

HANGINGSTONE SAGD PROJECT

AER DIRECTIVE 054 PERFORMANCE REVIEW



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SECTION 1.0 – SUBSURFACE OPERATIONS

HANGINGSTONE SAGD PROJECT

Scheme Approval No. 8788, as amended

EPEA Approval No. 1604, as amended

September 2019

1.1

1.1 BACKGROUND

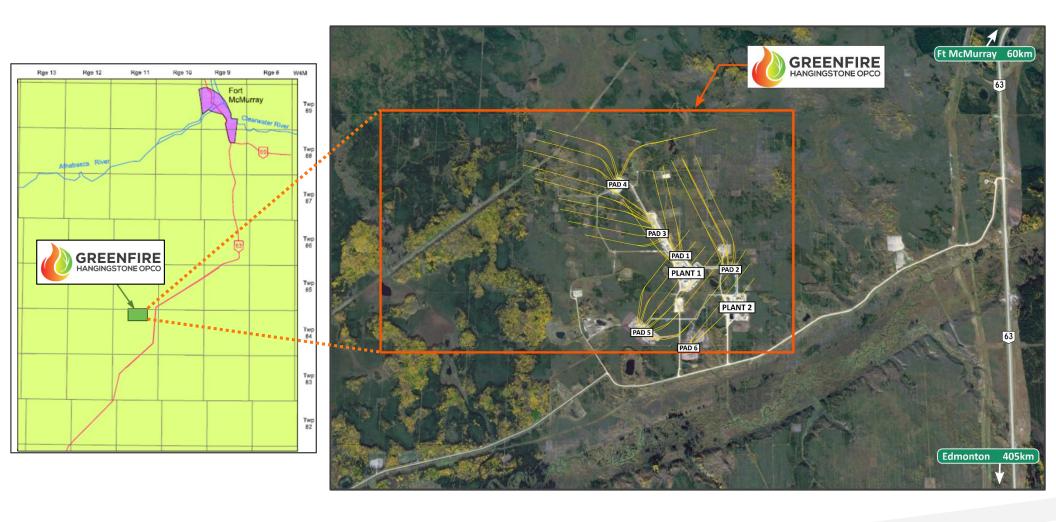
- Hangingstone Project (the "Project") was originally started up in 1999 by the previous owner, Japan Canada Oil Sands Limited ("JACOS")
- Alberta Energy Regulator ("AER") Approved production capacity of 1,760 m3/day
- Wildfires in May 2016 forced suspension of operations and JACOS decided to leave the operations suspended rather than re-start due to "the continuing severe business environment including low oil prices and the increasing technical risks of a re-start." (JAPEX Press Release, August 8, 2017)
- Project was officially transferred from JACOS to Greenfire on August 3, 2018
- Since acquisition, Greenfire has been diligently working on the recommissioning and re-start of the Project. Greenfire has achieved the following milestones to date:
 - September 2018: Plant operations re-established
 - October 2018: First steam
 - November 2018: First production
 - December 2018: First bitumen sales
 - June 2019: 41 of 46 wells have been re-activated





1.1 BACKGROUND - LOCATION

• The Project is located approximately 60km south of Fort McMurray, Alberta







1.2 GEOSCIENCE - OBIP (APPROVAL/OPERATING AREA)

Reservoir Parameters	Value
Initial oil saturation (%)	85
Porosity (%)	30
Average SAGD Pay Thickness (m)	23

Original Bitumen In Place (OBIP)	
Approval area OBIP (Mbbl)	116,000
Operating area OBIP (Mbbl)	77,500

OBIP Calculation Method

 $OBIP = Rv \times \varphi \times (1-Sw) \times FVF$

Where:

OBIP: Original bitumen in place

Rv: Rock Volume

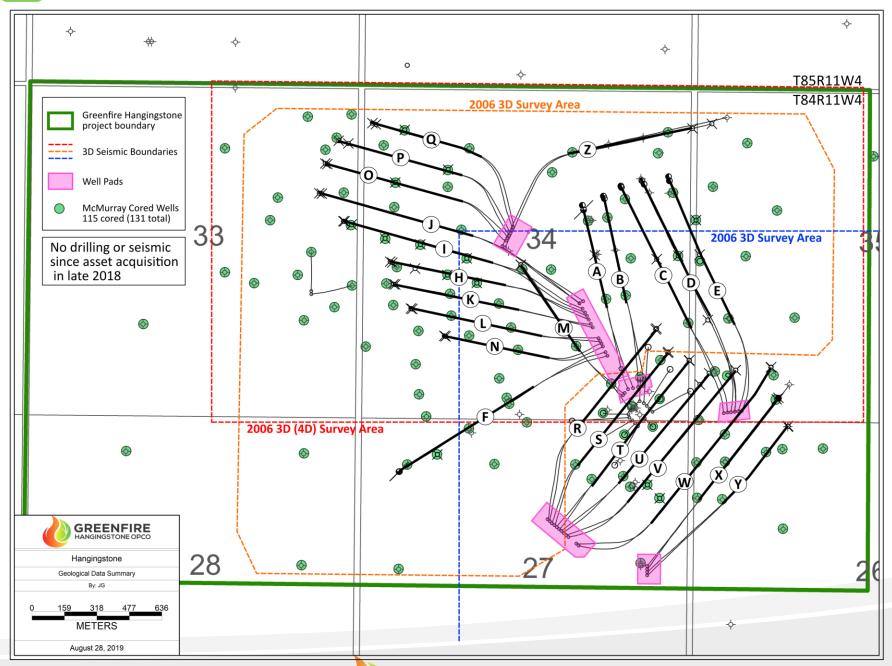
 ϕ : Porosity

Sw: Initial water saturation

FVF: Formation volume factor (1.001)

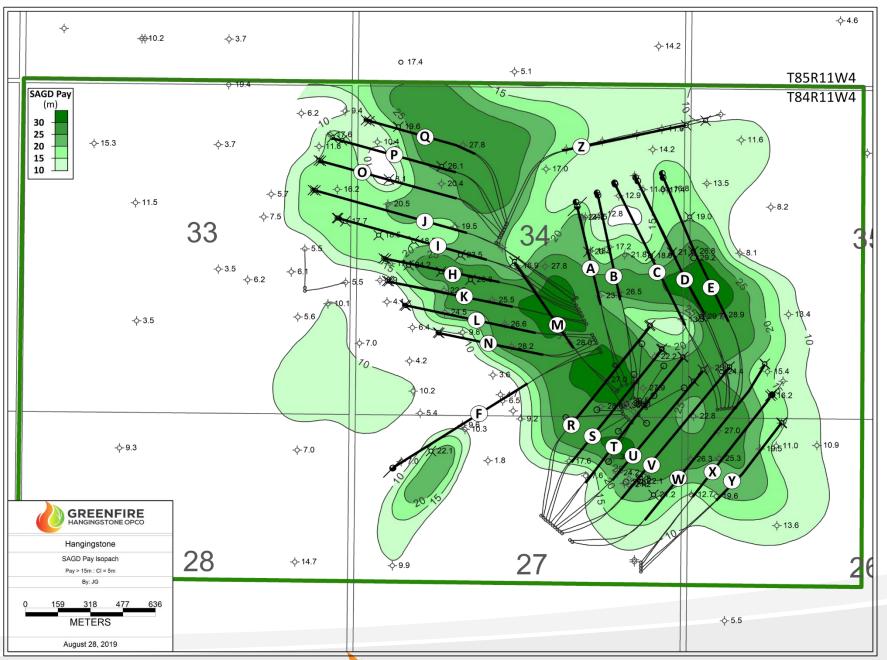


1.2 GEOSCIENCE - GEOLOGICAL DATA SUMMARY



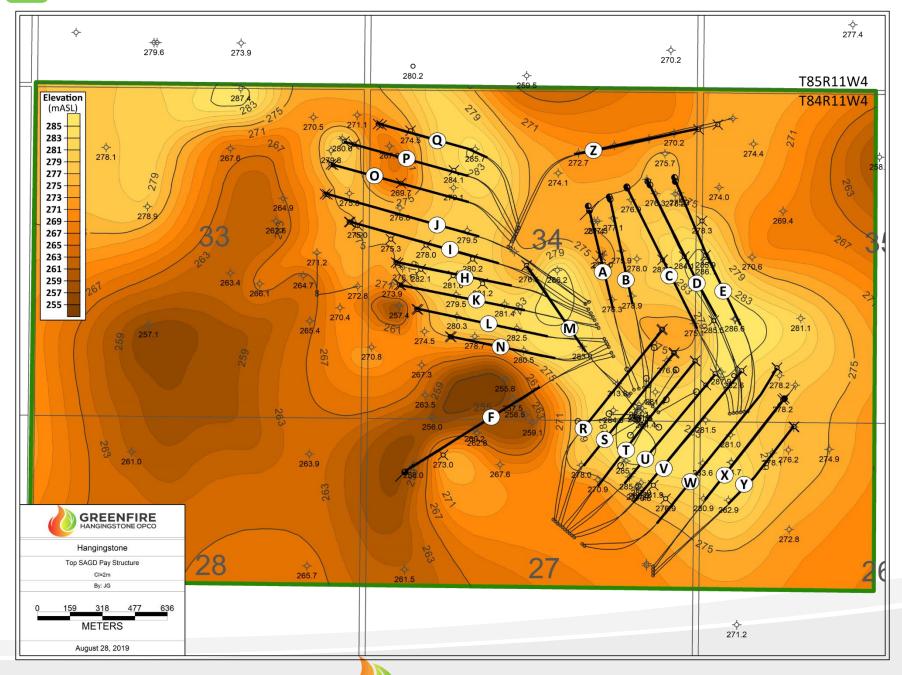


1.2 GEOSCIENCE - NET PAY ISOPACH



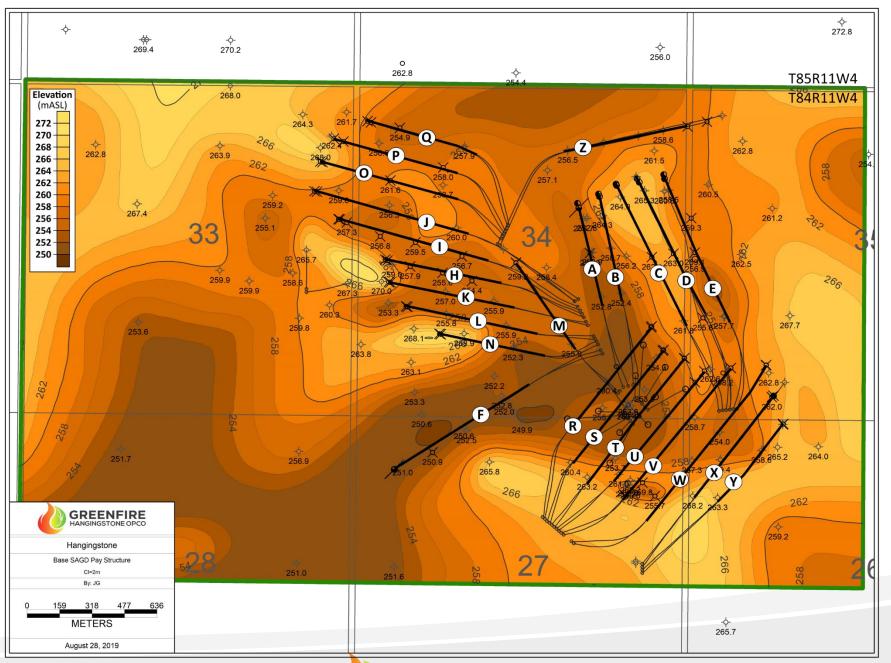


1.2 GEOSCIENCE - TOP SAGD STRUCTURE



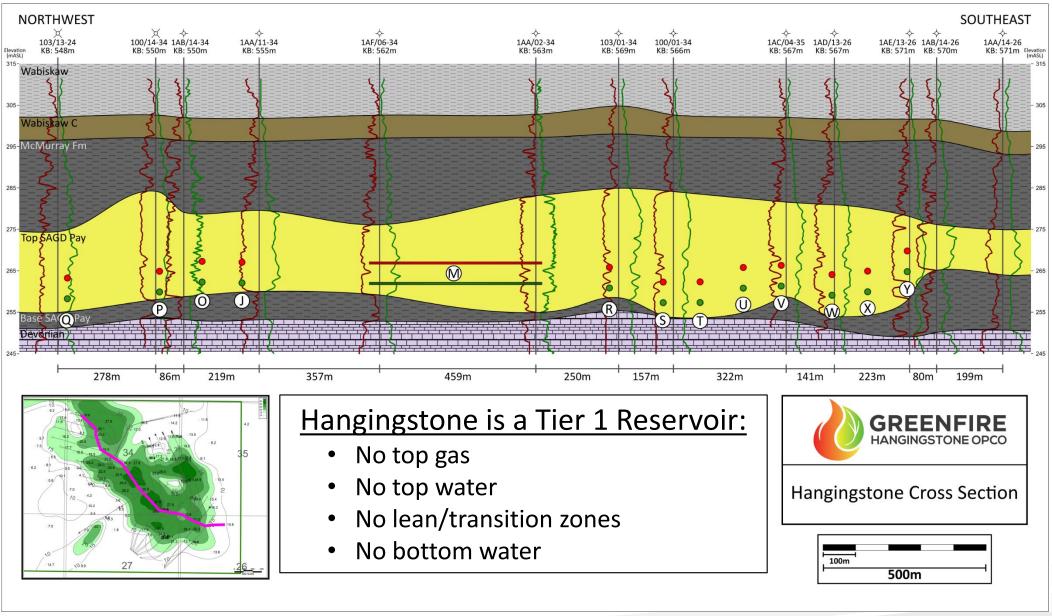
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1.2 GEOSCIENCE - BASE SAGD STRUCTURE





1.2 GEOSCIENCE - CROSS-SECTION



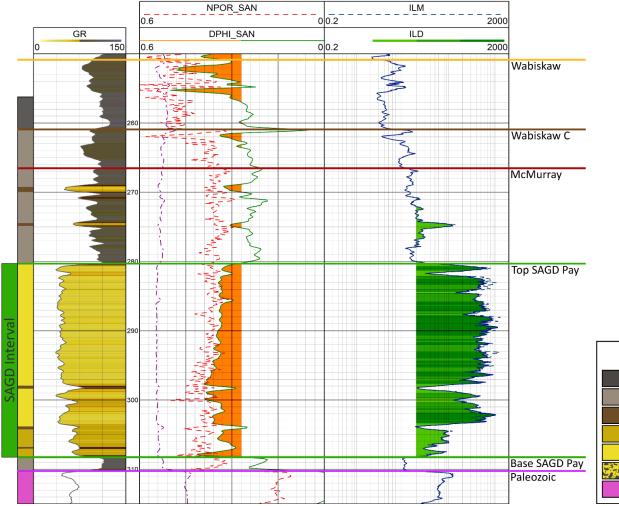


1.2 GEOSCIENCE - COMPOSITE WELL LOG



1AA/02-34-084-11W4/00

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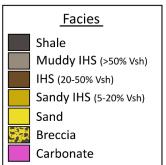


SAGD Interval Definition:

Porosity > 27%

Resistivity > 20 Ω ·m

Thickness >10m





^{**}No thief zones in asset area (top/bottom water, top gas, lean zones)



1.2 GEOSCIENCE – GEOMECHANICAL

- No change in caprock integrity analysis since taking over site from JACOS
- Original injection pressures determined by mini-frac tests in the 1980's
- JACOS' Hangingstone Expansion (~3km from Greenfire's Project) conducted mini-frac testing in 2010 and exhibited consistent results to original data
- 5 MPa determined to be maximum wellhead injection pressure (80% of fracture pressure)
- Reservoir pressure is monitored through blanket gas pressure readings in the casing annulus

	Depth	Min. Stress		Vertical Stress		Studen Beginne	
Formation/Lithology	TVD (m)	Мра	kPa/m	Мра	kPa/m	Stress Regime	
Clearwater Shale	272.0	5.39	19.82	5.73	21.07	Horizontal Fracture (?)	
Wabiskaw Shale	297.0	6.17	20.77	6.26	21.08	Horizontal Fracture	
McMurray Shale	314.5	5.55	17.65	6.64	21.11	Vertical Fracture	
McMurray Sand	327.0	5.59	17.09	6.91	21.13	Vertical Fracture	

From JACOS Hangingstone Expansion 2018 AER Performance Review



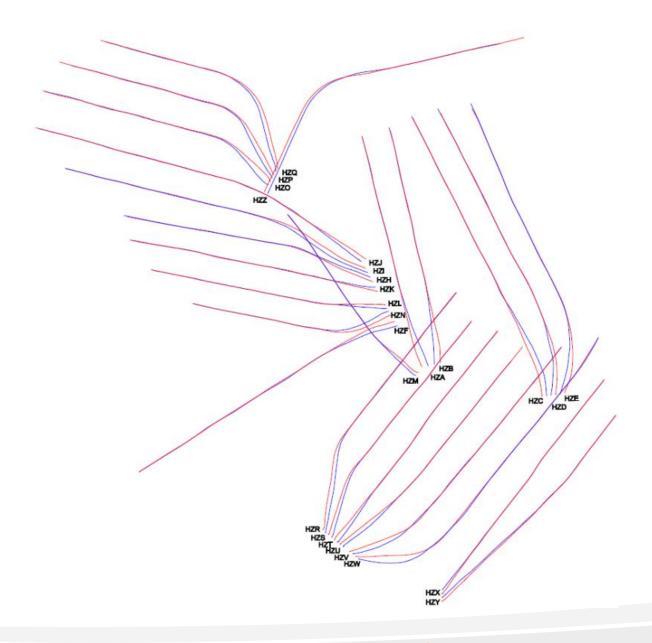


1.2 GEOSCIENCE – HEAVE MONITORING

 Greenfire did not conduct heave or other surface monitoring between August 1, 2018 and July 31, 2019 at the Hangingstone site



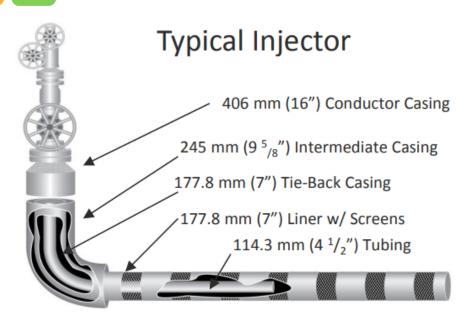
1.3 DRILLING & COMPLETIONS – WELL LAYOUT

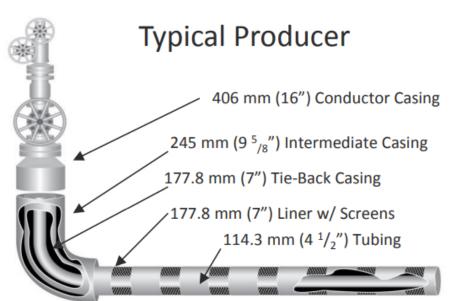


- 24 active well pairs
- "F" well pairs abandoned in 2014
- "A" Injection well abandoned in 2017
- "B" producer well abandoned in 2017



1.3 DRILLING & COMPLETIONS – SCHEMATICS (TYPICAL)





	Liner Size		S	creen Type	4-1/2" TBG	
Well Pair	7"	8-5/8"	Wire Wrap	Seamed Slotted Liner	To Mid	То Тое
Α	I/P	-	I/P	-	-	Р
В	I/P	-	I/P	-	-	_
С	I/P	-	I/P	-	-	I/P
D	I/P	-	I/P	-	-	I/P
Е	I/P	-	I/P	-	-	I/P
Н	Р	1	I/P	-	_	Р
1	I/P	-	I/P	-	1	Р
J	I/P	-	I/P	-	- 1	Р
K	I/P	-	I/P	-	- 1	Р
L	I/P	-	I/P	-	- 1	Р
М	I/P	-	I/P	-	- 1	Р
N	I/P	-	I/P	-	- 1	Р
0	I/P	-	I/P	-	-	I/P
Р	I/P	-	-	I/P		Р
Q	I/P	-	I/P	-	- 1	Р
R	I/P	-	_	Р	- 1	Р
S	Р	T.	-	I/P	-	I/P
Т	Р	- I	-	I/P	-	I/P
U	Р	- 1	-	I/P	-	I/P
V	Р	I	-	I/P	-	I/P
W	Р	I	-	I/P	-	I/P
Х	-	I/P	-	I/P	-	- 1
Υ	-	I/P	-	I/P	-	I/P
Z	Р	I	-	I/P	-	- 1



1.4 A

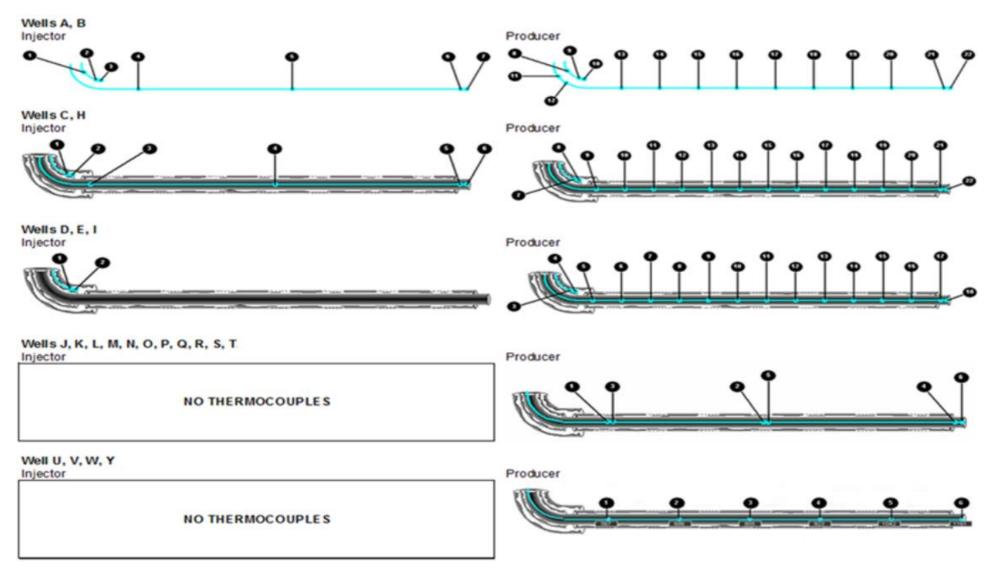
1.4 ARTIFICIAL LIFT

- Many of the wells associated with the Project use a combination of natural lift assisted with lift steam and/or lift gas
- Two wells within the Project use artificial lift: HZXP & HZYP
 - HZXP: SLB Hotline 550 high temperature electric submersible pump
 - Operating Temperatures up to 210°C
 - Intake Pump Pressure 2000 to 2800 kPa
 - Production Rate 80 to 120 m³/d
 - HZYP: SLB Hotline SA3 high temperature electric submersible pump
 - Operating Temperatures up to 175°C
 - Intake Pump Pressure 2000 to 2800 kPa
 - Production Rate 50 to 100 m³/d





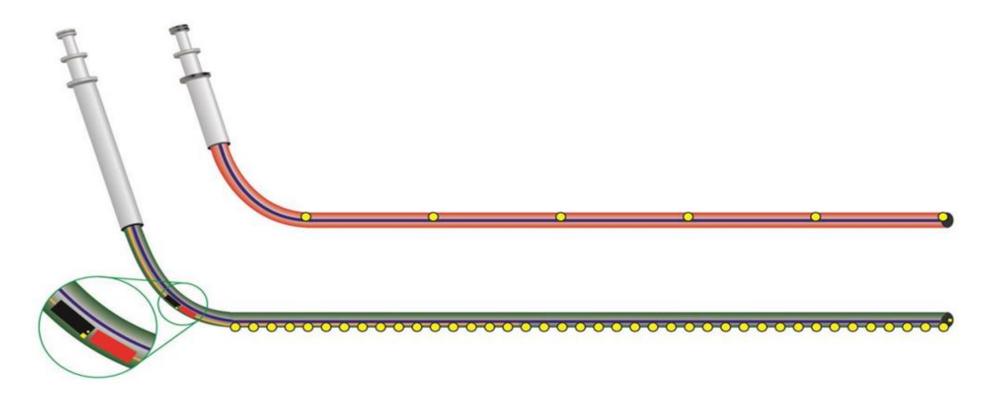
1.5 WELL INSTRUMENTATION – THERMOCOUPLES







1.5 WELL INSTRUMENTATION – THERMOCOUPLES (X)



- HZXI 6 thermocouples
- HZXP 40-point LX-Data Temperature, LX-Data Pressure
- ESP Single point LX-Data Temperature, LX-Data Pressure

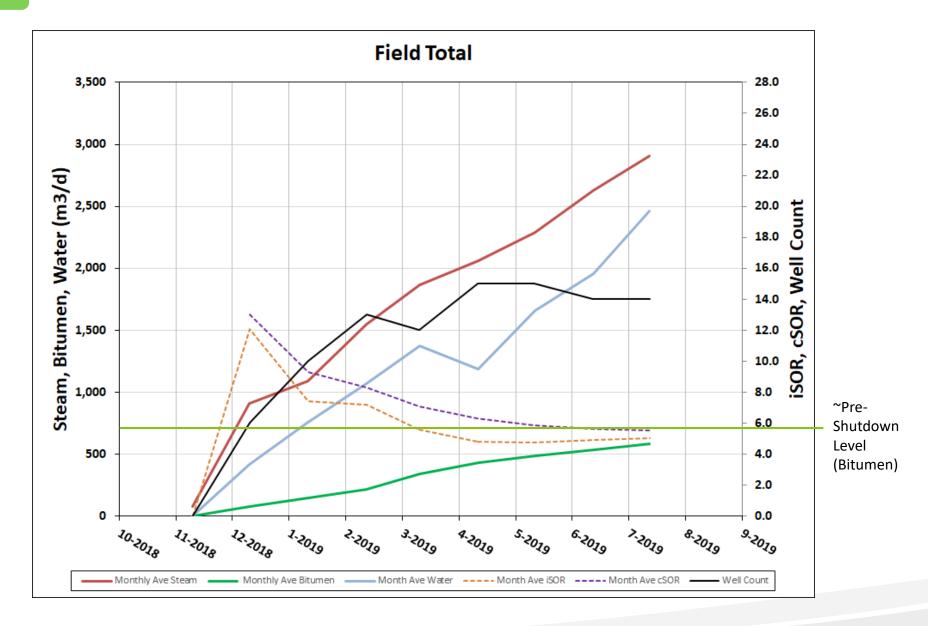


1.6 SEISMIC

 No seismic activity has been undertaken by Greenfire from August 2018 to the end of July 2019



1.7 SCHEME PERFORMANCE – CURRENT





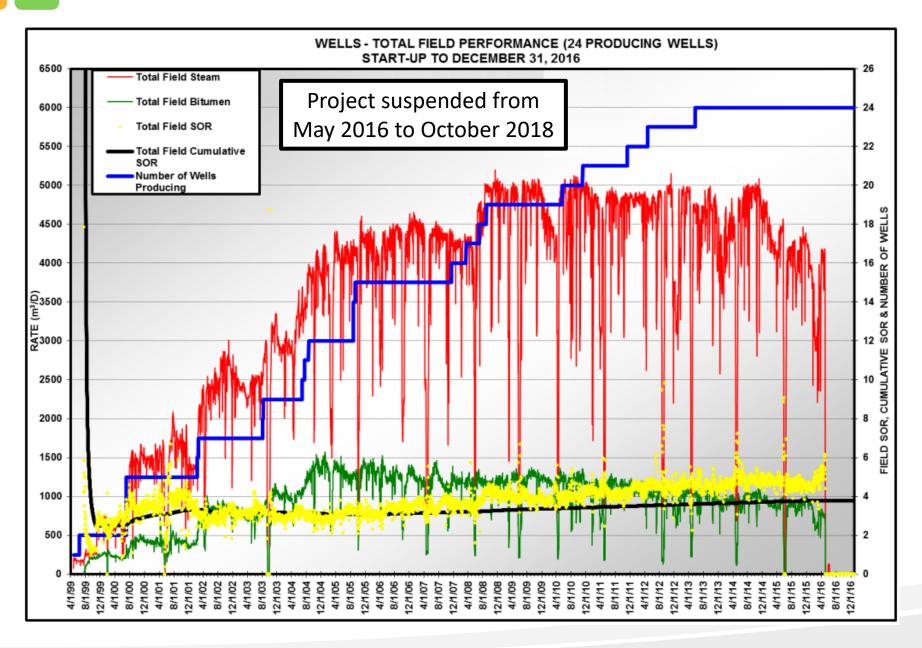


1.7 SCHEME PERFORMANCE – METHODOLOGY

- A linear trend is adopted to describe the steam-oil ratio ("SOR")
 performance
- The initial Project SOR has been evaluated as a function of effective net thickness. The initial SOR has four categories of thickness:
 - 10, 15, 20, and 25 metres
- The increasing SOR with time is from simulation results
 - SOR Increase of 0.025/month
- Greenfire has observed the actual trend is close to this prediction



1.7 SCHEME PERFORMANCE – HISTORICAL







1.7 SCHEME PERFORMANCE – ACTUAL VS. CAPACITY

- Greenfire's Hangingstone Project is currently approved for 1,749 m³/d of crude bitumen on an annual average basis
- Historical data shows that the Project reached nameplate capacity in 2004 and has been on a steady decline since
- The Project is still in a restart-up and ramp up after the extended suspension from May 2016 to November 2018
- Greenfire's current production rates are trending upwards and are anticipated to reach pre-shutdown levels in 2019





1.7 SCHEME PERFORMANCE – RECOVERY

Pad	Wellpairs	OBIP (Mbbl)	Cumulative Prod. Bitumen (Mbbl)	Current Recovery Factor (%)
1	A, B, M	13,562	8,407	62%
2	C, D, E	11,642	6,212	53%
3	H, I, J, K, L, N	16,040	12,086	75%
4	O, P, Q	9,797	4,278	44%
5	R, S, T, U, V, W	22,463	4,436	20%
6	X, Y	4,700	771	16%
Scheme (All)	ALL	78,204	36,189	46%

*Ultimate Recovery = 61% (as noted by previous operator)

OBIP= Rv x ϕ x (1-Sw) x FVF

Where:

OBIP → Original bitumen in place

Rv → Rock Volume

 $\phi \rightarrow$ Porosity

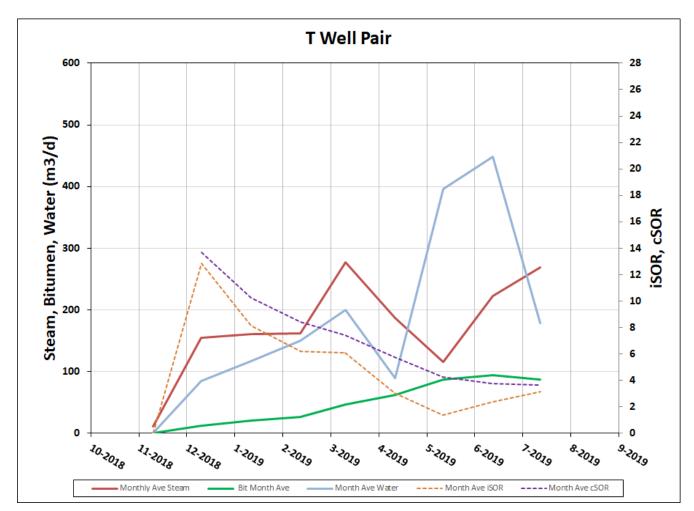
Sw → Initial water saturation

 $FVF \rightarrow$ Formation volume factor (1.001)



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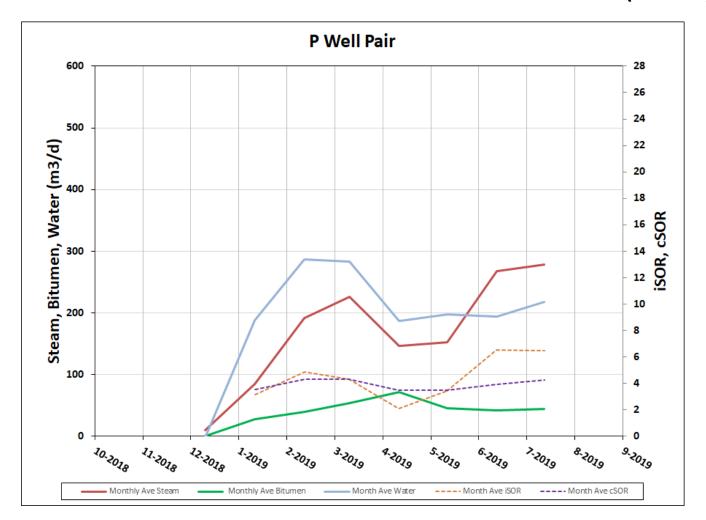
1.7 SCHEME PERFORMANCE – RECOVERY (HIGH)



- Subject well pair is in relatively clean, thick pay
- Middle of pad



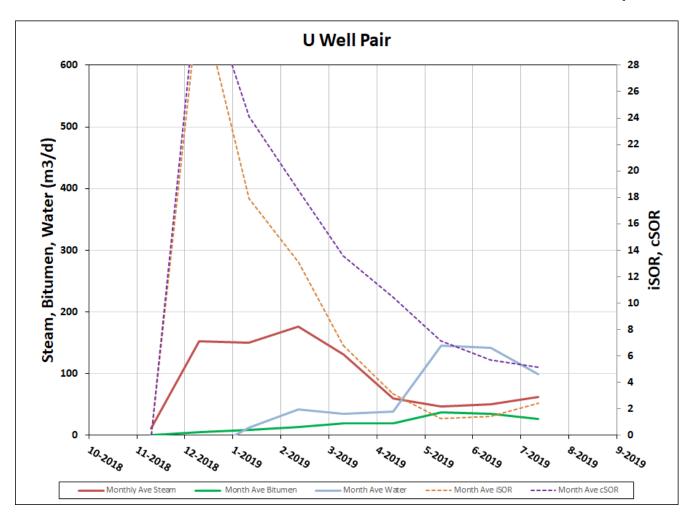
1.7 SCHEME PERFORMANCE – RECOVERY (MED)



- Subject well pair is in relatively clean pay
- Overall less net pay thickness than higher rate wells



1.7 SCHEME PERFORMANCE – RECOVERY (LOW)



- Subcool is currently limited by local heterogeneity
- Over time, the steam chamber will advance above the breccia, increasing the production rate



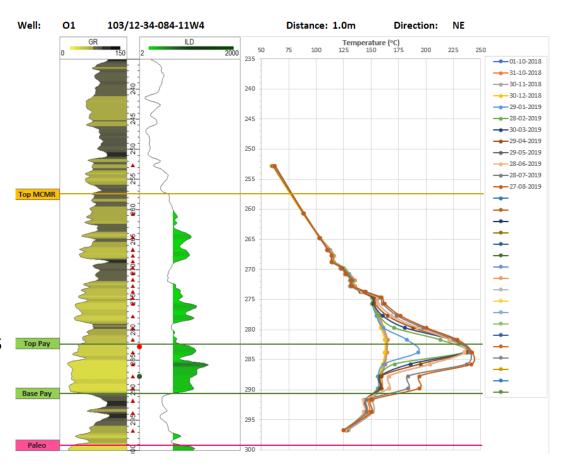


1.7 SCHEME PERFORMANCE – START-UP CHALLENGES

"O" Well Example

Challenges include:

- Initially high sub-cool (low oil cut) taking longer to decrease than other wells. Was an edge well until "J" well started > 3 months after.
- High liquid rates have to be choked to limit mobilization of solids
- Piping configuration only allows for steam injection to a single string of injector while producer requires steam lift to bring produced fluid to surface
 - This is temporary until reservoir pressure increased to target







1.7 SCHEME PERFORMANCE – PAD ABANDONMENT

 Greenfire does not intend to conduct any pad abandonments over the next five years of scheme operations





1.7 SCHEME PERFORMANCE – STEAM

Average Wellhead Pressure and Temperature					
2019 - During Operation					
Well					
Α	N/A	N/A			
В	3,209	239			
С	3,200	237			
D	3,500	242			
E	3,900	249			
Н	3,543	244			
1	3,941	251			
J	3,797	248			
K	3,266	240			
L	3,857	249			
М	3,950	250			
N	3,600 244				
0	3,508 244				
Р	3,710	247			
Q	3,423	243			
R	3,883	251			
S	3,584	247			
Т	3,748	249			
U	3,196	240			
V	3,970	250			
W	4,074	252			
X	2,543	227			
Υ	3,473	239			

- 100% Steam Quality at: HZA, HZB, HZC, HZD, HZE
- Average Steam quality for the remaining wells ~95%





1.7 SCHEME PERFORMANCE – NCG CO-INJECTION

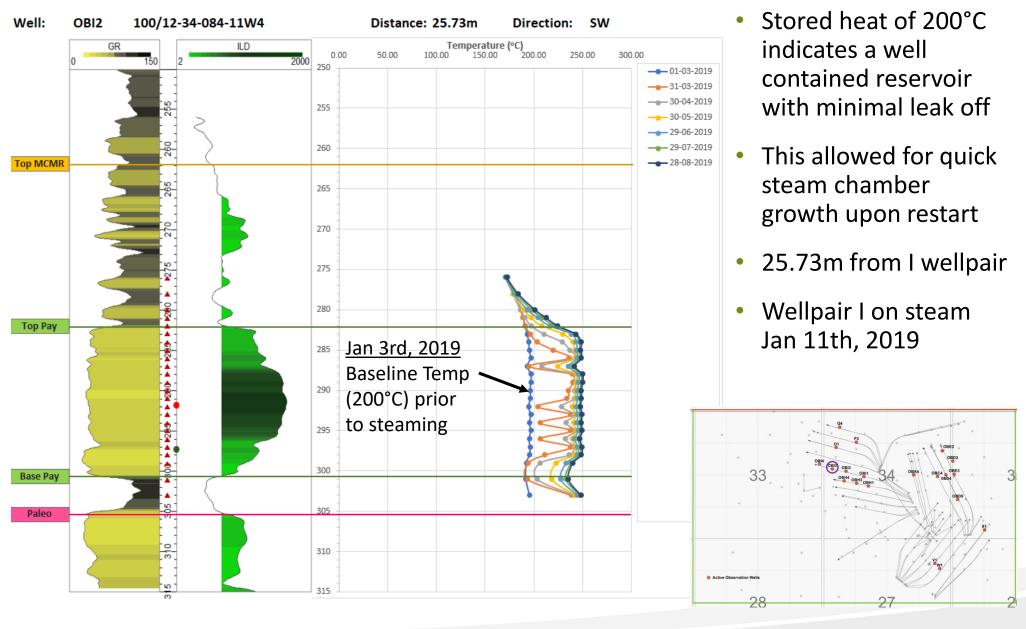
- The Project's NCG co-injection scheme was amended by Greenfire in 2018 and 2019
- Applications were approved for full field NCG co-injection and to increase injection to 50 mole percent with steam on a monthly basis
- Greenfire intends to continue with a high rate of NCG co-injection to assist with reservoir pressure maintenance, pending market conditions
- Table provides NCG co-injection carried out from January to July 2019
 - Average project injection was 43 e³m³/d
 - Cumulative NCG co-injection was 9,321 e³m³

Pad	Well	Max. Month, Daily Avg. NCG Rate (e ³ m ³ /d)	Avg. NCG Rate (e ³ m ³ /d)	
1	В	3.30	0.80	
1	М	12.35	4.63	
	С	0.10	0.02	
2	D	3.76	1.34	
	Е	20.54	5.95	
	Н	7.73	2.14	
	- 1	9.20	3.10	
3	J	18.00	5.22	
3	K	1.18	0.27	
	L	24.03	6.88	
	N	-	-	
	0	-	-	
4	P	8.28	2.89	
	Q	0.37	0.06	
	R	4.42	2.32	
	S	3.99	1.96	
5	T	4.13	2.09	
3	U	3.12	1.99	
	V	2.62	0.88	
	W	2.37	1.43	
6	X	-	-	
0	Y	-	-	





1.7 SCHEME PERFORMANCE – OBS WELL EXAMPLE







1.7 SCHEME PERFORMANCE – KEY LEARNINGS

- No well integrity issues encountered during re-start of SAGD wells
 - Detailed well start-up plan that was utilized focused on a controlled rate of temperature increase in the build section and on preventing condensation induced water hammer in the lateral
- Significant amount of stored heat in steam chambers prior to plant suspension. Well start-ups required minimal circulation periods resulting in efficient ramp-ups
- Strategic steam deployment and NCG co-injection has increased the reservoir pressure by 500 kPa since restart, reducing steam lift, gas lift, and quench water requirements
- Alternating heel and toe production has improved lateral conformance





1.8 FUTURE PLANS – SUBSURFACE

- There are no planned changes to the overall resources recovery strategy than what has been described in the original scheme application or subsequent amendments. Scheme amendments made by Greenfire over the reporting period include:
 - Application for Full Field NCG Co-Injection was approved by AER in November 2018
 - Application for Pressure Maintenance was approved by the AER in June 2019
- Drilling Plans (2019-2020)
 - Greenfire is examining the potential for one additional well pair within the approved project area
- Steam Strategy
 - Greenfire will continue to re-start and ramp-up the wells throughout 2019 and into 2020 until reservoir pressures return to the pre-suspension target of ~4,000 kPa







SECTION 2.0 – SURFACE OPERATIONS

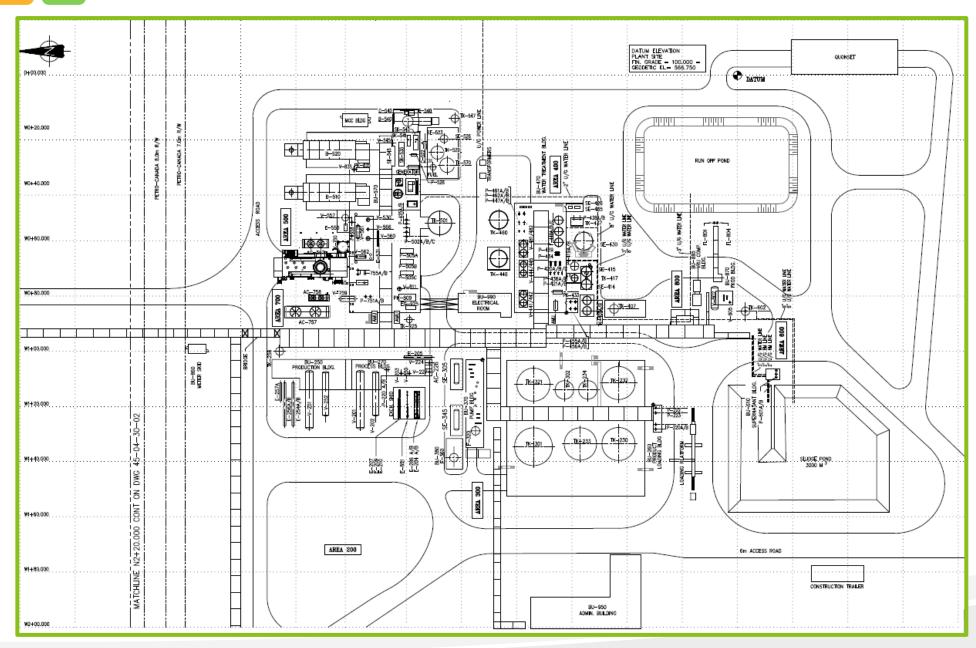
HANGINGSTONE SAGD PROJECT

Scheme Approval No. 8788, as amended

EPEA Approval No. 1604, as amended

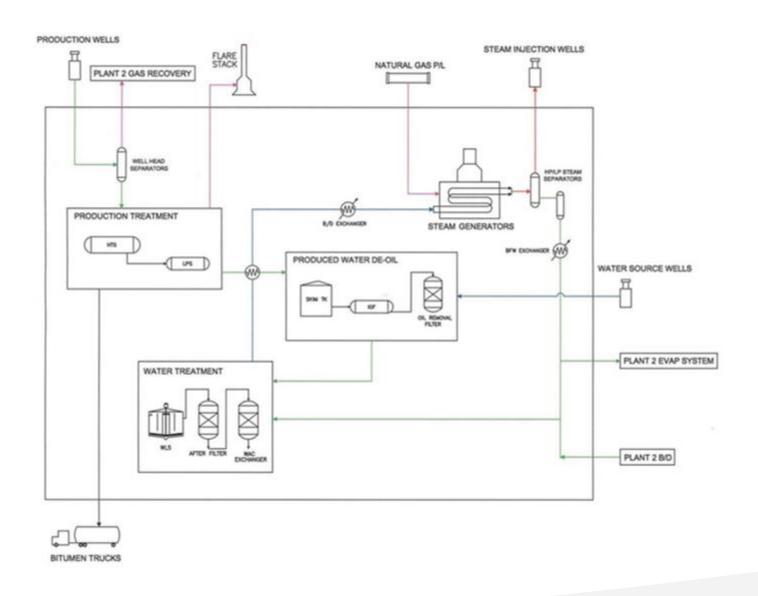
September 2019

2.1 FACILITIES - SURVEY/PLOT PLAN (PLANT 2)



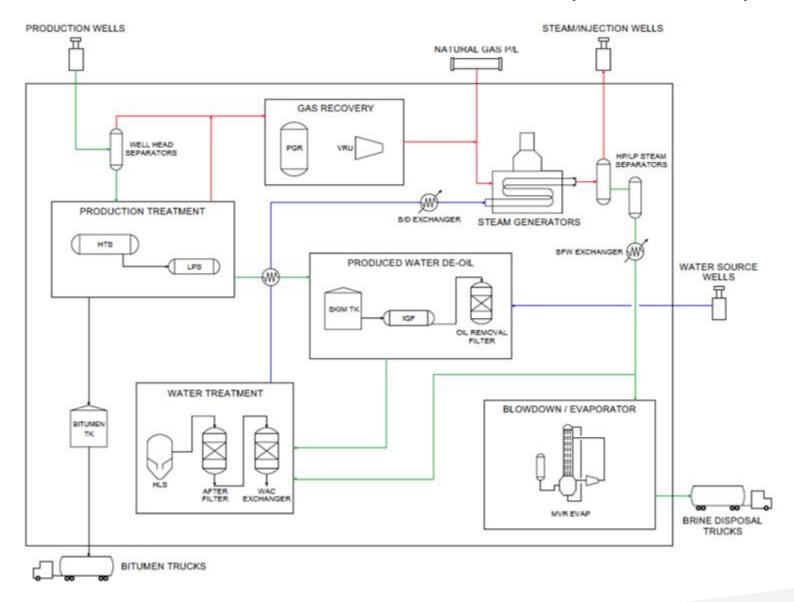


2.1 FACILITIES - PLANT 1 SCHEMATIC (SIMPLIFIED)





2.1 FACILITIES - PLANT 2 SCHEMATIC (SIMPLIFIED)







2.1 FACILITIES – PLANT SCHEMATIC MODIFICATIONS

 No major facility modification have been undertaken by Greenfire between August 2018 and July 2019





2.1 FACILITIES — PLANT PERFORMANCE

- Greenfire's operations are exceeding expectations
- Key accomplishments
 - Successful re-commissioning & start-up of the facility
 - Facility was under long term suspension for more than 900 days before the restart. This
 was the longest project shutdown ever experienced in the Alberta oil sands sector.
- Key Milestones

September 2018: Plant operations re-established

– October 2018: First Steam

November 2018: First Production of neat bitumen

December 2018: First Bitumen Sales

July 2019: Sustained > 4,000 bbl/d of bitumen production

August 2019: LMR of 6.67

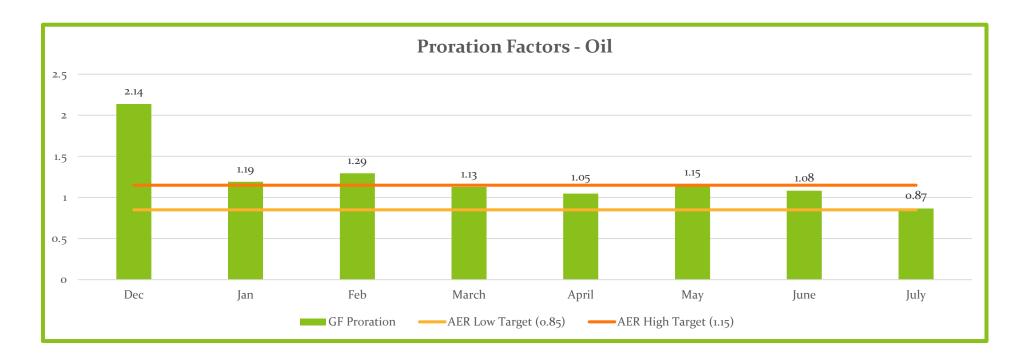


2.2 MARP – ESTIMATION METHODOLOGY

- The Project complies with Directive 017 and Directive 042
- Facility Measurement
 - Gas balance using gas/oil ratios (GOR)
 - Reservoir GOR = 4
 - Steam from CPF to well pads is within tolerance
 - Metering limitations due to re-start & ramp-up
 - Ex. Some FG meters are not properly sized.
 - Maintenance programs (including parameter changes) are in place to manage until identified limitations can be rectified during the 2019 turnaround
 - Limitations will decrease as Project is returned to steady-state operations
- Field (Well Pad) Measurements
 - Vortex steam meters on each injection well
 - Test and group separators at each well pad
 - Each production well is testing in compliance with AER measurement requirements
 - New NCG co-injection meters installed at select well pads



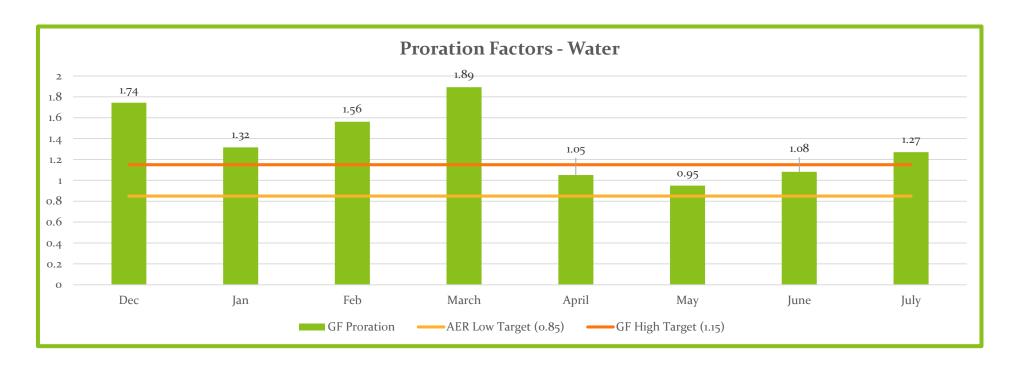




Proration factors for oil are in line with AER targets



2.2 - MARP PRORATION FACTORS (WATER)



- Proration factors for water have been out of target for the first four months of production
- Issues were anticipated due to long-term Project suspension and the re-start/ramp-up and are being managed
- Expect that factors will be in line by the end of 2019 as more stable operations are realized





2.2 MARP – COMPLIANCE

- Full MARP revisions where submitted to the AER for review in September 2018 with approval received July 2019
- Compliance issues noted by AER during review and inspection are scheduled for resolution during plant turnaround scheduled in Fall 2019



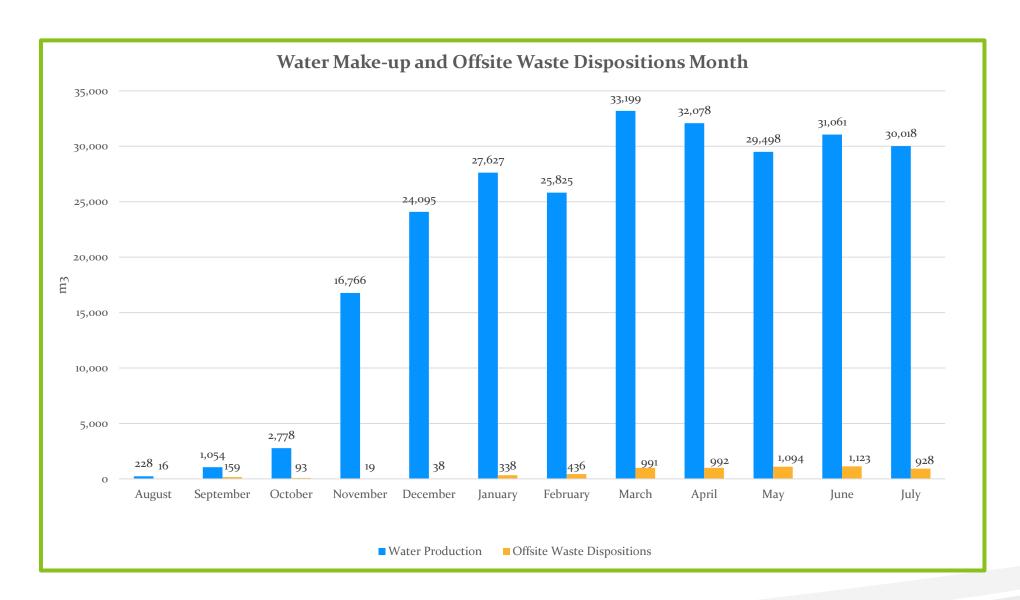


2.3 WATER SOURCE & USAGE

- Greenfire utilizes water for the Project under Water Act Licence No. 0229371-02-00, as amended
- There are two (2) high-quality, non-saline water wells associated with subject licence are located at 08-11-084-11W4
- The subject licence allocates 438,000 m³ per year for the Project
- From August 1, 2018 to July 31, 2019, the Hangingstone Project has utilized ~255,000 m³ of water under the subject licence
- Greenfire anticipates that once the Project is returned to steady-state operations usage will align with the annual allocation
- Greenfire has not withdrawn any fresh water from lakes, rivers, and/or ponds



2.3 WATER BALANCE





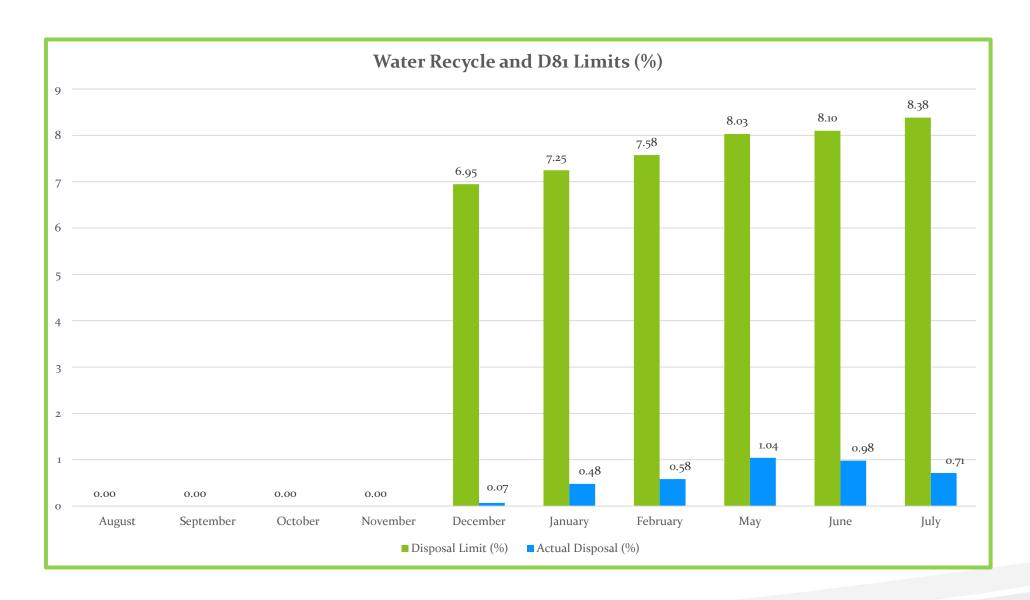


2.4 WATER TREATMENT

- Greenfire's Project utilizes both hot lime softeners ("HLS") and weak acid cation ("WAC") exchange process to treat all the water that is received at the central processing facility
 - Both systems are operating consistently above nameplate capacity
 - Flow limitations have been experienced with the WAC due to configuration
 - Plugging of the top spray nozzle in the HLS has created a high dP
 - Regular system maintenance and cleanings are minimizing these issues
- A mechanical vapour recompression ("MVR") system is utilized to treat blowdown from the steam generators
 - System is operating well
 - Increasing the concentration of the MVR is optimizing on-site water usage and recycle
- Steam production and quality increasing every month (recently above 80% quality)
 - OTSG's availability is very high and increasing every month.



2.4 WATER RECYCLE & LIMITS







2.5 WASTE DISPOSAL

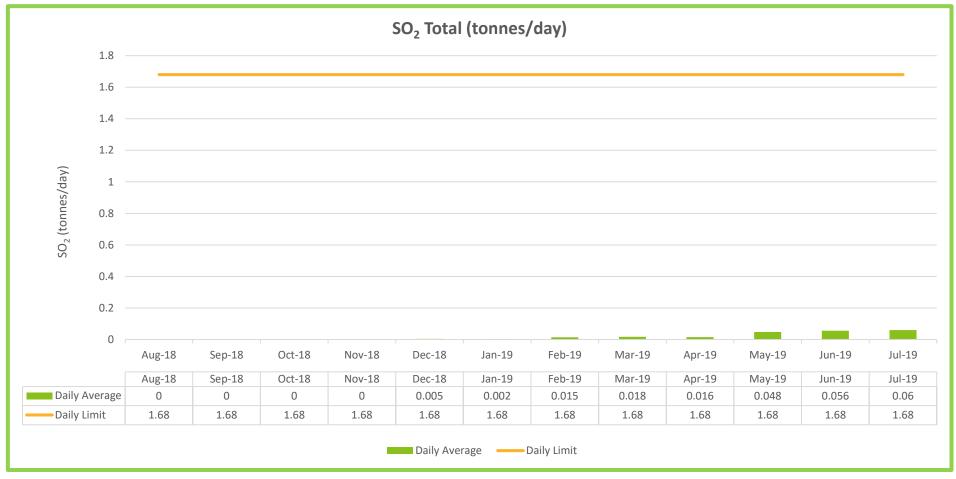
- The Project is in compliance with the Directive 081 disposal limits
- There are no onsite disposal wells associated with the Project
- All waste is shipped off site to AER approved regulated management facilities
- Waste generated on site is typically shipped to the following facilities:
 - White Swan Environmental Ltd. (Conklin WM 197)
 - White Swan Environmental Ltd. (Atmore WM 182/202)
 - Tervita Corporation (High Prairie WM 112)





2.6 SULPHUR – PLANT SO2 EMISSIONS

SO2 (tonnes/month) – August 2018 to July 2019



Note:

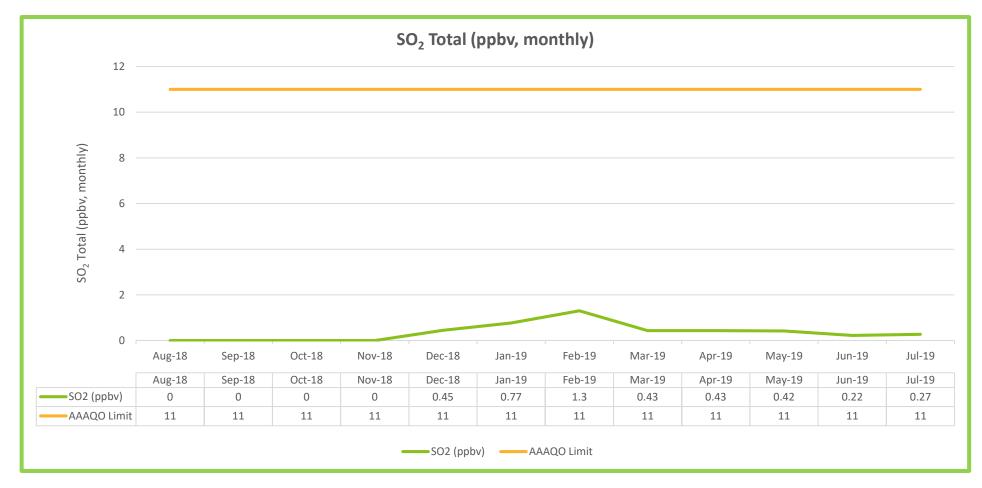
Due to suspension and restart of Project, monitoring commenced with first production in December 2018





2.6 SULPHUR – AMBIENT AIR SUMMARY (SO₂)

SO₂ (ppbv/month-average) – August 2018 to July 2019



Note:

Due to suspension and restart of Project, monitoring commenced with first production in December 2018





2.6 SULPHUR – AMBIENT AIR SUMMARY (H₂S)

H₂S (ppbv/month-average) – August 2018 to July 2019



Note:

Due to suspension and restart of Project, monitoring commenced with first production in December 2018





2.7 ENVIRONMENT – COMPLIANCE

 Greenfire has experienced no major compliance issues related to its Environmental Protection and Enhancement Act ("EPEA") Approval No. 1604, as amended





2.7 ENVIRONMENT – AMENDMENTS

- Greenfire has not undertaken any major amendments to the Project EPEA Approval
 - Request was made in September 2018 to extend the expiry date of the subject approval for 1 year
 - Approval was granted in October 2018
 - The subject EPEA Approval is now due for renewal on or before January 31, 2020





2.7 ENVIRONMENT – MONITORING

- Air Monitoring Continuous
 - Continuous air monitoring is currently suspended
 - Will be reviewed as part of pending EPEA renewal application
- Air Monitoring Passive
 - Program reimplemented in December 2018 with no exceedances to date
- Fugitive Emissions Survey & Stack Testing
 - Survey and testing was undertaken in July 2019
- Groundwater
 - No major exceedances or trends were noted as part of 2019 reporting
 - AER approved reduce monitoring frequency to once per annum for all shallow monitoring wells based on 2019 compliance reporting results
- Soils
 - AER Approval to submit soil monitoring report by end of November 2019
- Vegetation Management
 - Activities conducted in spring and summer 2019 at Project site





2.7 ENVIRONMENT – INITIATIVES

- Greenfire continues to support an ongoing reclamation research projects within its primary MSL
- The projects are being managed by Japan Canada Oil Sands Ltd. ("JACOS") supporting research by:
 - University of Waterloo
 - Canada's Oil Sands Innovation Alliance ("COSIA")
 - University of Laval
 - Northern Alberta Institute of Technology ("NAIT")





2.7 ENVIRONMENT – RECLAMATION

- Since August 2018, Greenfire has not engaged in any reclamation programs at the Project
 - Prior to obtaining control of the Project, the previous operator (JACOS)
 conducted remediation activates and reclamation certificates were obtained on
 22 sites within the Projects primary MSL
- At this time, there are no well production pads scheduled for abandonment, remediation, or reclamation





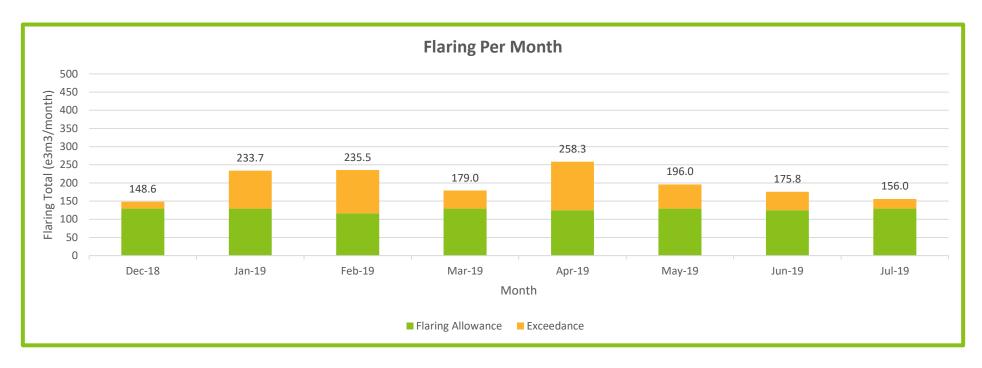
2.8 COMPLIANCE

- Greenfire is compliant with all conditions of its EPEA, OSCA, and Water Act Approvals and Licences, subject to the following:
 - Temporary exceedances above approved Directive 056 flaring limits
 - Temporary allowances approved by AER subject to conditions and reporting requirements
 - AER Operational Inspection completed June 18, 2019
 - Minor signage issues
 - Secondary containment concerns with build sumps and trenches
 - MARP tagging issues

Identified compliance issues are anticipated to be resolved on or before November 2019



2.8 COMPLIANCE – FLARING



- The Project is approved to flare up to 4.17 e³m³/d
- Exceedance resulted from lower reservoir pressure associated with long-term suspension and subsequent ramp-up
- Flaring notifications have been submitted as per AER direction
- Project will be within flaring limits once it is returned to steady-state





2.9 SURFACE — SUCCESSES

- The once through steam generators blow down mechanical vapour recompression unit is working well at high concentrations
- Limited off-spec production during the start-up of the plant
- There have been no major safety incidents or lost time accidents from August 1, 2018 to July 31, 2019





2.10 FUTURE PLANS – SURFACE

- Greenfire remains focused on start-up/ramp-up operations with an emphasis on returning its wells to steady-state operations
- Greenfire's plans include, but may not be limited to:
 - Plant optimizations, specific to water recycling
 - Metering upgrading, where required
 - Surface infrastructure upgrades/additions on legacy pads to increase production capacities

