

JetShear™ Processing Plant Pilot

Final Scheme 12346E Report

Submitted to the Alberta Energy Regulator

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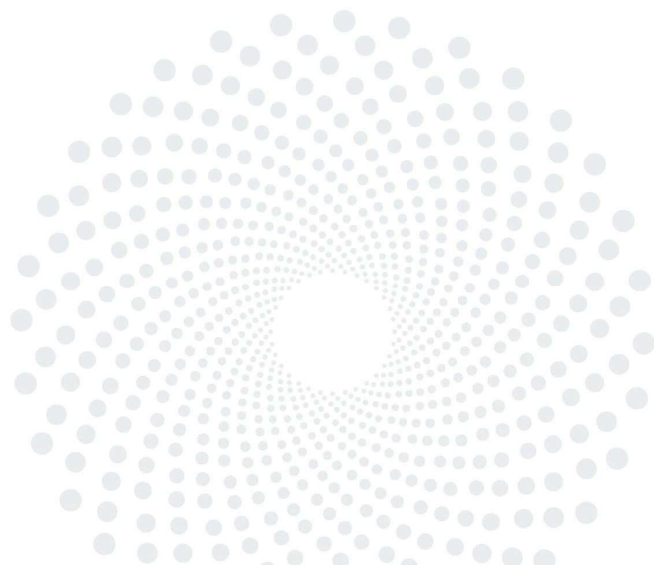


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1. Project Introduction

1.1 Background

The Project is located 14.7 km north of the Hamlet of Hayter, Alberta, within the Municipal District of Provost No. 52 (Figure 1) at 08-35-040-01W4M on private farmland within a lease (8-35) held by Harvest Operations Corp. (Figure 2).

The Project was first constructed in 2011 as a commercial demonstration unit to process dilbit from a conventional heavy oil battery. In July 2014, the owner of the Project (Fractal Systems Inc.) applied for Experimental Scheme Approval under the *Oil Sands Conservation Act* (OSCA). At that time, approval under the *Environmental Protection and Enhancement Act* (EPEA) was not required. In 2017 Cenovus acquired the facility from Fractal Systems and in 2021 were advised by the AER that Scheme and EPEA approvals would now be required to continue to operate the pilot facility. These were applied for and in 2022 Cenovus submitted these applications and received Scheme approval 12346E and EPEA Approval 00483474-00-00. In February, 2023 the EPEA was amended to increase the stack height of the thermal oxidizer.

The Project is a pilot plant to test the Jetshear™ technology capabilities of reducing the viscosity of bitumen with a production capacity of up to 159 m³/day (1,000 barrels per day (bpd)) of diluted bitumen (dilbit). The pilot plant consists of a:

- tank farm with two inlet tanks (TK-81101 and TK-81201) and an outlet tank (TK-81271);
- a thermal oxidizer;
- heat exchangers;
- several pumps and JetShear™ nozzles;
- glycol air cooler;
- several stripping columns, as well as a heater and pop tank (TK-81275- hydrotreated gas oil tank).

A plot plan is shown as Figure 3.

1.2 Plant Design and Operation

The purpose of the pilot plant is to optimize and validate the partial upgrading technologies such as JetShear™ and HDR technologies, determine maintenance cycles and cleaning frequencies of various equipment, and to demonstrate its benefits of displacing diluent through partial upgrading of diluted bitumen. The process is best described as a light upgrading or treating process comprised of both thermal and mechanical (e.g., cavitational) upgrading components with or without adding Synthetic Crude Oil (SCO). Heavy oil or bitumen treated in the process realizes significant transport property transformation characterized through reductions in viscosity and density. These property transformations facilitate the reduction of total net diluent addition required to meet pipeline specifications for transportation. The facility

was modified to accommodate the testing of the HDR (Hydrogen-donor Diluent Reduction) process, which involves running at lower pressure with the addition of Synthetic Crude Oil (SCO) to the feed.

A process flow diagram is shown as Figure 4. The key processing units for the Project include:

- tankage area;
- main process area;
- H₂S stripping;
- cooling loop; and
- off gas treatment.

Produced dilbit is introduced to the processing facilities via a pre-charge feed pump from the tankage area. Dilbit is then transferred by pump through the tube side of four heat recovery heat exchangers installed in series by the hot product. It is then pumped through another set of heat exchangers where it is further heated. The feed is then heated to its final temperature (410°C) in a dilbit heater. The high pressure / temperature dilbit is then sent through proprietary nozzles which subject the oil to cavitation. The treated oil is then cooled to an intermediate temperature to strip off any unwanted gases that are solubilized in the liquid. After stripping, the liquid is cooled and ready to be shipped, while gases are oxidized in a thermal oxidizer.

The Project processes clean dilbit. There are no water or solids byproducts generated. Emissions (*e.g.*, nitrogen, oxygen, water vapour, carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides and sulphur dioxide) are generated from the combustion of natural gas and air in the process. The thermal oxidizer combusts all off gases generated by the pilot plant.

2. Operations and Activities

Operational activities for the year are summarized in Table 1. In January 2024 an application was made to extend the expiry date of the Scheme approval from March 31, 2024 to March 31, 2026. Cenovus intends to decommission the facility and start the reclamation process according to the AER requirements.

Table 1 - Operational Activities Summary

Date Range	Activity
Aug 31/21 to Aug 31/22	Construction of facility modifications to accommodate HDR and additional test options.
Aug 31 to Oct 2/22	Plant commissioning and preliminary operation.
Oct 3 to Oct 23/22	Enhanced JetShear™ runs (Phase A set of runs).
Nov 2 to Nov 14/22	HDR runs (Phase B set of runs).

Nov 22/22	Plant shut down due to exceedance of Sulphur dioxide (SO ₂) emissions from thermal oxidizer (AER FIS #20222607). Plant remains shutdown.
Jan 20/23	An EPEA amendment submitted to the AER to increase the stack height of the thermal oxidizer. Plant remains shutdown until amendment is approved.
Jan 31/23	Groundwater monitoring proposal submitted.
Feb 27/23	AER approval of EPEA amendment (00483474-00-01) to increase TOX stack height
Mar – Aug 2023	Design, fabrication, installation, and commissioning of extended TOX unit. Plant maintenance activities.
Jul 27 – Aug 10/23	TOX transport and installation.
Aug 15 – 17/23	TOX commissioning.
Aug 17 – Sep 4/23	Plant commissioning and start-up.
Sep 5/23 – Sep 27/23	Phase C set of runs.
Sep 27/23	Plant was shutdown due to a pump failure incident resulting in a fire. AER was notified and investigation was conducted. (FIS 20232415)
Sept 28 – Nov 20/23	Plant remained shutdown while incident investigation, root cause analysis, and rectifying actions were completed.
Nov 20/23	AER approval given to Cenovus to restart the portion of the facility not directly involved in the incident. Fire affected area kept bypassed and isolated. Plant remained shutdown until all actions have been completed to ensure safe operation.
Dec 4/23	Plant restart.
Dec 4 – 13/23	Phase D set of runs.
Dec 13 – 31/23	Plant shutdown, equipment flushed, tanks drained.
Janu 1/24	Application submitted to extend the expiry date of the scheme approval from March 31, 2024 to March 31, 2026. Approval received February 23rd.
Jan 1 - Dec 31/24	Complete weekly site inspections.
Dec/23 – Jun/24	Draining of feed, sales and ARP tanks.
Jul 15/24	Waste materials shipped to Clean Harbors.
Aug/24	First groundwater sampling event.
Oct/24	Second groundwater sampling event.
Oct - Nov/24	Waste materials and unused process chemicals removed from site.
Jan 1 - Dec 31/25	Complete weekly site inspections.
Feb/25	Isolate tanks and other equipment.
Jun/25	First groundwater sampling event.
Oct/25	Second groundwater sampling event.

3. Energy and Materials Balance

The operation of the pilot involved 4 phases of testing. The first phase (Phase A) was conducted at high pressure and mainly without the addition of SCO-Gas Oil (SCO-GO), while the second phase (Phase B) was conducted mainly at low pressure and with SCO-Gas Oil addition. At the end of Phase B, additional dilbit was received in preparation for another set of runs. However, the plant was shut down due to exceedance of SO₂ emissions from the thermal oxidizer. The received dilbit was not processed and was

trucked out at the end of December 2022. Phase C included repeat runs from previous tests to confirm reproducibility of results, as well as further optimizing process pressure and thermal cracking severity. A set of runs were planned to test the Acid Reduction Process part of the facility; however, these tests were cancelled due to the pump failure incident on Sep 27, 2023. Phase D included a set of key runs, in which final refinery acceptance samples were produced. Phase D also tested low severity conditions. With the completion of the Phase D set of runs, the pilot was concluded in December 2023.

Table 2 shows the energy and materials balance for Phase A of testing, which ran from October 12 to 23. Table 3 shows the energy and materials balance for Phase B of testing, which ran from November 2 to 14. Table 3 shows the energy and materials balance for Phase C of testing, which ran from September 5 to 27. Table 4 shows the energy and materials balance for Phase D of testing, which ran from December 4 to 15. The material balance includes sections on total material entering and leaving the plant, and sections including only streams that entered and exited the partial upgrading process. The inputs include the dilbit feed, natural gas used as stripping gas for product separation, hydrogen, and SCO-Gas Oil. The outputs include process waste gases and dilbit product.

The energy balance includes all feedstock, natural gas, hydrogen, and electricity inputs during the time that the plant was operational for each phase. The energy outputs include the processed dilbit and the process gases that were oxidized in the thermal oxidizer.

Table 2 - Energy and Material Balance for Phase A Tests

Start and End Dates			
Initial Truck Unload	30-Aug-22	Last Truck Load	25-Oct-22
Phase A Start	2022-10-03 13:00	Phase A End	2022-10-23 22:00
Energy Assumptions			
Feed LHV (kJ/kg)	43,812	Natural Gas (MJ/m3)	39.7
Product LHV (kJ/kg)	45,338	Hydrogen (MJ/kg)	120
SCO LHV (kJ/kg)	43,050	Process Gas (MJ/m3)	42.8
Process Gas MW (g/mol)	22.4		
Total Mass Received (kg)		Total Energy Input (GJ)	
Dilbit Feed	1,321,116	Electricity	178.0**
Stripping Gas	4,455	Dilbit Feed	44,529
Hydrogen	583.8	Natural Gas	4,769**
SCO-GO	38,838	Hydrogen	70.05
	1,364,993	SCO-GO	615.7
Total Input to Process (kg)			50,162
Dilbit Feed	1,048,410	Total Energy Output (GJ)	
Stripping Gas	4,455	Dilbit Product	45,811
Hydrogen	583.8	Oxidized Gas	1,112.6
SCO-GO	14,303		46,923
	1,067,752	Energy Efficiency	
			94%
Total Output from Process (kg)			
Diluent Recovered	229,152		
Bitumen Product	781,278		
Process Gas	24,632*		
	1,035,062		
Total Mass Removed (kg)			
Dilbit Product	923,596		
Process Gas	24,632		
	948,228		
Accumulation in Tanks (kg)			
SCO-GO	24,535		
Feed	272,706		
Intermediate	32,047		
Sales	86,834		
	416,123		

*Corrected based on average over periods where meter was unreliable (see section 6)

**Electricity and natural gas usage during operational run-time only

Table 3 – Energy and Material Balance for Phase B Tests

Start and End Dates			
Initial Truck Unload	25-Oct-22	Last Truck Load	15-Nov-22
Phase B Start	11-2-22 14:00	Phase B End	11-14-22 17:30
Energy Assumptions			
Feed LHV (kJ/kg)	43,812	Natural Gas (MJ/m3)	39.7
Product LHV (kJ/kg)	45,338	Hydrogen (MJ/kg)	120
SCO LHV (kJ/kg)	43,050	Process Gas (MJ/m3)	42.8
Process Gas MW (g/mol)	22.4		
Total Mass Received (kg)		Total Energy Input (GJ)	
Dilbit Feed	849,730	Electricity	221.2
Stripping Gas	4,559	Dilbit Feed	43,149
Hydrogen	13.9	Natural Gas	3,366
SCO-GO	54,549	Hydrogen	1.67
	908,853	SCO-GO	1,983
Total Input to Process (kg)			48,720
Dilbit Feed	894,622	Total Energy Output (GJ)	
Stripping Gas	4,559	Dilbit Product	46,260
Hydrogen	13.9	Oxidized Gas	684.9
SCO-GO	46,058		46,944
	945,254	Energy Efficiency	
			96%
Total Output from Process (kg)			
Diluent Recovered	213,971		
Bitumen Product	806,357		
Process Gas	15,162		
	1,035,489		
Total Mass Removed (kg)			
Dilbit Product	919,838		
Process Gas	15,162		
	935,000		
Accumulation in Tanks (kg)			
SCO-GO	8,491		
Feed	(44,892)		
Intermediate	(90,236)		
Sales	100,490		
	(26,147)		

Table 4 - Energy and Material Balance for Phase C Tests

Start and End Dates			
Initial Truck Unload	2023-08-21	Last Truck Load	2023-09-27
Phase C Start	2023-09-04	Phase C End	2023-09-27
Energy Assumptions			
Feed LHV (kJ/kg)	43,812	Natural Gas (MJ/m3)	39.5
Product LHV (kJ/kg)	45,338	Hydrogen (MJ/kg)	120
SCO LHV (kJ/kg)	43,050	Process Gas (MJ/m3)	42.8
Process Gas MW (g/mol)	22.4		
Total Mass Received (kg)		Total Energy Input (GJ)	
Dilbit Truck-in	1,121,098	Electricity	189.6
Stripping Gas	5,673	Dilbit Feed	42,684
Hydrogen	-	Natural Gas	4,404
SCO-GO	-	Hydrogen	-
Totals	1,126,771	SCO-GO	393.4
Total Input to Process (kg)			47,670
Dilbit Feed	1,000,401	Total Energy Output (GJ)	
Stripping Gas	5,673	Dilbit Product	43,645
Hydrogen	-	Oxidized Gas	1,192.8
SCO-GO	9,138	Totals	44,837
Totals	1,015,212	Energy Efficiency	
			94%
Total Output from Process (kg)			
Diluent Recovered	223,497		
Bitumen Product	739,153		
Process Gas	26,406		
Totals	989,056		
Total Mass Removed (kg)			
Treated Dilbit Truck-out	924,003		
Process Gas	26,406		
Totals	950,409		
Accumulation in Tanks (kg)			
SCO-GO	(9,138)		
Feed	120,697		
Intermediate	26,156		
Sales	77,768		
Totals	215,483		

Table 5 – Energy and Material Balance for Phase D Tests

Start and End Dates			
Initial Truck Unload	2023-12-04	Last Truck Load	2023-12-15
Phase B Start	2023-12-04	Phase B End	2023-12-15
Energy Assumptions			
Feed LHV (kJ/kg)	43,812	Natural Gas (MJ/m3)	39.5
Product LHV (kJ/kg)	45,338	Hydrogen (MJ/kg)	120
SCO LHV (kJ/kg)	43,050	Process Gas (MJ/m3)	42.8
Process Gas MW (g/mol)	22.4		
Total Mass Received (kg)		Total Energy Input (GJ)	
Dilbit Truck-in	453,671	Electricity	149.9
Stripping Gas	2,022	Dilbit Feed	25,188
Hydrogen	83.2	Natural Gas	2,260
SCO-GO	-	Hydrogen	9.99
Totals	455,776	SCO-GO	-
Total Input to Process (kg)		Totals	27,608
		Total Energy Output (GJ)	
Dilbit Feed	569,128	Dilbit Product	25,644
Stripping Gas	2,022	Oxidized Gas	511.0
Hydrogen	83.2	Totals	26,155
SCO-GO	-	Energy Efficiency	95%
Totals	571,233		
Total Output from Process (kg)			
Diluent Recovered	126,810		
Bitumen Product	438,805		
Process Gas	11,313		
Totals	576,928		
Total Mass Removed (kg)			
Treated Dilbit Truck-out	783,524		
Process Gas	11,313		
Totals	794,837		
Accumulation in Tanks (kg)			
SCO-GO	-		
Feed	(115,457)		
Intermediate	(5,778)		
Sales	(201,255)		
Totals	(322,489)		

4. Monthly Volumetric Summaries

4.1 Receipts and Dispositions of Hydrocarbons, Gas, and Electricity

Table 6 shows the volumetric summary of hydrocarbon, gas, and electricity receipts and dispositions, along with total tank inventory at the site at the end of each month in which the plant was operational.

Table 6 – Volumetric Summary of Plant Inputs and Tank Inventories

	Dilbit Received (m3)	SCO-GO Received (m3)	Dilbit Out (m3)	Total Tank Inventory (m3)	Electricity Use (GJ)	H2 Use (e3m3)	Natural Gas Use (e3m3)
Jul/22	-	-	-	-	135.3	-	0.51
Aug/22	192	-	109	84.6	129.6	1.03	6.25
Sep/22	750	43.06	378	498.0	149.9	0.81	153.84
Oct/22	993	30.64	1,009	545.7	250.6	5.94	152.96
Nov/22	1,007	29.84	1,152	471.2	298.5	0.07	98.09
Dec/22	-	-	289	187.3	257.9	-	56.91
Aug/23	455	-	-	N/A	170	-	22
Sep/23	1,045	-	1,010	432	260	-	111
Oct/23	-	-	-	429	182	-	62
Nov/23	-	-	-	418	194	-	60
Dec/23	490	-	856	-	266	0.93	57

4.2 Waste Generation

The Project processes clean dilbit. There are no water or solids byproducts generated. Emissions (e.g., nitrogen, oxygen, water vapour, carbon dioxide, carbon monoxide, hydrocarbons, nitrogen oxides and sulphur dioxide) are generated from the combustion of natural gas and air in the process. The thermal oxidizer combusts all off gases generated by the pilot plant.

Typical wastes generated at the facility include:

- rags, leak pads, domestic waste which are stored in dedicated waste bins;
- process liquid waste (samples, oil, solvents) stored in a dedicated drum and recycled back in the feed tank and processed;
- process tank bottoms which are removed by vacuum truck and disposed off-site; and,
- soil waste (contaminated/spills) stored in dedicated drums and disposed off-site.

Table 7 provides a summary of waste generated at the facility.

Table 7 – Summary of Waste Generated

Date	AER Waste Code	Quantity (m³)	Management
March 8	Heavy oil waste and wastewater	0.5	Cavern disposal (Hughenden - operator code A267)
April 1	Heavy oil waste and wastewater	6.0	Cavern disposal (Hughenden - operator code A267)
April 18	Office Waste	4.6	Landfill
June 28	Heavy oil waste and wastewater	6.0	Cavern disposal (Hughenden - operator code A267)
July 11	Office Waste	4.6	Landfill
October 12	Heavy oil waste and wastewater	2.1	Cavern disposal (Hughenden - operator code A267)
November 10	Leachable solid waste (rags, sorbent pad)	1.4	Recycled – RBW Waste Management
November 23	Heavy oil waste and wastewater	1.0	Cavern disposal (Hughenden - operator code A267)
December 14	Heavy oil waste and wastewater	5.0	Cavern disposal (Hughenden - operator code A267)
04-Oct-23	COEMUL	6	Recycle Facility (ABR 10118)
13-Oct-23	SLGHYD	5	Cavern disposal (Hughenden - operator code A267)
24-Oct-23	SLGHYD	3	Cavern disposal (Hughenden - operator code A267)
22-Nov-23	UNCLASSIFIED	5	MD Provost Landfill (soil cuttings from boreholes)
11-Dec-23	COEMUL	20	Cavern disposal (Hughenden - operator code A267)
15-Dec-23	COEMUL	32	Waste Processing Facility (operator code A6T6)
15-Dec-23	COEMUL	7	Waste Processing Facility (operator code A6T6)
18-Dec-23	SLGHYD	8	Cavern disposal (Hughenden - operator code A267)
27-Dec-23	SLGHYD	9	Cavern disposal (Hughenden - operator code A267)
28-Dec-23	SLGHYD	10	Cavern disposal (Hughenden - operator code A267)
15-Jul-24	H153	0.82	Clean Harbors Canada
31-Oct-24	WSTFLQ	0.23	RBW Waste Management Ltd
31-Oct-24	LUBOIL	0.22	RBW Waste Management Ltd
31-Oct-24	METHNL	0.02	RBW Waste Management Ltd
31-Oct-24	SOLARO	0.1	RBW Waste Management Ltd
31-Oct-24	SOILCO	1.4	RBW Waste Management Ltd
21-Nov-24	H153	615 kg	Clean Harbors Canada
21-Nov-24	H154	615 kg	Clean Harbors Canada
21-Nov-24	NR	205 kg	Clean Harbors Canada
21-Nov-24	NR	205 kg	Clean Harbors Canada
21-Nov-24	NR	205 kg	Clean Harbors Canada

4.3 Sulphur Balance

Table 6 shows the sulfur balance for each test run. During times when no test run was being conducted, no sulfur was produced. The sulfur content of bitumen feed and product were obtained from samples across several runs. The sulfur content in the process waste gas was determined from gas analyses conducted by third party labs. On-site daily Draeger tube testing was also done as a secondary check.

Table 8 - Sulphur Balance for All Test Runs

Test Run	Date Start	Date End	Run Time (days)	Sulfur in Bitumen ¹ (kg/d)	Sulfur out (Product) ² (kg/d)	SO ₂ per Run (kg)	Sulfur out (Gases) ^{1,2} (kg/d)
A1	10-13-22 8:40	10-14-22 13:30	1.20	3,208	2,720	1,096	548
A2	10-14-22 17:00	10-15-22 17:20	1.01	2,885	2,362	1,722	861
A3	10-15-22 20:10	10-16-22 14:05	0.75	3,155	2,649	1,969	985
A4	10-19-22 16:00	10-20-22 13:00	0.88	3,137	2,708	965	483
A5	10-20-22 21:30	10-21-22 16:00	0.77	3,210	2,702	1,023	512
A6	10-21-22 18:00	10-23-22 10:00	1.67	3,197	2,763	1,174	587
B1	11-3-22 16:00	11-4-22 14:00	0.92	3,230	2,839	407	204
B2/A4	11-4-22 14:00	11-5-22 13:00	0.96	3,196	2,802	495	248
B3	11-5-22 15:00	11-6-22 16:15	1.05	3,392	2,976	504	252
B4	11-6-22 16:15	11-7-22 16:15	1.00	3,381	2,958	473	236
B5	11-7-22 16:15	11-8-22 14:40	0.93	3,336	3,008	589	294
B6	11-10-22 16:00	11-11-22 11:00	0.79	3,390	2,954	735	367
B7	11-11-22 22:00	11-12-22 18:30	0.85	3,351	2,933	600	300
B8	11-12-22 18:30	11-13-22 12:00	0.73	3,342	2,912	724	362
B9	11-13-22 13:45	11-14-22 10:30	0.86	3,370	2,942	687	343
C1	9-6-23 10:45	9-7-23 18:20	1.32	3193	2755	882	416
C2	9-8-23 11:30	9-8-23 20:40	0.38	3400	2741	336	487
C3	9-12-23 9:45	9-12-23 17:00	0.30	3365	2703	324	536
C4	9-12-23 23:45	9-13-23 16:15	0.69	3356	2494	767	558
C5	9-13-23 17:30	9-14-23 11:55	0.77	3374	2752	724	562
C6	9-14-23 18:00	9-15-23 10:30	0.69	3193	2583	773	545
C7	9-15-23 11:40	9-16-23 0:18	0.53	3189	2522	574	472
C8	9-16-23 0:25	9-16-23 12:55	0.52	3368	2538	614	589
C9	9-17-23 19:00	9-18-23 9:55	0.62	3367	2399	888	714
D1	12-6-23 11:00	12-7-23 13:30	1.10	3201	2498	803	364
D2 ⁵	12-8-23 1:30	12-8-23 12:15	0.45	3246	2482	551	615
D3	12-8-23 14:30	12-9-23 8:15	0.74	3259	2728	518	350
D4	12-9-23 9:30	12-9-23 20:00	0.44	3255	2820	209	170
D5	12-9-23 21:20	12-10-23 8:00	0.44	3256	2811	195	219
D6	12-11-23 14:45	12-12-23 1:45	0.46	3273	2922	155	170

Notes and discussion on Table 8

1. Sulfur content for bitumen in and bitumen out are based on average of available data, if no data for the specific run is available. The average sulfur content of bitumen was 4.5 wt% ± 0.1% for the feed, and 4.0 wt% ± 0.1% for product.

2. Bitumen feed rate is measured using a Coriolis mass flow meter and totaled in the PLC. Bitumen product output rate was calculated based on the bitumen feed rate and gas make.
3. Due to a potential flow meter measurement issue for runs A1 to A3, the gas make readings may be higher than actual for these runs. This issue has been resolved and for future runs, a Coriolis-type mass flow meter will be installed to allow for measurement independent of gas composition. This meter will also be used to check the existing thermal mass meter readings.
4. The hydro-polishing unit was offline for all the Phase B set of runs, which is why SO₂ was lower for runs B1 to B9.
5. D2 was the only run conducted with the hydropolishing unit; more desulfurization is expected due to the use of hydrotreating catalyst during this run.

5 Measurement and Accounting Procedures

Measurement of all plant inputs and outputs are metered using mass flow meters. Volumes of dilbit hauled in and out are also metered by dedicated truck In/Out mass flow meters. SCO volumes hauled into site are measured from the truck meters and the meters at the supplying facility. On January 30, 2023, all plant inlet and outlet flow meters were removed and sent in for recalibration prior to the start of testing except for the dilbit feed meter which could not be removed due to inability to isolate it properly. However, this meter was checked versus the newly calibrated sales meter by flowing dilbit in a circuit through both meters. Process waste gas is measured using a thermal mass meter at the inlet of the Thermal Oxidizer.

All meter and tank level readings are recorded by the plant central PLC/DCS system which in turn sends them to a historian system to record the results for later analysis.

Mass balance results are calculated from the difference in totaled values at the start and end of the applicable operations period. The change in each tank volume from start to end is then added to the total mass in or out as applicable.

6 Measurements and Observations

Experimental runs at the facility typically take place during a two-week “on” shift. Different test conditions are planned during the run and typically test conditions are adjusted at the start of the day, then the plant is allowed to reach steady state overnight before samples are taken the next morning. Once sampling is complete, test conditions are adjusted for the next day’s operation and the process repeats.

A mass balance calculation is on-going for each set of test parameters for the steady state operating period to confirm the amount of mass lost from the inlet stream during the upgrading process. This will allow prediction of mass loss in an actual plant. Daily samples are tested on-site for density, viscosity, TAN number, and asphaltene stability. Samples are also blended with various amounts of diluent recovered from the diluent recovery system to determine properties of the products and various blend

ratios and to determine the amount of potential diluent savings due to the upgrading process. Samples are also sent out to third party labs to measure olefins, sulphur content and other properties.

Several sets of experimental parameters were selected based on the 2022 results and additional experiments were conducted in Phase C and D runs, including key runs to produce final product samples. Key runs were extended runs to ensure fully developed steady state conditions and sampling involved additional quantities and numerous additional sample locations to allow for detailed analysis of the various streams. This detailed information will be used for final evaluation of the upgrading processes (diluent savings, product quality, refinery acceptance, potential marketing value, etc.) and to inform design of a future commercial plant.

Sales Product Mass Meter

The mass flow meter on the treated product out of the facility failed in 2022 during the first phase of testing. This meter was not repairable and as a result, the mass balance closure could not be verified with meter data for the majority of runs in 2022. Prior to testing in 2023, a new micro motion meter was installed on the treated oil line. It was found that the meter had higher than expected flow measurement error (~5%) as its intent purpose is to provide highly accurate density measurement. The mass balance closure is therefore expected to reflect this measurement error. Before the start of a set of runs, this micro motion meter was compared against the inlet mass flow meter by circulating dilbit through the plant. The associated bias between the inlet and sales meters was noted to be 4-5%.

Thermal Oxidizer Waste Gas Thermal Mass Sensor

This mass flow meter requires a gas analysis to be entered into the meter to allow the meter to correctly calculate the mass flow as different gases will result in different amounts of cooling to the thermal sensor element for a given mass flow. Because the gas analysis was unknown prior to the completion of testing, an estimated gas analysis from previous testing was used.

Due to the rapid sequence of testing, it was not possible to input the exact gas analysis for each run into the meter. A typical gas composition was used as the process gas composition does not cause significant inaccuracy in the measurement. However, the presence of hydrogen from the hydropolishing unit does significantly affect the flow measurement. Therefore, 2 different gas analyses were prepared, one which represents process gasses without hydropolishing and the other with hydrogen from the hydropolishing units. All Phase C runs were conducted without hydropolishing. During one key run in Phase D, the hydropolishing unit was used and the proper gas analysis was entered into the thermal mass meter to reflect the change.

7 Technical Interpretation of Pilot Data

The majority of Alberta's crude oil production is in the form of thick and heavy bitumen which needs diluent (30-40 vol%) for transportation via pipeline to US refineries. Diluent occupies valuable pipeline capacity and must be separated at refineries and transported back. In addition, diluted bitumen (dilbit) is sold at a discount on the open market as it has a low API density, a high sulfur content and Total Acid Number (TAN), and numerous other impurities that create challenges compared to sweet light crude. For these reasons, Cenovus has been investigating and developing solutions to reduce diluent and add value. HDR is Cenovus owned technology which is designed to minimize the need for diluent and partially replaces condensate with locally manufactured Synthetic Crude Oil (SCO). The pilot plant operations aim to optimize the process and produce final product for market and refinery assessments.

A total of 30 runs were completed at the Provost pilot facility. These tests allowed the team to optimize process conditions for viscosity reduction, evaluate various technologies including HDR and Jetshear™, and obtain valuable data for commercial design. The results have proven the process performance and data collected from these runs revealed efficient methods to reduce capital and operating costs.

8 Conclusions

The screening runs conducted at the Provost pilot facility provided valuable data for assessing the performance of various technologies and optimizing operational parameters. The screening runs executed, achieving product viscosity targets while meeting stability requirements. The available data shows that the technology can reduce diluent (natural gas condensates) requirement by 75% and total diluent (condensate and SCO) by over 35%.

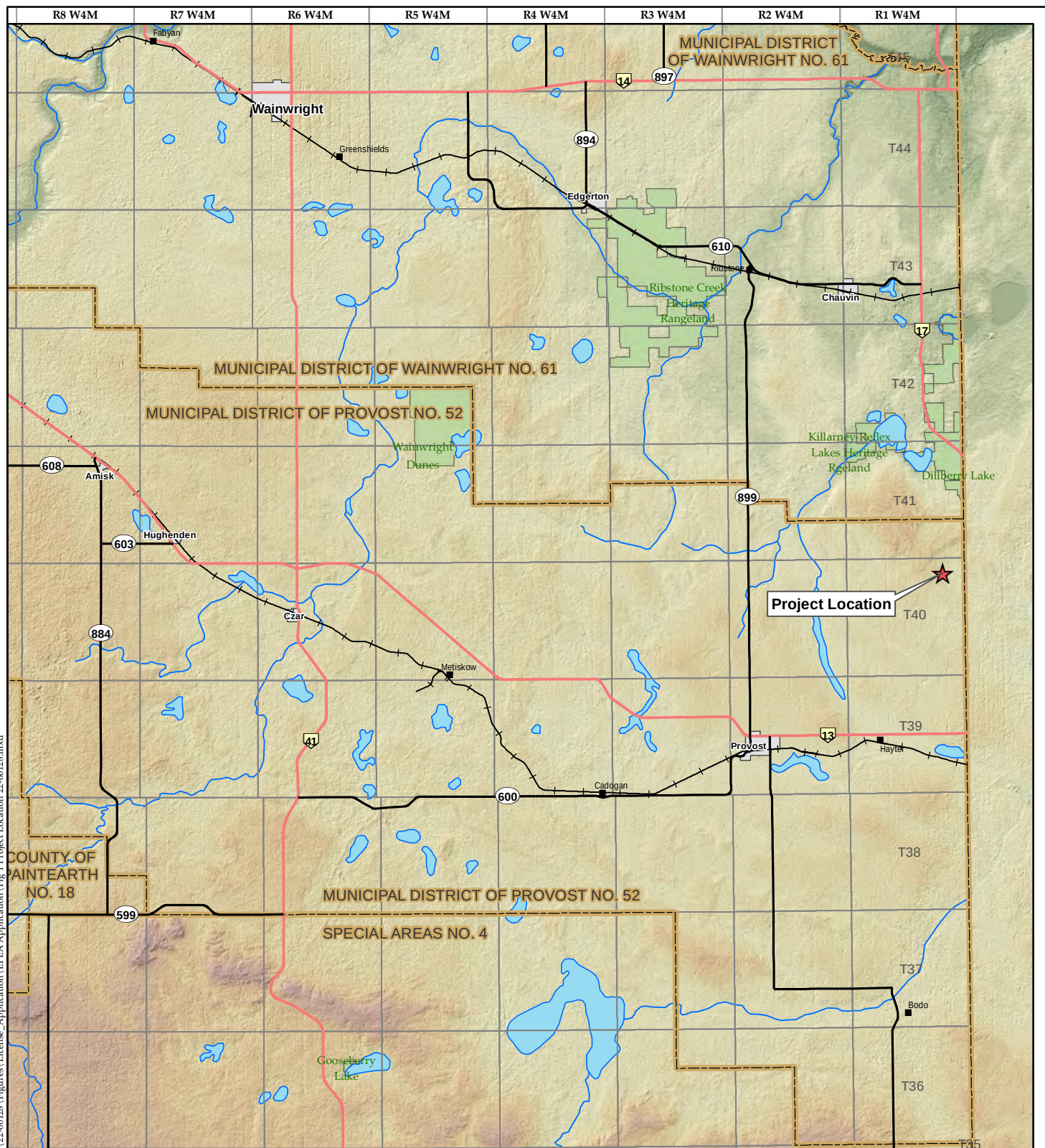
Increasing residence time had the same effect as increasing process temperature. The pressure and residence time optimization findings could lead to reduction in OPEX and CAPEX by operating at low pressure and minimum residence time.

From this it appears that the most cost-effective combination of thermal cracking components would exclude the high-pressure components (i.e. pumps and Fractal-proprietary nozzles) and SCO-blending within the process. SCO benefits are primarily product-quality related and would be an optional post-process blend, depending on the economics of blending SCO vs. condensate as residual diluent. This would reduce the overall equipment sizing below what initial HDR estimates used.

The technology tested offers a flexible process that has potential to be economically viable under certain conditions. Currently Cenovus has no plans to commercialize the technology.

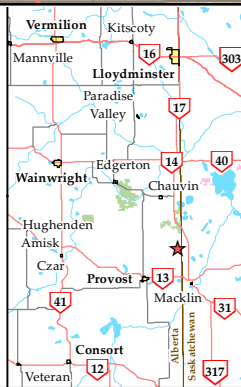
FIGURES

Document Path: K:\Active Projects 2022\AP 22-00101 to 22-00150\22-00128\Figures\License_Application\EP EA Application\Fig.1 Project Location 22-00128.mxd



LEGEND

- ★ Project Location
 - Primary Highway
 - Secondary Highway
 - Railway
 - Park/Protected Area
- Topography (m asl)**
- High : 920
 - Low : 483

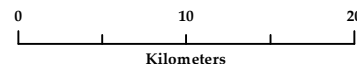


CENOVUS ENERGY INC.
JETSHEAR™ PROCESSING PLANT

PILOT PLANT PROJECT LOCATION

AltaLIS, 2021; MEMS, 2022;
ASTER GDEM v2, 2022 (Image Date: 2018)

Coordinate System: NAD 1983 UTM Zone 12N



PROJECT: 22-00128

DRAWN BY: EPITTMAN

CHECKED BY: KK

DATE: APRIL 7, 2022

FIGURE

1

Disclaimer: This figure was derived from multiple data sources and while we make every effort to assure its accuracy, Millennium EMS Solutions Ltd. disclaims any representation or warranty and assumes no liability either for any errors, omission or inaccuracies that may occur.

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CENOVUS ENERGY INC.
JETSHEAR™ PROCESSING PLANT

PILOT PLANT PROJECT FOOTPRINT

LEGEND

- Harvest 8-35 Battery Site
- Project Footprint

8-35

5-36

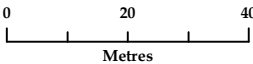
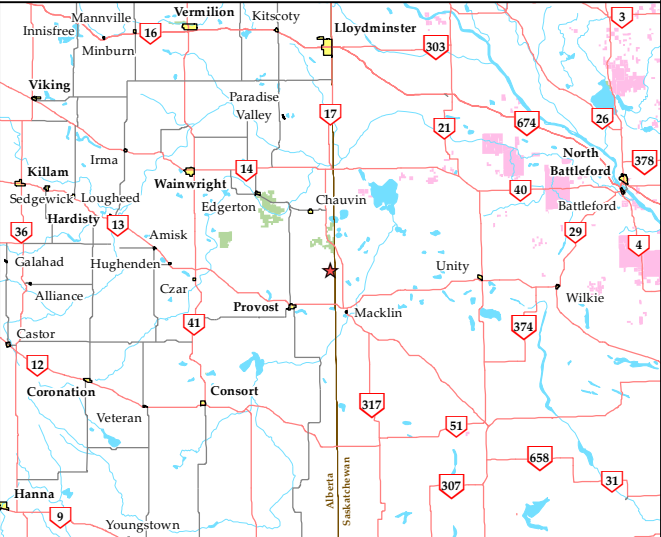
Range Road 11

T40

1-35

Project Footprint

4-36



Coordinate System: NAD 1983 UTM Zone 12N
AltaLIS, 2021; Fractal Systems, 2014; MEMS, 2022;
ESRI Imagery, 2022 (Image Date: July 2020)

PROJECT: 22-00128
DRAWN BY: EPITTMAN
CHECKED BY: KK
DATE: APRIL 7, 2022

FIGURE

