</sup>	1,756,051	67,082,446
Process Gas	10 <sup>3</sup> m <sup>3</sup>	2,023,468	50,586,693
Sulphur	tonnes	114,950	1,052,943
Electricity Generated	MWH	6,148	22,131
<b>Energy Out</b>	GJ		<b>321,422,643</b>
<b>Exports</b>			
Bitumen Exported	m <sup>3</sup>	258	11,070
PSC Exported	m <sup>3</sup>	1,538,612	58,776,108
Diluent Exported	m <sup>3</sup>	961,502	33,787,648
Process Gas Delivered	10 <sup>3</sup> m <sup>3</sup>	1,344,186	33,604,638
Sulphur sales & disposal	tonnes	113,896	1,043,291
<b>Site Use and Losses</b>			
Bitumen	m <sup>3</sup>	2,127,347	91,454,194
Intermediate Hydrocarbons	m <sup>3</sup>	1,461,117	55,815,764
Measurement Difference	m <sup>3</sup>	-1,958	-74,797
Diluent	m <sup>3</sup>	169,347	5,950,924
Process Gas	10 <sup>3</sup> m <sup>3</sup>	410,829	10,270,713
Process Gas to Flare	10 <sup>3</sup> m <sup>3</sup>	143,287	3,582,185
Process Gas Consumed	10 <sup>3</sup> m <sup>3</sup>	97,290	2,432,250
Electricity Consumed	MWH	811,937	2,922,972
Sulphur Flared or Wasted	tonnes	493	4,512
Natural gas	10 <sup>3</sup> m <sup>3</sup>	147,112	4,967,976
Other			16,114,913
<b>Closing Inventory</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	10,851	414,526
Synthetic Crude Oil	m <sup>3</sup>	8,622	329,374
Sulphur	tonnes	1,570	14,383

**Table 5.9 - 2016 Upgrader Energy Balance**

	Input		GJ
<b>Energy In</b>	GJ		<b>69,068,347</b>
<b>Opening Inventory</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	10,851	414,526
Synthetic Crude Oil	m <sup>3</sup>	8,622	329,374
Sulphur	tonnes	1,570	14,383
<b>Imports</b>			
Bitumen Received	m <sup>3</sup>	90,905	3,907,991
Synthetic Crude Oil	m <sup>3</sup>	1,426,763	54,503,397
Diluent Imported	m <sup>3</sup>	48,829	1,715,879
Electricity Imported	MWH	231,997	835,189
NG Imported	10 <sup>3</sup> m <sup>3</sup>	95,839	0
<b>Production</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	57,665	2,202,842
Synthetic Crude Oil	m <sup>3</sup>	68,736	2,625,755
Process Gas	10 <sup>3</sup> m <sup>3</sup>	98,902	2,472,553
Sulphur	tonnes	5,019	45,977
Electricity Generated	MWH	134	482
<b>Energy Out</b>	GJ		<b>69,068,347</b>
<b>Exports</b>			
Bitumen Exported	m <sup>3</sup>	0	0
PSC Exported	m <sup>3</sup>	70,533	2,694,420
Diluent Exported	m <sup>3</sup>	46,114	1,620,473
Process Gas Delivered	10 <sup>3</sup> m <sup>3</sup>	70,637	1,765,928
Sulphur sales & disposal	Tonnes	6,519	59,709
<b>Site Use and Losses</b>			
Bitumen	m <sup>3</sup>	90,905	3,907,991
Intermediate Hydrocarbons	m <sup>3</sup>	59,220	2,262,259
Measurement Difference	m <sup>3</sup>	0	0
Diluent	m <sup>3</sup>	2,715	95,406
Process Gas	10 <sup>3</sup> m <sup>3</sup>	16,679	416,983
Process Gas to Flare	10 <sup>3</sup> m <sup>3</sup>	3,808	95,188
Process Gas Consumed	10 <sup>3</sup> m <sup>3</sup>	6,257	156,415
Electricity Consumed	MWH	232,131	835,672
Sulphur Flared or Wasted	Tonnes	45	409
Natural gas	10 <sup>3</sup> m <sup>3</sup>	95,839	3,236,486
Other			51,316,765
<b>Closing Inventory</b>			
Intermediate Hydrocarbons	m <sup>3</sup>	7,968	304,395
Synthetic Crude Oil	m <sup>3</sup>	7,751	296,109
Sulphur	Tonnes	408	3,739

**Table 5.10 - 2015 Fuel and Electricity for Long Lake**

2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
<b>Natural Gas Purchased</b>	14,903.0	14,945.9	12,046.7	9,011.8	9,140.6	3,578.8	12,250.0	10,711.0	11,391.1	9,929.3	19,480.3	19,723.6	147,112.1
<b>Natural Gas Consumed</b>	14,841.1	14,940.7	12,041.8	9,011.8	9,140.6	3,577.0	12,248.0	10,708.8	11,391.1	9,929.3	19,478.9	19,714.5	147,023.6
<b>Natural Gas Flared</b>	61.9	5.2	4.9	0.0	0.0	1.8	2.0	2.2	0.0	0.0	1.4	9.1	88.5
<b>Process Gas Produced</b>	179,351.5	127,094.3	209,205.1	211,280.2	213,173.0	3,745.0	153,753.0	234,908.7	218,556.6	243,574.4	106,536.8	122,288.7	2,023,467.3
<b>Process Gas Further Processing</b>	36,543.5	27,942.4	45,288.7	46,277.4	45,602.5	588.1	33,715.1	44,317.5	44,078.6	47,417.4	18,472.6	20,584.7	410,828.5
<b>Process Gas Delivered</b>	105,292.8	80,684.6	141,644.8	142,160.5	148,715.4	221.1	82,736.8	159,077.7	157,606.7	175,186.3	73,874.4	76,984.4	1,344,185.5
<b>Process Gas Consumed</b>	7,362.3	7,399.9	9,523.0	8,884.1	9,270.1	2,370.9	6,930.1	9,009.1	12,023.9	11,540.3	5,938.8	7,037.5	97,290.0
<b>Process Gas Flared</b>	27,567.6	9,315.1	10,064.4	11,144.5	6,616.3	419.4	27,957.3	19,074.7	2,145.3	6,858.7	6,539.0	15,585.1	143,287.4
<b>Electricity Imported</b>	70,312.0	63,875.0	72,203.0	71,155.0	72,574.0	33,294.0	68,232.0	77,746.0	72,736.0	71,943.0	62,725.0	68,994.0	805,789.0
<b>Electricity Generated</b>	1,144.2	112.8	120.6	0.0	0.0	0.0	110.0	118.0	110.0	2,344.0	1,968.0	120.0	6,147.6

UNITS: Products in gaseous phase are reported in 10<sup>3</sup> m<sup>3</sup>  
 Electricity reported in MWH

**Table 5.11 – 2016 Fuel and Electricity for Long Lake**

2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
<b>Natural Gas Purchased</b>	19,231.0	17,383.9	17,787.7	12,539.3	1,053.1	236.0	2,902.9	4,985.9	7,435.5	4,655.9	3,502.6	4,125.3	95,839.1
<b>Natural Gas Consumed</b>	19,217.6	17,381.8	17,787.7	12,537.0	1,053.1	235.9	2,902.9	4,983.6	7,382.6	4,655.9	3,502.6	4,125.3	95,766.0
<b>Natural Gas Flared</b>	13.4	2.1		2.3		0.1		2.3	52.9				73.1
<b>Process Gas Produced</b>	98,902.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	98,902.1
<b>Process Gas Further Processing</b>	16,679.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16,679.3
<b>Process Gas Delivered</b>	70,637.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	70,637.1
<b>Process Gas Consumed</b>	6,256.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6,256.6
<b>Process Gas Flared</b>	3,807.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3,807.5
<b>Electricity Imported</b>	56,942.0	34,333.0	36,689.0	35,507.0	3,062.0	7.0	2,649.0	27,558.0	22,986.0	3,967.0	4,054.0	4,243.0	231,997.0
<b>Electricity Generated</b>	89.0	45.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	134.0

UNITS: Products in gaseous phase are reported in 10<sup>3</sup> m<sup>3</sup>  
 Electricity reported in MWH

## 6.0 BUSINESS UNIT OPERATIONS SUMMARY

Progress was made on the reliability of the Upgrader since the last report, especially in the operation and maintainability of the Pressure Swing Absorbers (PSA) which had caused Upgrader trips in the past. During this reporting period, a turnaround was conducted during the summer of 2015 to complete the tie in of DRU project as well as to complete maintenance in the OrCrude™ Unit.

During 2015 and 2016, the availability of individual Upgrader units was as follows:

**Table 6.12 - Availability of Upgrading Units**

Unit	2015 (%)	2016 (%)
OrCrude™ Unit	88.5	0
Hydrocracker	74.8	0
Air Separation Unit	88.3	0
Asphaltene Gasification Unit	53.5	0
Sulphur Recovery Unit	87.1	0
Utilities & Offsites	100.0	100.0

### 6.1 OrCrude™ Unit

The current design of the Long Lake Facility uses ORMAT's OrCrude™ proprietary configuration of Atmospheric and Vacuum distillation, Solvent Deasphalting (SDA), and Thermal Cracking processes. The objective of this unit is to process an undiluted Bitumen feed of 72,000 BPD. The bitumen is diluted in SAGD with recycled diluent to 16°API to ensure adequate desalting.

This area of the operation had been focusing on increasing yield and equipment reliability, specifically pumps. During the 2015 turnaround, the following major activities for the OrCrude™ unit were undertaken:

- Vacuum tower packing change;
- Vacuum tower overhead exchanger metallurgy upgrades;
- Repair of Asphaltene stripper internals; and
- Regulatory inspection of vessels and cleaning of vessels and exchangers.

Due to fouling in the internal packing of the Vacuum tower some yield loss was observed in 2015. This loss was minimized with the higher yield operation of the Solvent De-Asphaltene Unit (SDA). Modifications to the OrCrude™ unit were completed as part of a Diluent Recovery (DRU) Project. Operation in both units (DRU and OrCrude™) was stable by the time the HCU incident occurred.

### 6.2 Hydrocracker Unit (HCU)

Improvements in the HCU operation during 2015 resulted in optimization of the yield while meeting product specifications for customers and shipping companies. Test runs were performed to optimize HCU catalyst operation and liquid product recovery in the Saturation Gas Plant located downstream of

the HCU reactors. Butane recovery in the Saturation Gas Plant was increased by optimizing operating conditions of the PSC stripper and Depropanizer towers, which contributed to increase the HCU yield.

Low feed rates as compared to design and low hydrogen availability were attributed to low feed rates to the OrCrude™ Unit and mechanical availability of the Pressure Swing Absorption (PSA) plant, where Nexen produces the necessary hydrogen to feed to the HCU.

### **6.3 Air Separation Unit (ASU)**

The ASU operated during this reporting period without any issues. Proposals for optimizing and reducing power consumption were implemented in 2014 and key performance indicators were developed to monitor and sustain these results.

### **6.4 Ash Processing Unit (APU)**

The APU is not operational as construction has not been completed. Until January 2016, soot byproduct was shipped to Clean Harbors Landfill (Ryley, Alberta) for disposal and Nexen continues to evaluate other disposal options.

### **6.5 Asphaltene Gasification Unit (AGU)**

The AGU is important for energy efficiency as syngas production displaces natural gas imports and is an effective means of recovering energy from the low-value asphaltene product. It is comprised of four identical gasifier trains with the operating expectation that at least three are running at all times.

Gasifier reliability was improved in 2015 by installing upgraded valves, upgraded Syngas Effluent Cooler elbows and redundant instrumentation. After the 2015 turnaround, the gasification unit had stable operation. PSA logic was upgraded in the 2015 turnaround to increase its reliability, and reduce the frequent trips due to valves failure.

### **6.6 Sulphur Recovery Unit (SRU)**

During the 2012 turnaround, one third of the first converter bed catalyst was replaced with metal traps in order to capture undesirable deposits, keep the differential pressure across the beds under control and extend the run lengths from 10 to 12 months, to at least 18 months. Performance reports showed that the Claus units have been able to run more than 18 months and processed more than four times the acid gas per kilogram of catalyst compared to previous runs, while maintaining expected sulphur recovery targets. Further optimization will be required to be able to extend the operation of the SRU to 4 years without having to replace the catalyst.

As mentioned in previous reports, the main burner of the reaction furnaces was experiencing plugging issues with a similar material deposited on top of the catalyst. Modifications to the reaction furnace burners were implemented in 2012 and further changes were planned to be completed during the Upgrader turnaround in 2016 which was cancelled due to HCU incident. New burner design is expected to improve acid gas combustion and reduce particle formation which may contribute to fouling.

Performance evaluations of the Claus units and the Tail Gas Treating Unit (TGTU) were conducted by a third party company. Final reports showed that the activity of the hydrogenation catalyst was decaying and there was a plan for replacement during the 2016 turnaround.

## 6.7 Utilities and Offsites (U&O)

The U&O area has two 150 tonne/hr MCR natural gas fired utility steam boilers, tank farm and rail yard.

The Long Lake rail yard operations have significantly changed after the Upgrader shutdown in January 2016. The rail yard is currently handling condensate import to sustain SAGD only operations.

## 7.0 SULPHUR RECOVERY

The average sulphur recovery rates in 2015 was 99.4% calculated using the methodology outlined in the S-23 Report as (Total Produced Sulphur -Total Sulphur Flared or Wasted)/Total Produced Sulphur\*100.

The total sulphur flared or wasted was reduced significantly in 2015 and early 2016 compared with previous years. These results were credited to:

- A lower number of operational upsets in the Upgrader,
- Improvements in reaction furnace burners.
- Installation of metal traps which improves Claus catalyst performance.
- Developed a software predictor to minimize flaring incidents.
- Implementation of additional alarms to warn operators.

Redesign of reaction furnaces' mirror walls to ensure proper burner alignment and improvements in acid gas feed quality are key recommendations to further extend run lengths. This redesign was scheduled to be implemented in 2016 turnaround which was cancelled.

**Table 7.13 - 2015 Sulphur Recovery and Emissions**

2015	Q1	Q2	Q3	Q4	Total
<b>Sulphur Production (tonnes)</b>					
Sulphur Produced	29,901.8	25,132.8	34,001.3	25,914.1	114,950.0
Sulphur Flared	161.4	102.5	122.4	106.3	492.6
Sulphur Delivered	29,388.6	25,522.8	32,521.3	26,463.7	113,896.4
Sulphur Recovery %	99.0%	99.3%	99.7%	99.5%	99.4%
<b>SO<sub>2</sub> Emissions (tonnes)</b>					
Total Incinerator Stack	219.7	150.6	235.8	169.8	775.9
Total Flare SO <sub>2</sub> Emissions	754.9	396.9	291.3	478.4	1921.6
Total Power Stack and Boilers	77.7	92.2	8.8	97.8	276.5
Total SO <sub>2</sub> Emissions	456.5	268.2	414.2	380.8	1,519.6

**Table 7.14 - 2016 Sulphur Recovery and Emissions**

	Q1	Q2	Q3	Q4	Total
<b>Sulphur Production (tonnes)</b>					
Sulphur Produced	5,019.3	NA	NA	NA	5,019.3
Sulphur Flared	39.2	5.5	NA	NA	44.7
Sulphur Delivered	6,518.5	NA	NA	NA	6,518.5
Sulphur Recovery %	99.5%	NA	NA	NA	99.5%
<b>SO<sub>2</sub> Emissions (tonnes)</b>					
Total Incinerator Stack	48.0	4.6	0.0	0.0	52.5
Total Flare SO <sub>2</sub> Emissions	107.6	0.4	0.2	0.2	108.4
Total Power Stack and Boilers	22.0	3.3	5.7	7.3	38.4
Total SO <sub>2</sub> Emissions	177.5	8.3	6.0	7.5	199.3

## 8.0 REFERENCES

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