# Suncor ESEIEH Phase 2 Small Scale Pilot Project
# 2017 AER Performance Presentation
# Experimental Scheme Approval No. 12074

Reporting Period September 1, 2016 – August 31, 2017

# Table of Contents

# ESEIEH Pilot Project Overview

Effective Solvent Extraction Incorporating Electromagnetic Heating

- “ESEIEH” is an in-situ process using solvent dilution with moderate electromagnetic heating that may:
  - minimize Greenhouse Gas Emissions
  - improve efficiency, eliminating steam and water
  - access more bitumen at shallower depths
  - lower capital intensity and improve economics
  - present a *transformative technology* beyond SAGD
  - Potential for lower upgrading needs
- Partners
  - CCEMC, Suncor, Devon, Nexen, Harris.

# ESEIEH Pilot: Objectives

The primary objective of the Pilot Project is to demonstrate the proof of concept field test for the coupled vapour extraction and electromagnetic heating recovery process.

**The principal objectives are to:**

- Quantify bitumen drainage due to radio frequency (RF) reservoir heating and solvent vapour (the ESEIEH process extraction).
- Test the sensitivity of drainage to operating conditions (power, solvent injection rate or pressure, production rate control, etc.).
- Provide reliable field data to guide predictive numerical modelling and optimization studies.
- Establish key economic indicators including solvent performance, retention, power consumption, and delivery efficiency of RF energy to the reservoir.
- Pioneer the development of ESEIEH RF hardware and well design with respect to installation, functionality, reliability and efficiency.



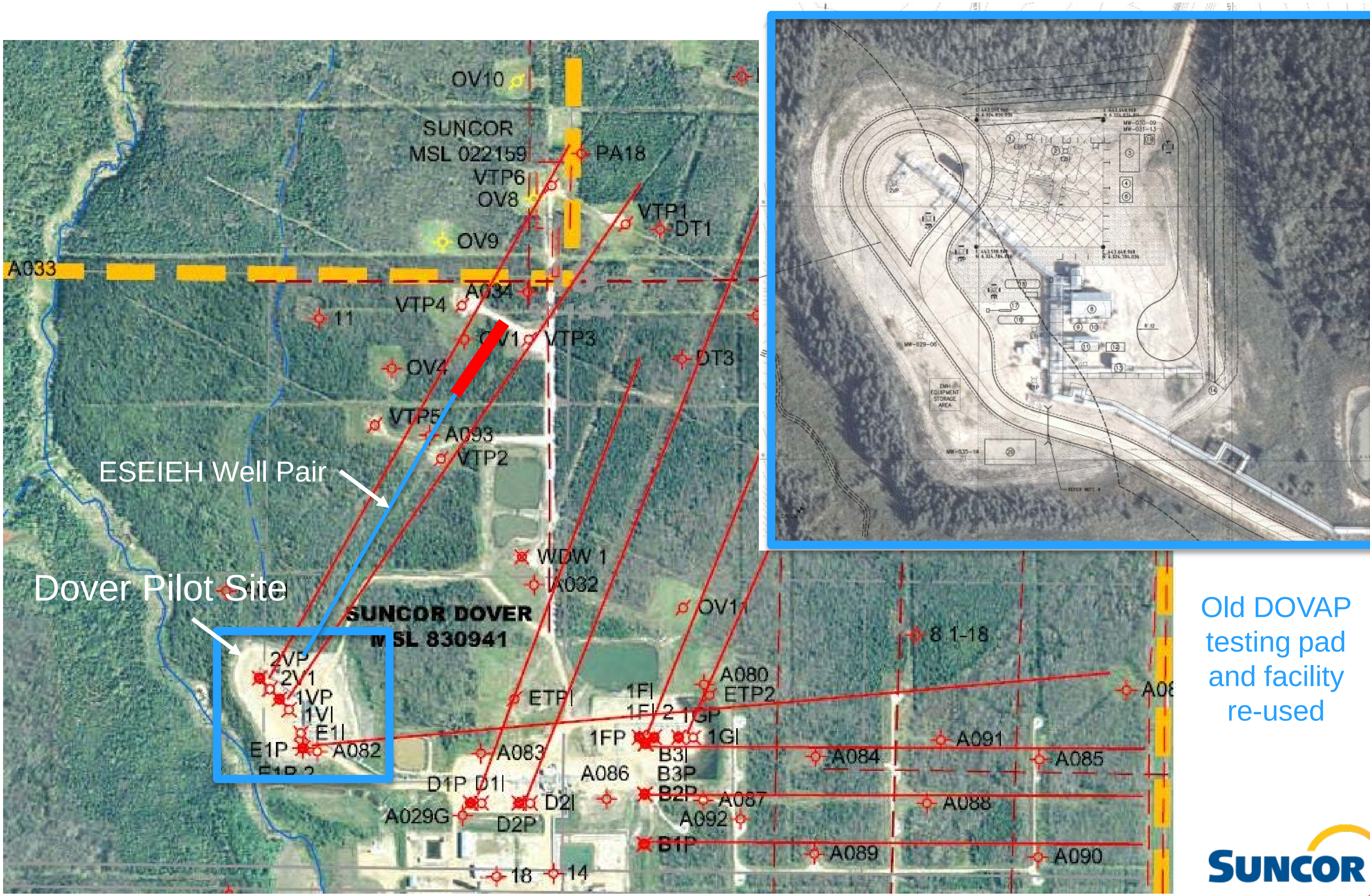
SUNCOR

# ESEIEH Pilot: Key Criteria

**Key criteria necessary to ensure a successful pilot operation are**:

- Obtain sufficiently accurate field data to guide predictive numerical modelling and optimization studies for commercialization.
- Develop a comprehensive understanding of the effect of operating parameters on production controls.
- Determine the impact of factors such as methane accumulation and related controls on bitumen drainage.
- Validate the antenna design is capable of delivering sufficient power to the formation to sustain the solvent extraction process (up to 4 kW/m).
- Establish that the well design and RF system can be efficiently and reliably installed and operated.
- Establish measurable economic indicators including production rates, solvent retention, power consumption, and delivery efficiency of RF energy to the reservoir.
- Evaluate process economics and determine viability for commercialization.

# Project Site



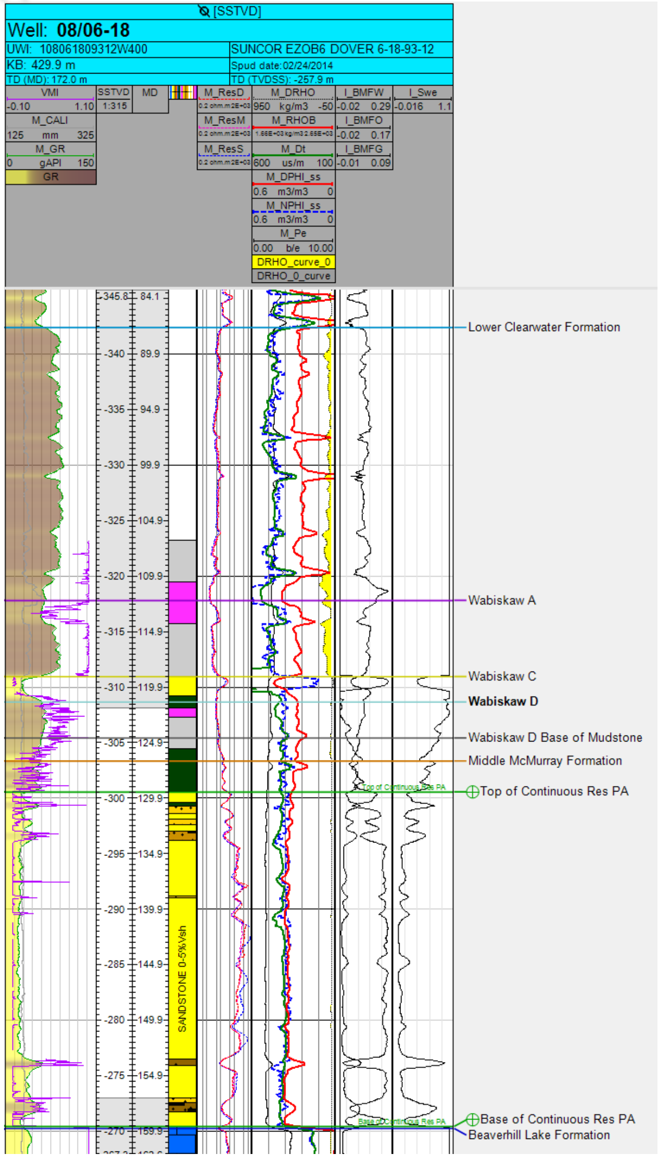

Old DOVAP testing pad and facility re-used

# ESEIEH Pilot Performance Presentation

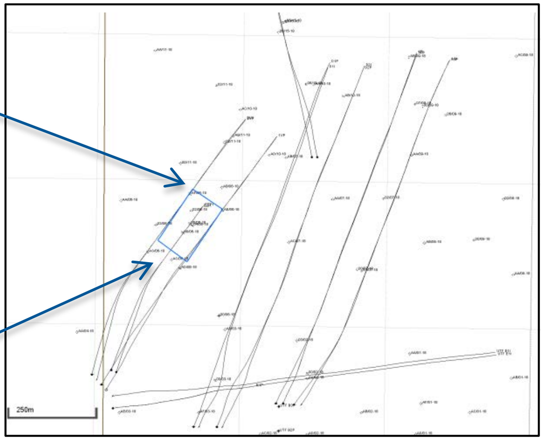
Geoscience

# Stratigraphy

## 108-06-18-093-12W4 _EZOB-6



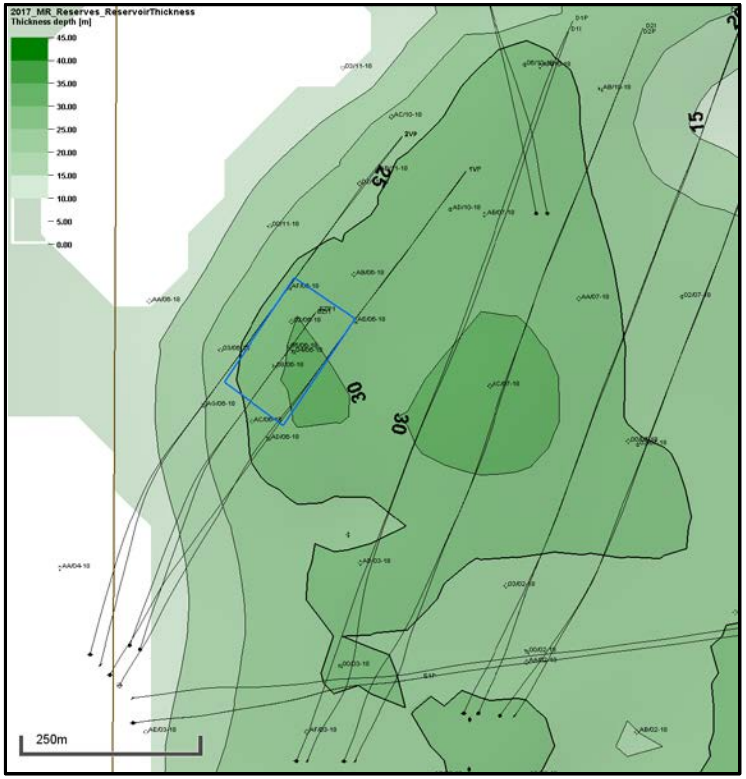





- Caprock in region is mappable, predictable, and laterally consistent (>36m thick)
- McMurray Formation Reservoir predominantly sand with minor breccia ranges 24m – 30m thick
- No top or base lean zones are observed within the reservoir

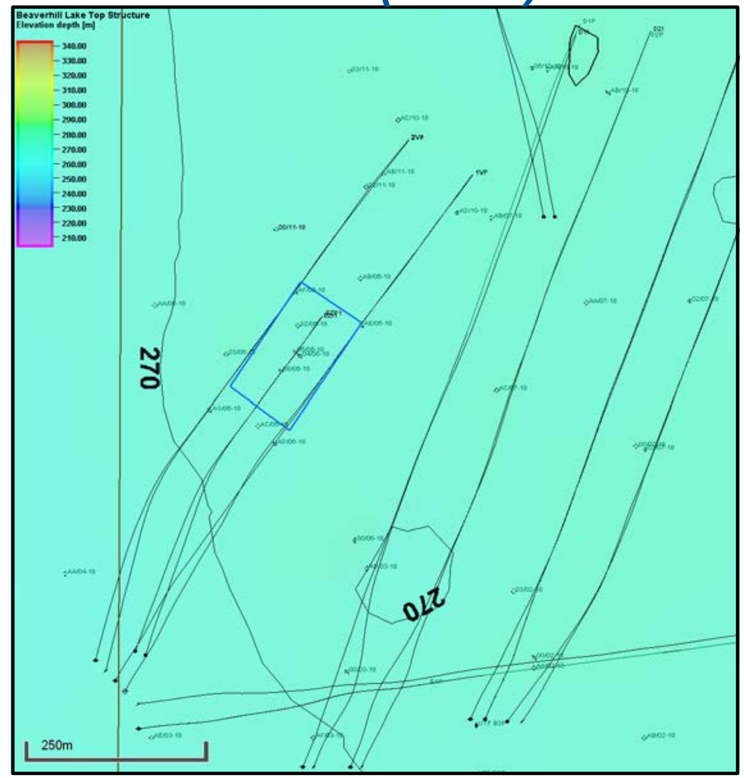
# McMurray Pay and Devonian Structure Mapping

## *McMurray Continuous Reservoir Isopach (CI: 5m)*




- Up to 30 m thick Continuous Reservoir
- Reservoir:
  - McMurray Formation reservoir
  - Clean, bitumen saturated sandstone interbedded with breccia.

## *Devonian Top Structure TVDSS (CI: 5m)*

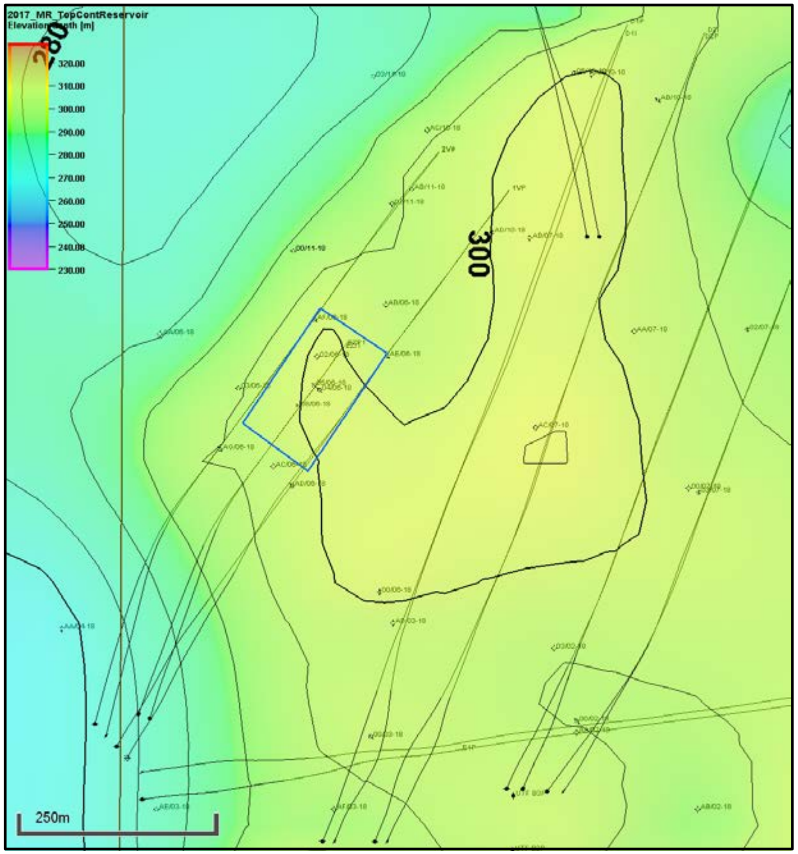



- Pilot site situated atop structurally flat Devonian surface:
  - Several offsetting wells with less than 1m structural variation on Devonian surface
- High resolution 2D Seismic (2003) coverage exists in the region and supports structurally flat Devonian surface.

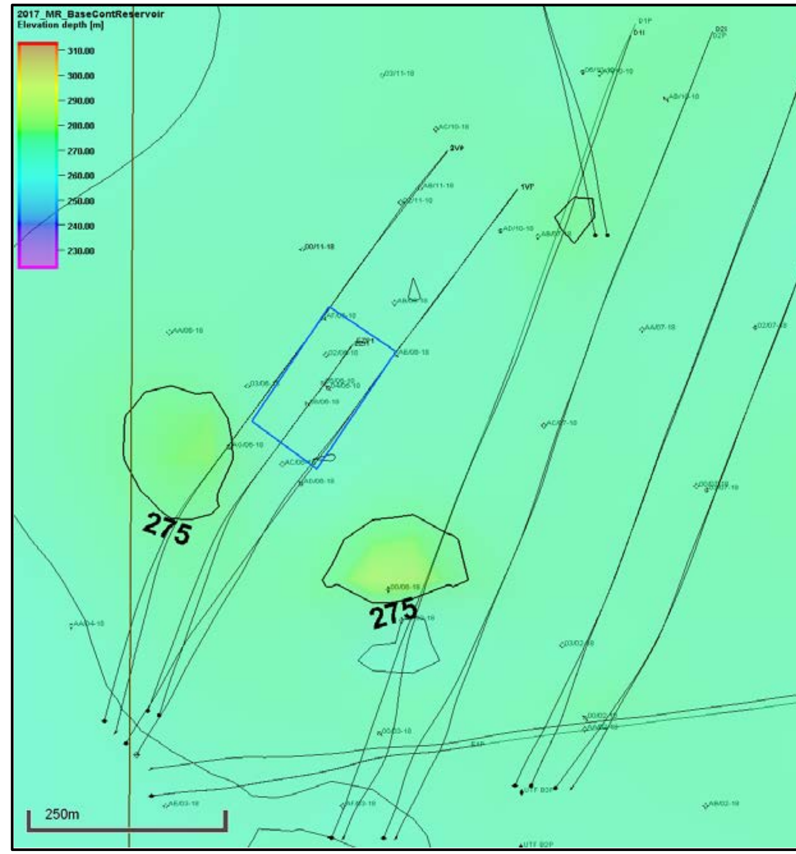
*ESEIEH Well Pair Drainage Box*

# Top and Base of Pay Structure Mapping and Average Properties

***Pay Top Structure Map (CI: 5m)***




***Pay Base Structure Map (CI: 5m)***




| Porosity | Water Saturation | Rock Vol ($m^3$) | OBIP ($m^3$) | OBIP(MMbbls) |
|---|---|---|---|---|
| 34% | 22% | 498967 | 127779 | 0.80 |

Updated volumes are consistent with Suncor volumetric criteria

*ESEIEH Well Pair Drainage Box*

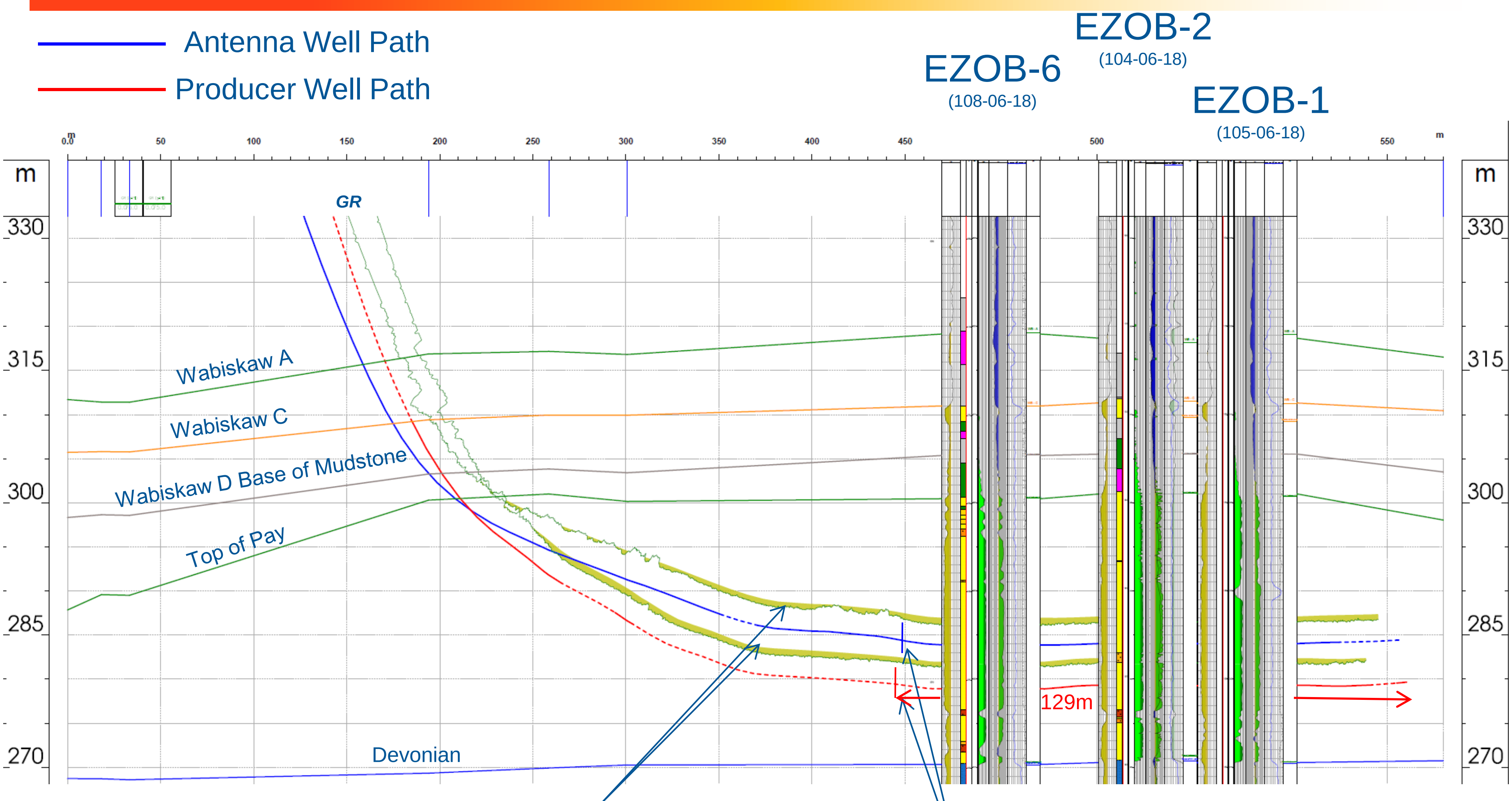
# Core Hole Evaluation Program

- 3 vertical Observation wells (2013-14)

- EZOB-2 cored and logged, conventional core analysis was conducted:
  - Photography
  - Dean Stark: (avg, BMFO: 0.14 and avg. porosity 37%)
  - PSD

- EZOB-1 & EZOB-6 drilled and logged:
  - Core analysis conducted on EZOB-6. EZOB-1 was not cored
  - Dean Stark: (avg, BMFO: 0.13 and avg. porosity 37%)
  - Viscosity
  - Water (Analysis and Salinity)
  - Vertical and Horizontal Permeability
  - XRD/SEM for understanding of clays

# ESEIEH Horizontal Cross Section



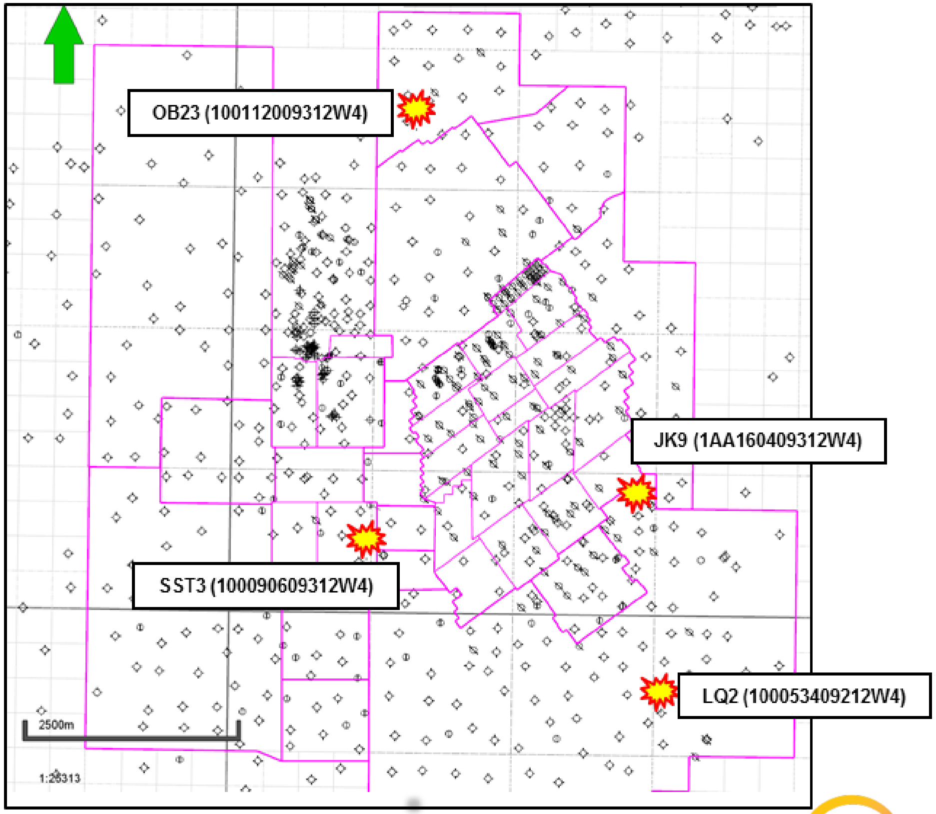

Color fill on GR is at 35 API cutoff (very clean sand)

Approximate position of ICP
ICP EZI1: 448m
ICP EZP1: 445m

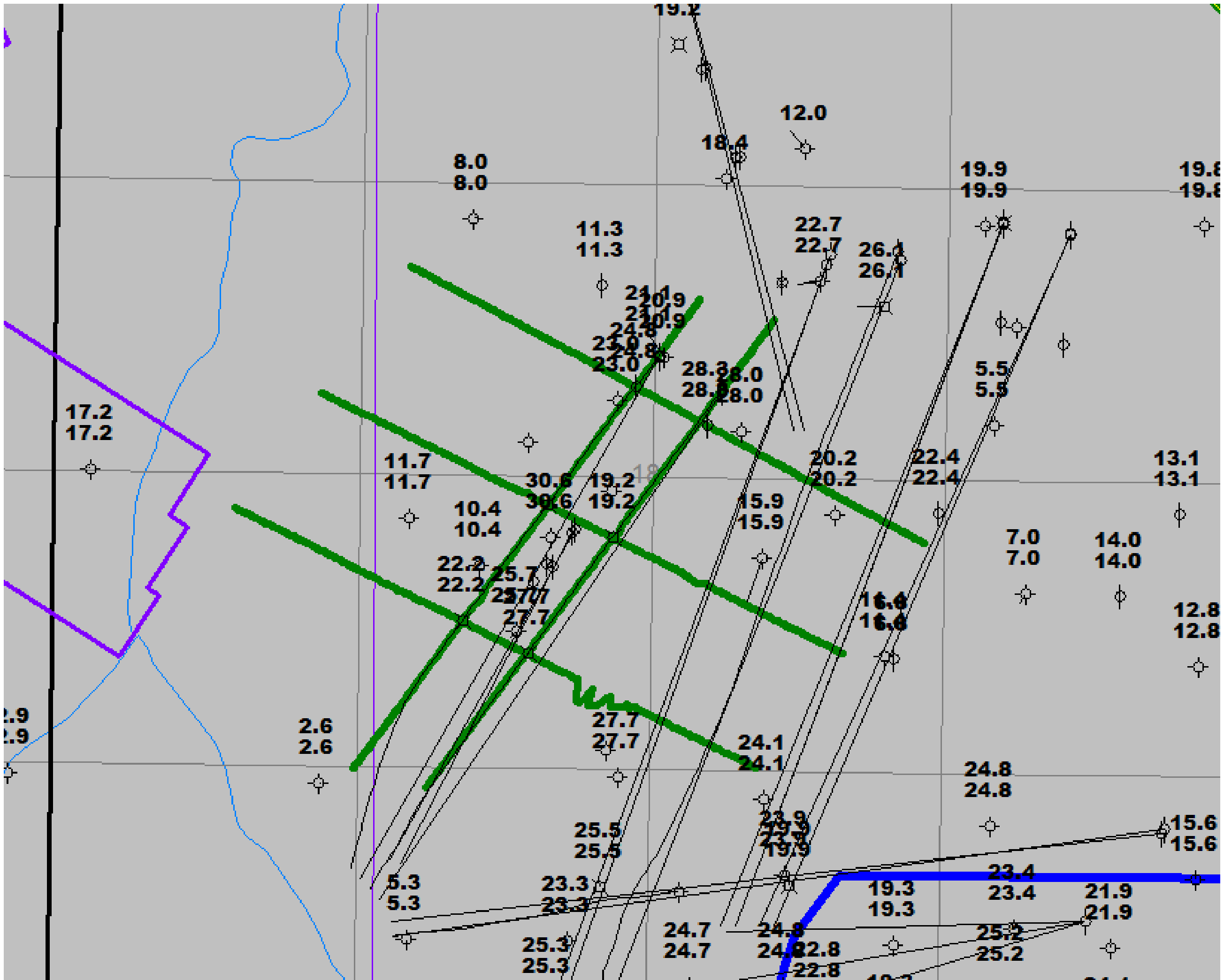
# Geomechanics: Mini-frac Test

- New mini-frac tests conducted at OB23 (100/11-20-93-12W4/0)
- Fracture gradient within operating area still holds at or above 21 kPag/m:
  - Fracture gradient measured (kPag/m) from mini-frac test

| Formation | OB23 (2017) | JK-9 (2014) | LQ2 (2011) | SST3 (2008) |
|---|---|---|---|---|
| Clearwater | Evaluation on-going | 22.3 | 21.3 | 24.1 |
| Wabiskaw A | | 21.1 | 21.2 | - |
| Wabiskaw D | | 22.1 | 22.6 | 24.3 |
| McMurray | | - | 21.1 | 19.9 |



# ESEIEH Seismic Lines



# ESEIEH Pilot Performance Presentation

Well  Drilling and Completion Operations

# Drilling Operations

- The well pair (EZ-WP1) was drilled in Feb 2014:
  - 5m separation between injector and producer was achieved 100% of the HZ length
  - 8 5/8" production slotted liner with seamed slots 0.014" x 0.020"
  - 10 ¾" injection slotted liner with straight cut slots 0.012"

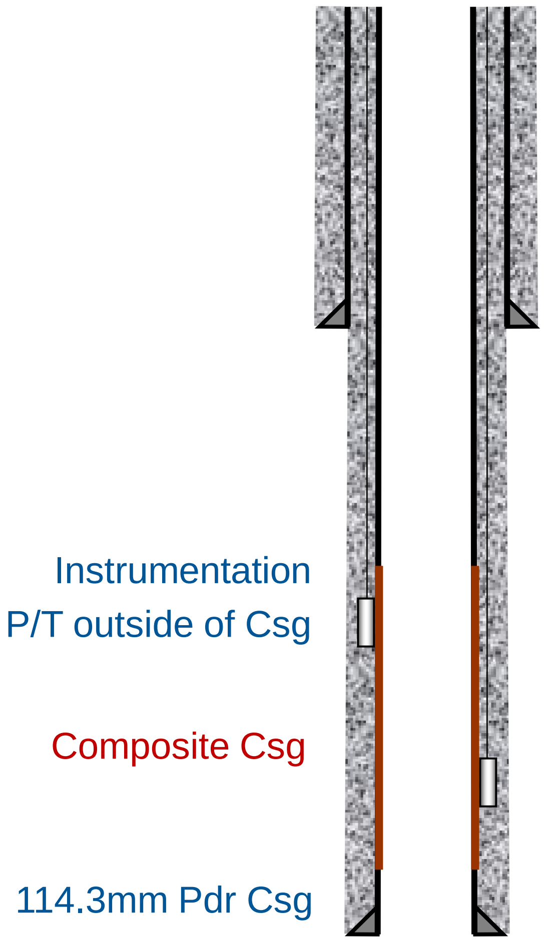
- 3 observation wells were drilled within a few meters of the well pair:
  - EZOB-2 is ≈ 5m from EZ-WP1; cored and logged in Sep 2013
  - EZOB-6 is ≈ 4m from EZ-WP1; cored and logged in Mar 2014
  - EZOB-1 is ≈ 2m from EZ-WP1; logged only in Mar 2014

- Installed RF transparent composite casing joints and instrumentation in all observation wells (cemented in place)

- Drilling pulled liner from the injector well (EZ-WI1) in Sep 2016
  - Found damage to composite liner
  - Found evidence of formation collapse

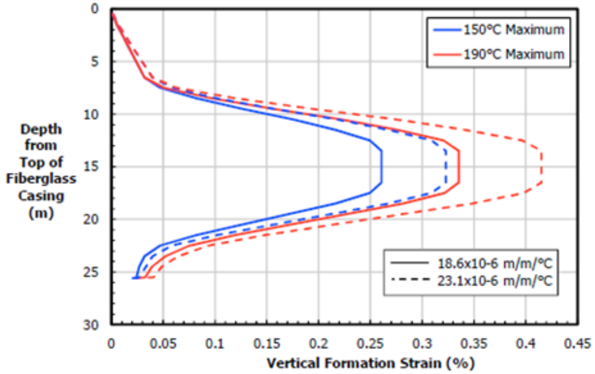
# Observation wells Design

- Production casing design with dual material string in order to guarantee well integrity and hydraulic isolation:
  - 114.3mm 17.26 kg/m K55, Hydril 563 Production casing into the McM formation (reservoir), to ensure well integrity across the caprock
  - 114.3mm composite casing (E-Glass/Epoxy material), with K55 metal fittings, Hydril 563
    - 1 Short joint (~6.17m), and 2 long joints (~9.7 m) of composite casing used per OB well
    - E-Glass/Epoxy specially designed by ACPT to withstand thermal loads (external load tests performed)
- Production casing cementing within the McMurray formation (reservoir)
- RF instrumentation strapped outside of 4 ½" casing from TD to surface
- With this design fluid containment is similar to a standard Mackay OB well as the design is similar down to the reservoir. The only changes are the use of the composite casing, and the instrumentation strapped to the outside of the casing.



# Composite Casing

- Model was originally used to estimate load rates
- Real data lab test was conducted after:
  - Composite casing tests showed reasonable correlation in tension and less accuracy in compression compared to model
  - Compression results do not fully represent tube behavior as boundary conditions of test significantly different from in situ conditions (small block cut from tube was used so there is loss of continuity of fiber winding around a whole cylinder)
- Refined model was done to predict system behavior:
  - Modeled temperature profile
  - Cement CTE obtained from vendor
  - Formation strain both from model and field measured
- 3 different scenarios used and results show that in the worse case scenario composite casing would be able to withstand the loads



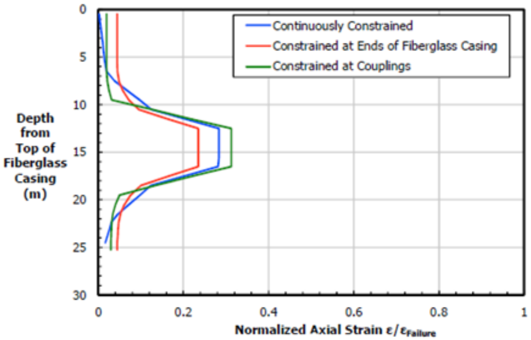
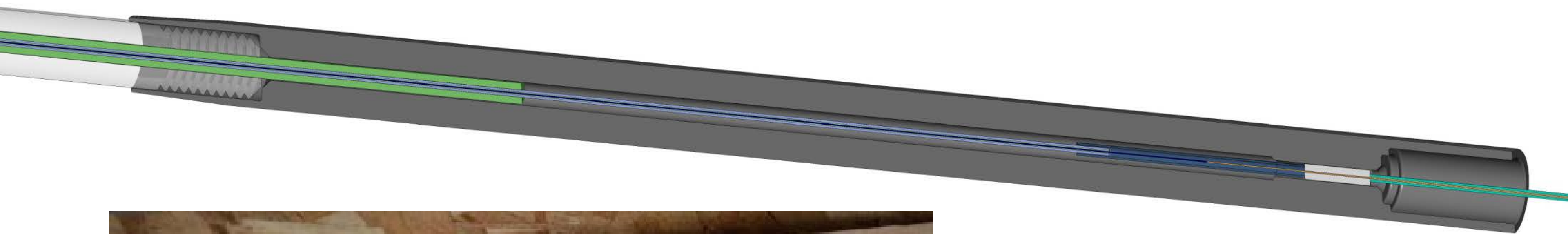
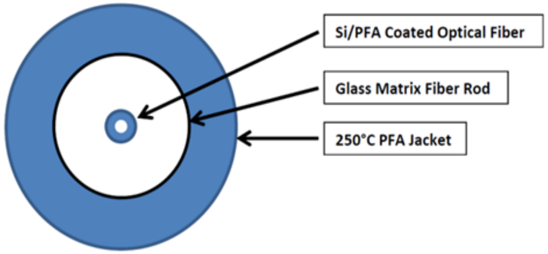




Figure 15. Normalized axial mechanical strains in reservoir heated to 190°C maximum and CTE = $23.1\times10^{-6}$ m/m/°C.

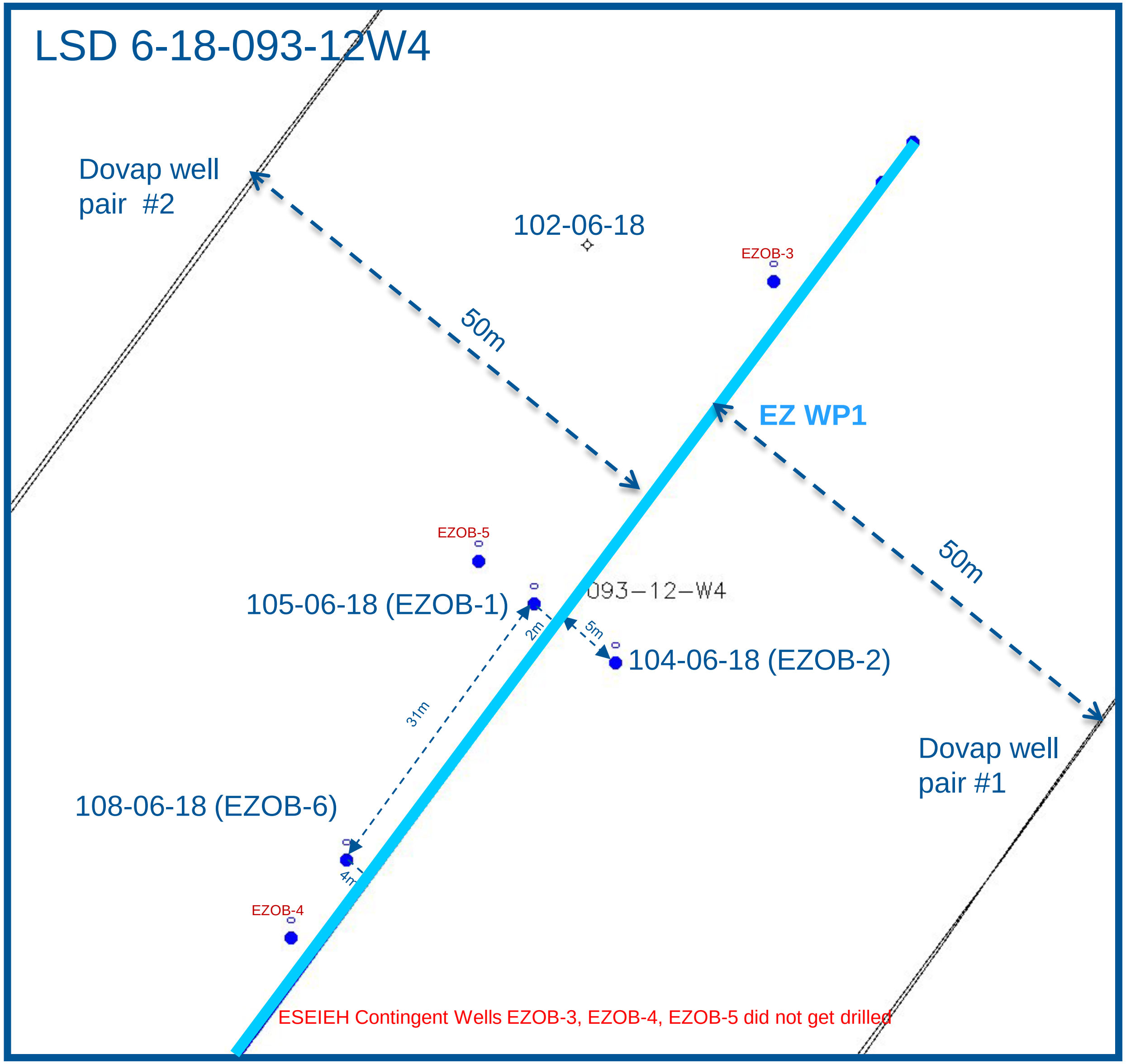
# RF Instrumentation Design

- Instrumentation line and attachment to piezometer were specially developed for this project:
  - PFA jacket used instead of common stainless steel capillary line
  - Fiber developed by AFL in conjunction with Harris
  - Attachment to piezometer develop by Harris and final assembly develop by Opsens Solutions
- Final assembly successfully passed test in an environment chamber under expected In-Situ pressure and temperature
- Feed through connector on wellhead guarantee isolation of PFA jacket





# Well placement



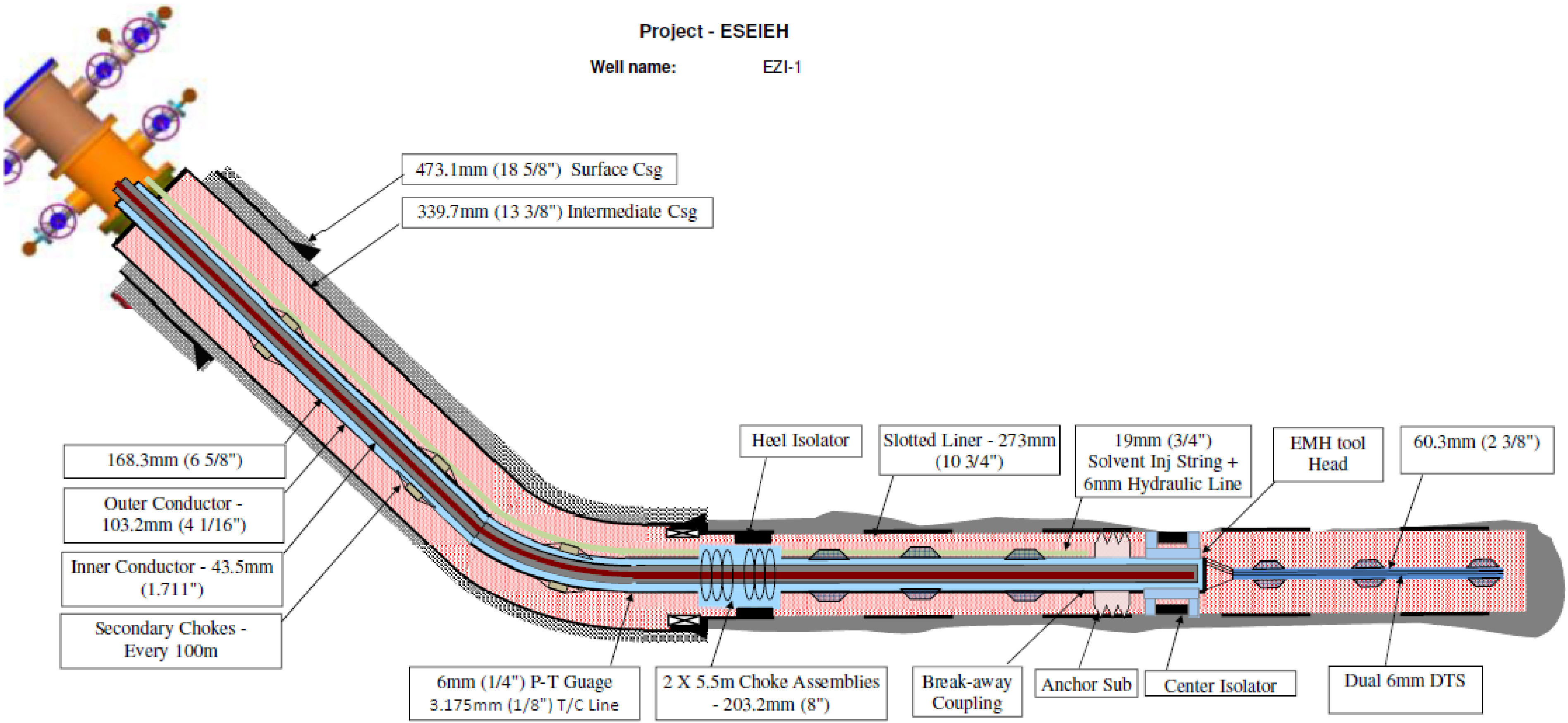

- EZOB-2 is ≈ 5m from EZ-WP1
- EZOB-6 is ≈ 4m from EZ-WP1
- EZOB-1 is ≈ 2m from EZ-WP1

# Completion Rig on ESEIEH Injector/Antenna Well

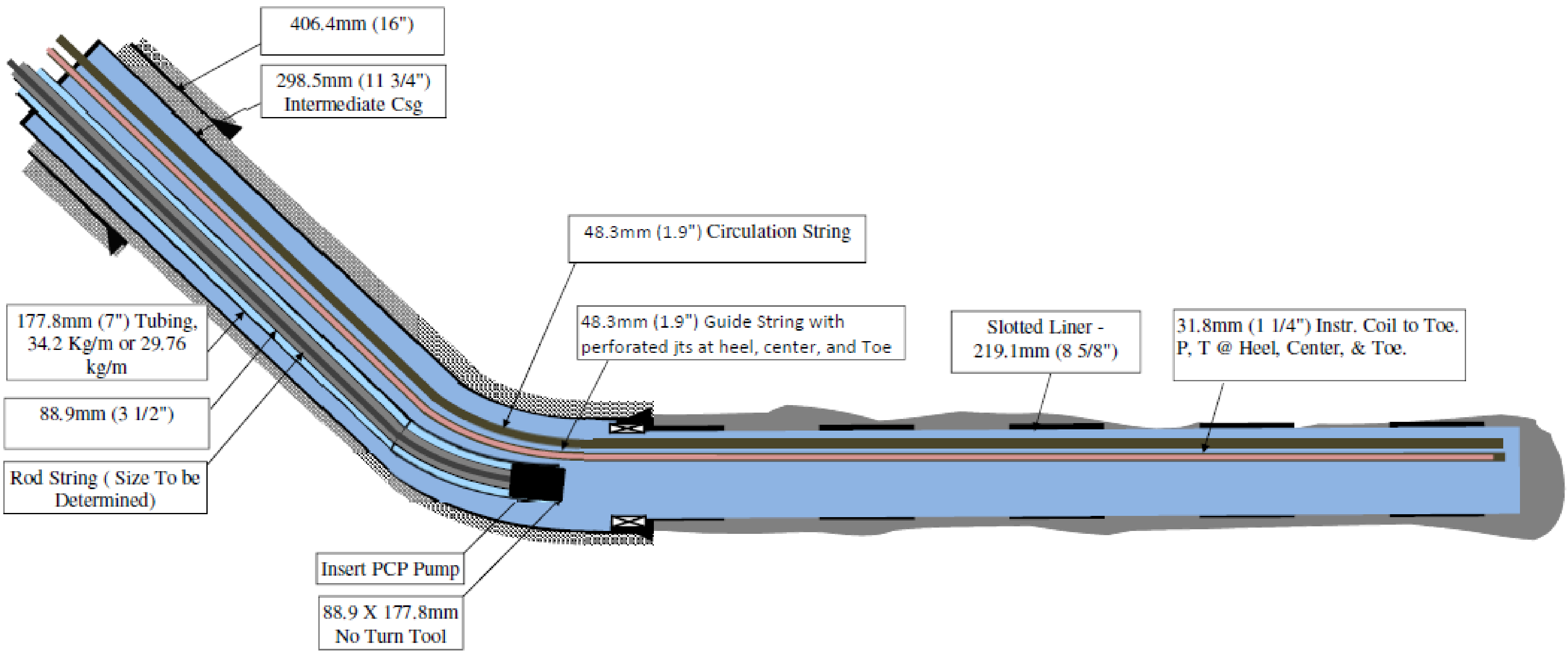
# Well Completion – ESEIEH Injector/Antenna Well

**Project - ESEIEH**

**Well name:** EZI-1



# Well Completion – ESEIEH Production Well



# Completion Operations

- Diesel was injected to condition the injector/antenna wellbore by displacing the surrounding fluids, but was unsuccessful in lowering the VSWR. Dilbit was subsequently selected to try conditioning the well because its higher viscosity and density would be better for displacement. Two separate dilbit injection activities were conducted:
  - 26m$^3$ of dilbit injected [September 1, 2015]
  - 53m$^3$ of dilbit injected [September 29-October 2, 2015]

- After it was determined that the IOB had internal arcing, the completions rig was brought on site in December, 2015 to remove the IOB for repair and replacement

- After the IOB was removed measurements were taken to assess the health of the subsurface toolhead, and it was determined that this too had been damaged and require removal:
  - The toolhead pull took place in February of 2016. A caliper log was run at that time to assess the condition of the liner isolator, which also showed damage
  - The liner pull activity was planned for September 2016

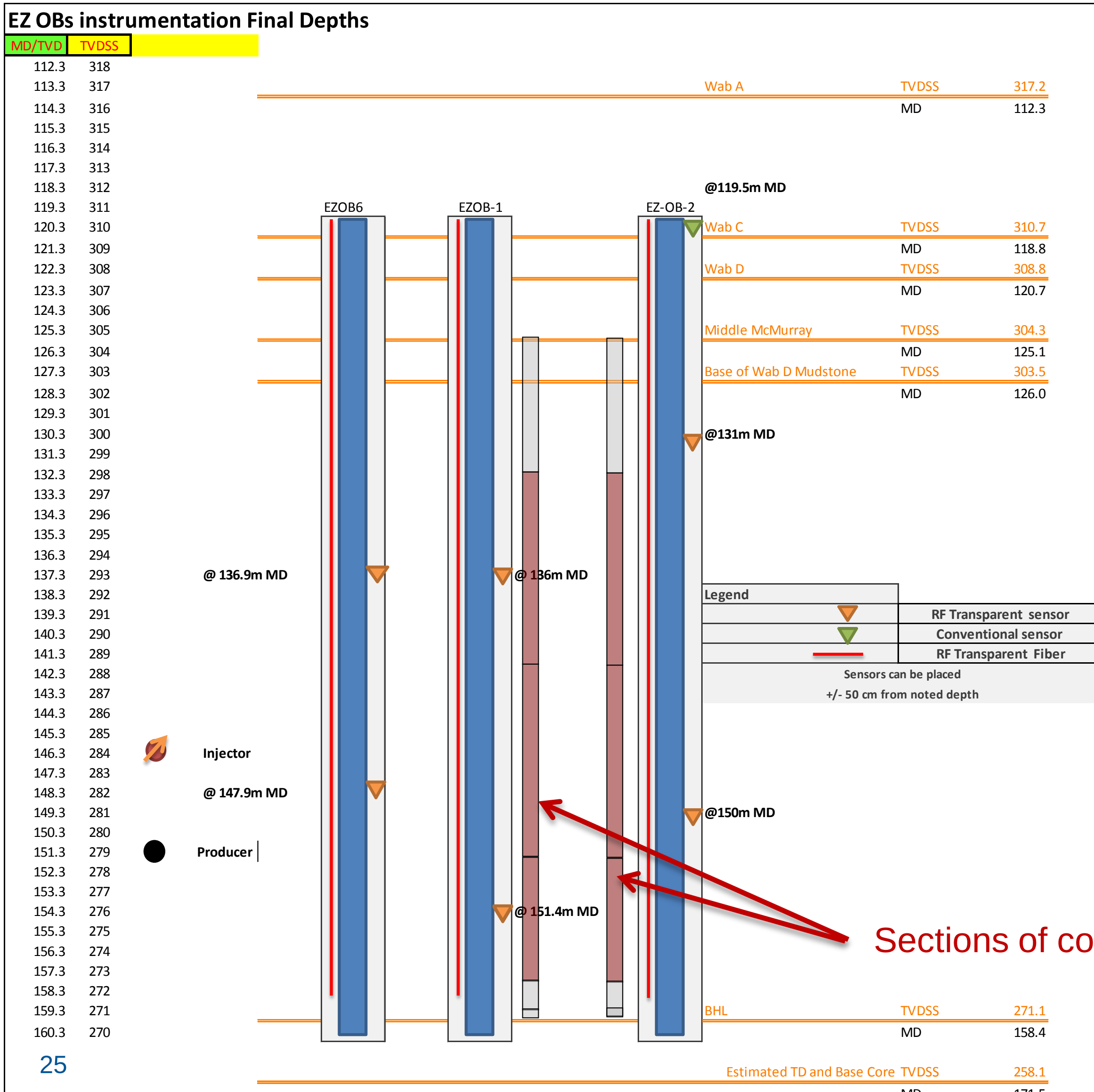


SUNCOR

# Artificial Lift

- EZ Producer was completed at the end of November 2014 with PCP, landed at 85° inclination in a 3°/30m slant section, 2m TVD above liner depth:
  - 2 x pumps available with theoretical volumetric capacity of $4m^3/d$ or $8m^3/d$ at 100 rpm
  - Larger capacity 7-750 pump currently installed
- A specialized tool was installed on the producer to allow operations to pull the rotor out of the stator without a service rig on site. This was added so that in the event of an unplanned shutdown, the pump would not become plugged and inoperable due to cold bitumen inside.
- Artificial lift was run for a short period of time in July, 2015, and was on again briefly for short periods of time in early 2016
  - The producer was run in 2016 to achieve D13 compliance because wells had not been applied for under the experimental scheme. This has since been corrected through conversations with the AER. The producer pump has not been run since this time.

# Observation Wells




Sections of composite casing in production casing

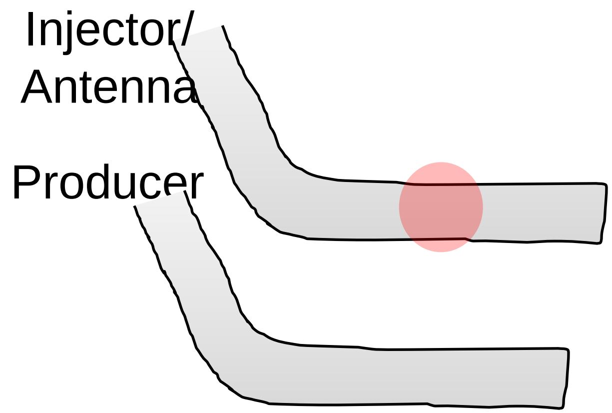
- Each well equipped with a RF transparent Temperature Optic Fiber from surface to TD
- Each well equipped with 2 RF transparent optic Fiber Pressure & Temperature Sensors, located in the McMurray
- EZ-OB2 equipped with a standard Pressure & Temperature Sensor in the WAB C

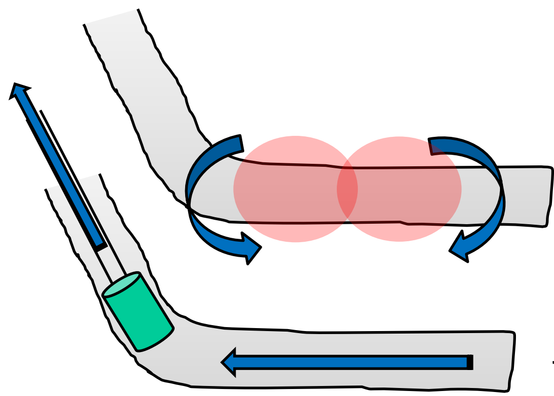
# ESEIEH Pilot Performance Presentation

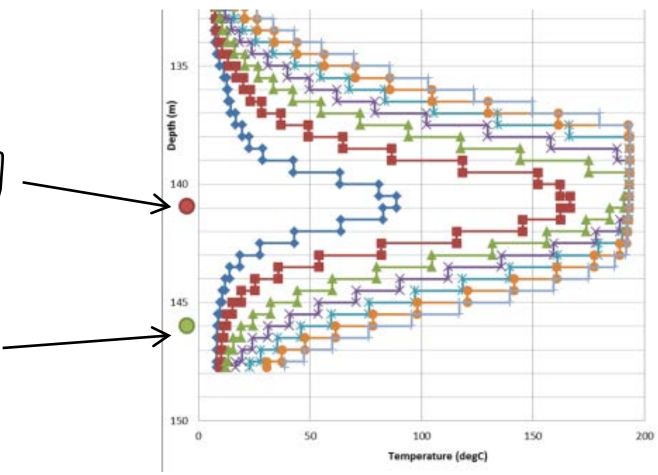
Operating Plan

# Summary of Operating Plan

1 Initialization / Antenna Ramp-up → 2 Initial Flow Establishment → 3 Initial Inter-wellbore Bitumen Mobility






- Review all instrumentation outputs
- Begin ramp-up of antenna power levels
- Heat is initially localized to center of antenna

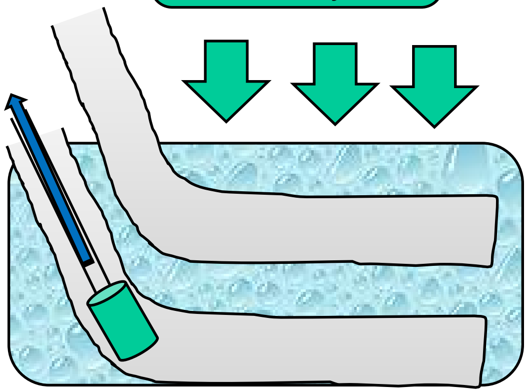
- As heated fluids expand they are produced to control reservoir pressure
- Pump operation is initiated with diesel circulation

- Look for indications of initial mobile bitumen
- Manage pressure differential between wells to prevent “pushing” reservoir fluids

# Summary of Operating Plan

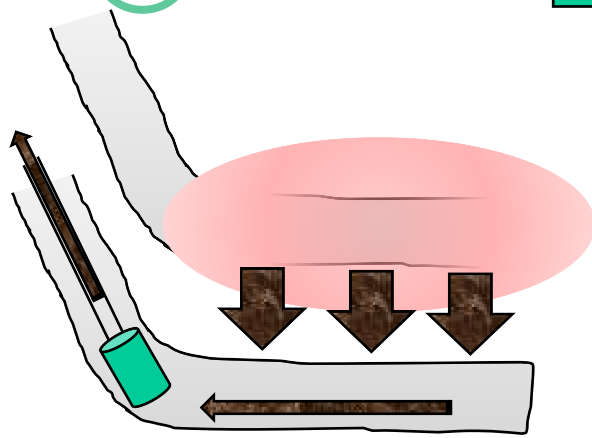
4

Draw-down / Reservoir Deliverability Test



- Confirm reservoir deliverability can sustain pump operation w/o diesel circulation

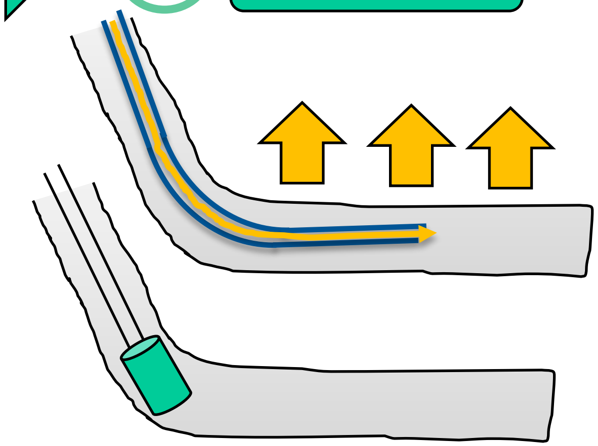
5



- Produce hot reservoir fluids to create void space for propane

6

Propane Injection



- Draw down liquid level below injector elevation
- Initiate propane injection at high antenna power

7

Power Optimization

- Once producer conformance is achieved, reduce power to long term optimum level

8

Process Testing

- Once ESEIEH base objectives have been met, test variants of process variables, such as power and pressure

# Summary of Operating Plan

- Steward to reservoir pressure of 1750 kPag (MOP of 2230 kPag)
- Steady heating and passive displacement of inter-wellbore region
- Prevent solvent breakthrough from the injection well to the producer directly below
- Build a healthy solvent chamber
- Find optimum power levels and solvent injection rates, and maximize solvent recovery
- Once ESEIEH successfully demonstrated →test boundaries of process (low power, etc.)

# Summary of Operations To Date

- First RF energy was delivered to the reservoir on May 31, 2015:
  - Part of commissioning activities
  - Power run for short durations (~15 min) at 10-15 kW
- Pilot officially started on July 10th and power began ramping up:
  - Reached 60kW before a high VSWR (Voltage Standing Wave Ratio - measure of reflected power) and transmitter trip led to shutting down the antenna to troubleshoot
- After the initial transmitter trip, efforts were made to condition the antenna tool head area to improve the ability to deliver power:
  - Nitrogen applied to the injector casing annulus July 23-25 to displace fluid in the toolhead
  - 17$m^3$ of diesel was injected into the casing annulus on August 11, 2015
  - An additional 10$m^3$ of diesel was injected on August 27, 2015 - 2$m^3$ in the solvent line and 8$m^3$ down the casing
- Downhole pump was run briefly, but the decision was made to shut it down on July 18th, 2015 and leave it off in order to maintain reservoir integrity until fluid mobility could be established.

# Summary of Operations To Date

- VSWR began increasing steadily after the initial warm up stage was initiated in July of 2015
- The antenna was run at low power levels to keep the VSWR below a set limit, but VSWR continued to rise slowly over time
- It was believed that high conductivity fluids were the cause of the rising VSWR measurement, and that the heating process was exacerbating the problem
- The diesel injection reported in the previous annual report did not result in a measureable improvement, but it was believed that the diesel may have been lost to the formation instead of flushing the area of interest due to the low density and viscosity.
- It was then decided that we would attempt displacement with a higher viscosity fluid with a density that would better match that of water, and diluted bitumen was selected. The first dilbit test seemed to indicate a there may have been a VSWR improvement, so a second dilbit injection was conducted, but no improvement was observed.
- Two fluid displacement activities were conducted to push conductive fluid away from the tool head at the center of the injector well:
  - 26m$^3$ of dilbit at the start of September, 2015
  - 53m$^3$ of dilbit at the end of September/beginning of October , 2015

# Summary of Operations To Date

- Another attempt was made to form a desiccated area around the antenna by increasing the applied power at the antenna. The premise was that not enough energy was being applied to overcome the influx of fluids, and that by applying high power would boil off the nearby water improving the antenna efficiency and effective antenna length:
  - During a power ramp the transmitter shut off, cause was later found to be arc in IOB caused by debris
  - Prior to discovery of IOB damage a 15 minute transmitter tuning operation triggered an LEL alarm in the luminol cooling system
  - Investigation into the cause of the LEL alarm determined that FOD (foreign object and debris) had contaminated the luminol system, and combined with the high power, caused luminol breakdown. The IOB was removed to determine whether this issue was isolated to the IOB, or whether there were subsurface issues as well. Upon removal of the IOB, a TDR scan of the subsurface tool head determined that it had been damaged and would need to be removed

- Upon pulling the subsurface RF assembly, it was determined that an event had occurred subsurface resulting in damage to the tool and the injector liner

- A rigorous root cause analysis was conducted to determine possible causes of the tool failure:
  - Evidence indicates that the initial arcing event took place during the initial antenna ramp up

- The facility was safely shutdown in May due to the fires in Fort McMurray, and has remained staffed but nonoperational. Since this time the project team has been working to redesign both the surface and subsurface equipment

# Summary of Operations To Date

- The facility was unstaffed in December 2016 and the facility remained nonoperational and in safemode while the project team continued working on surface and subsurface redesign

# ESEIEH Pilot Performance Presentation

Surface facilities

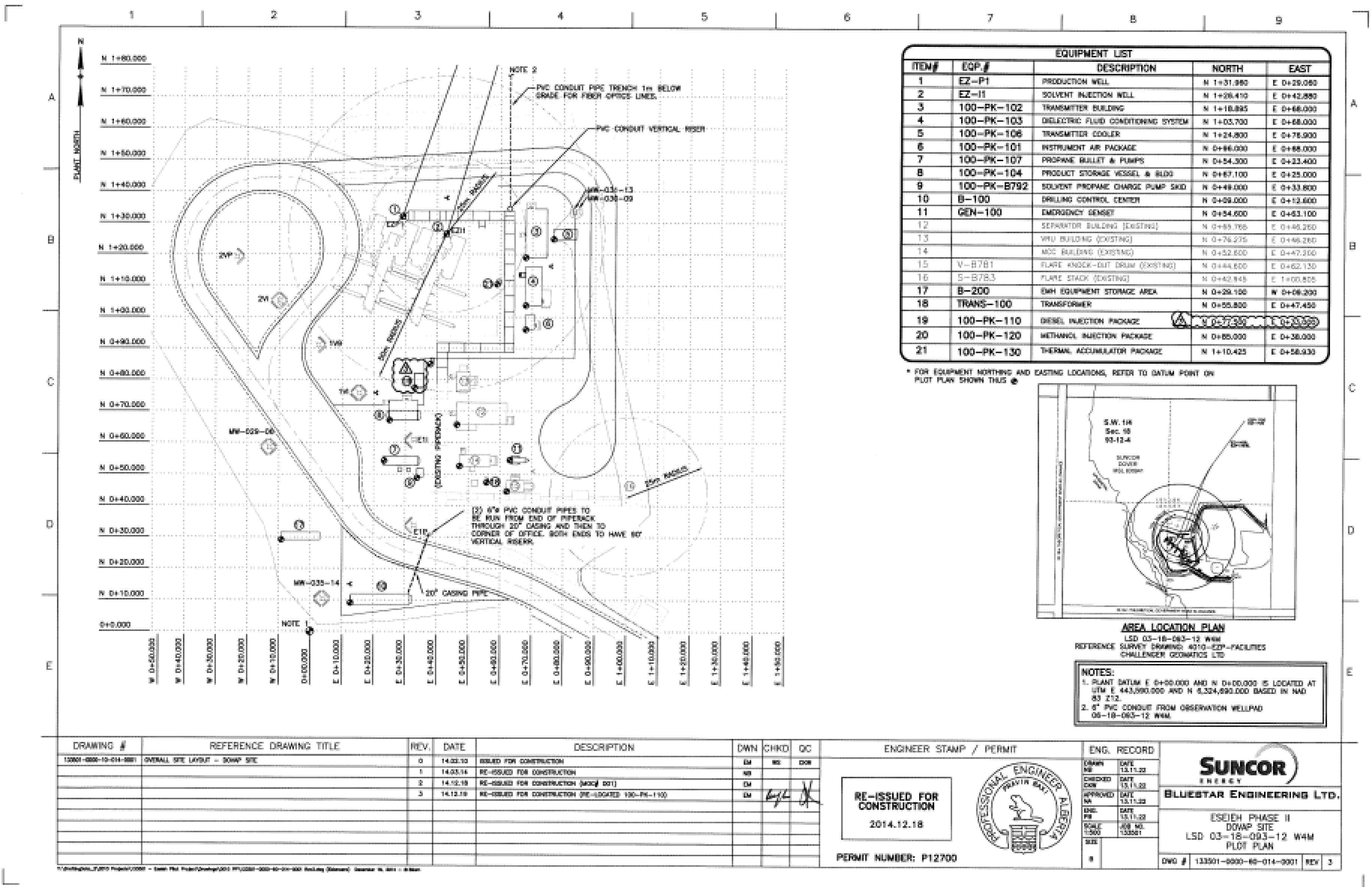
SUNCOR

# Surface Facilities

# Surface Facilities

# Surface Facilities

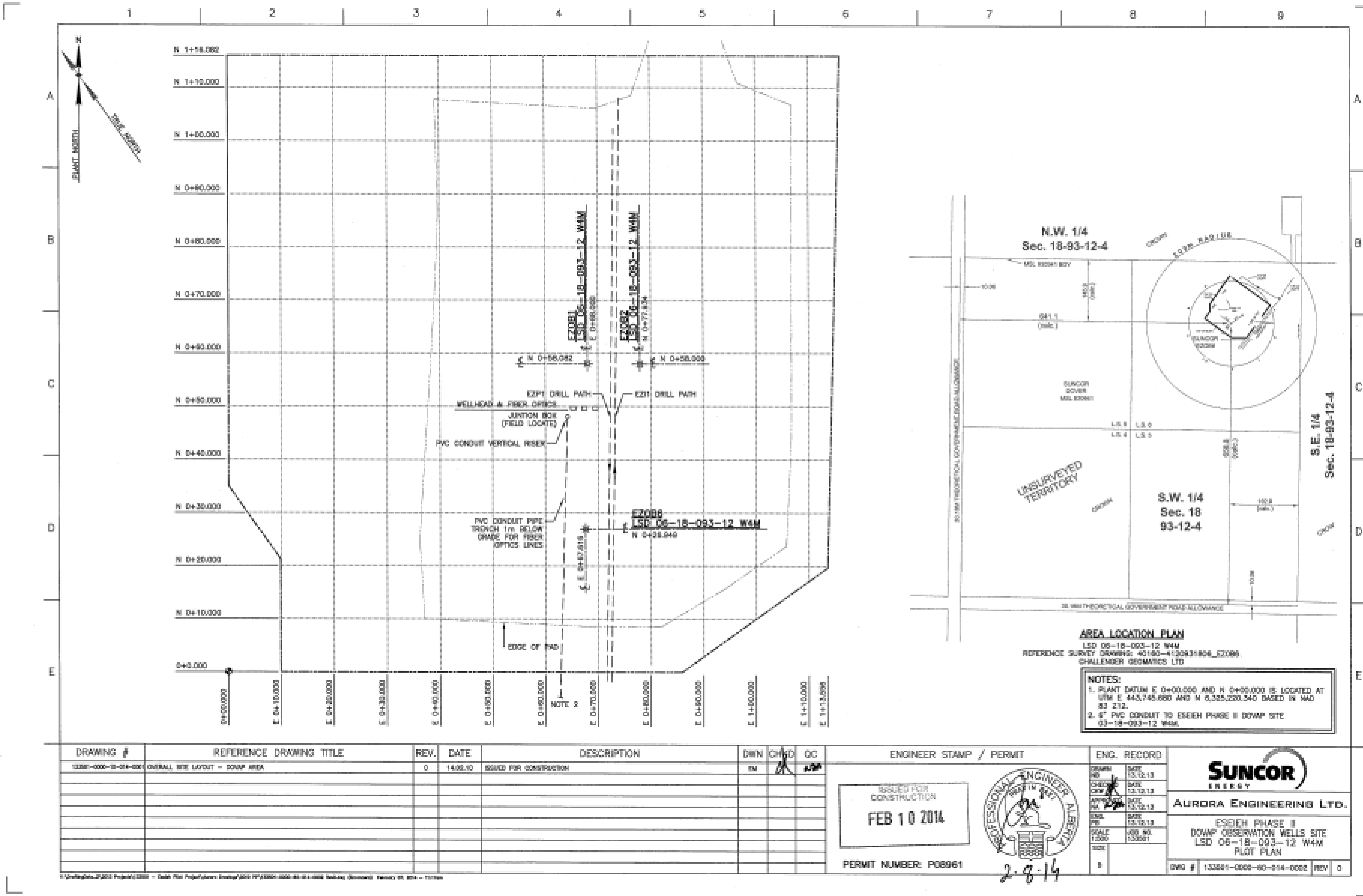
# Surface Facilities – Plot Plan



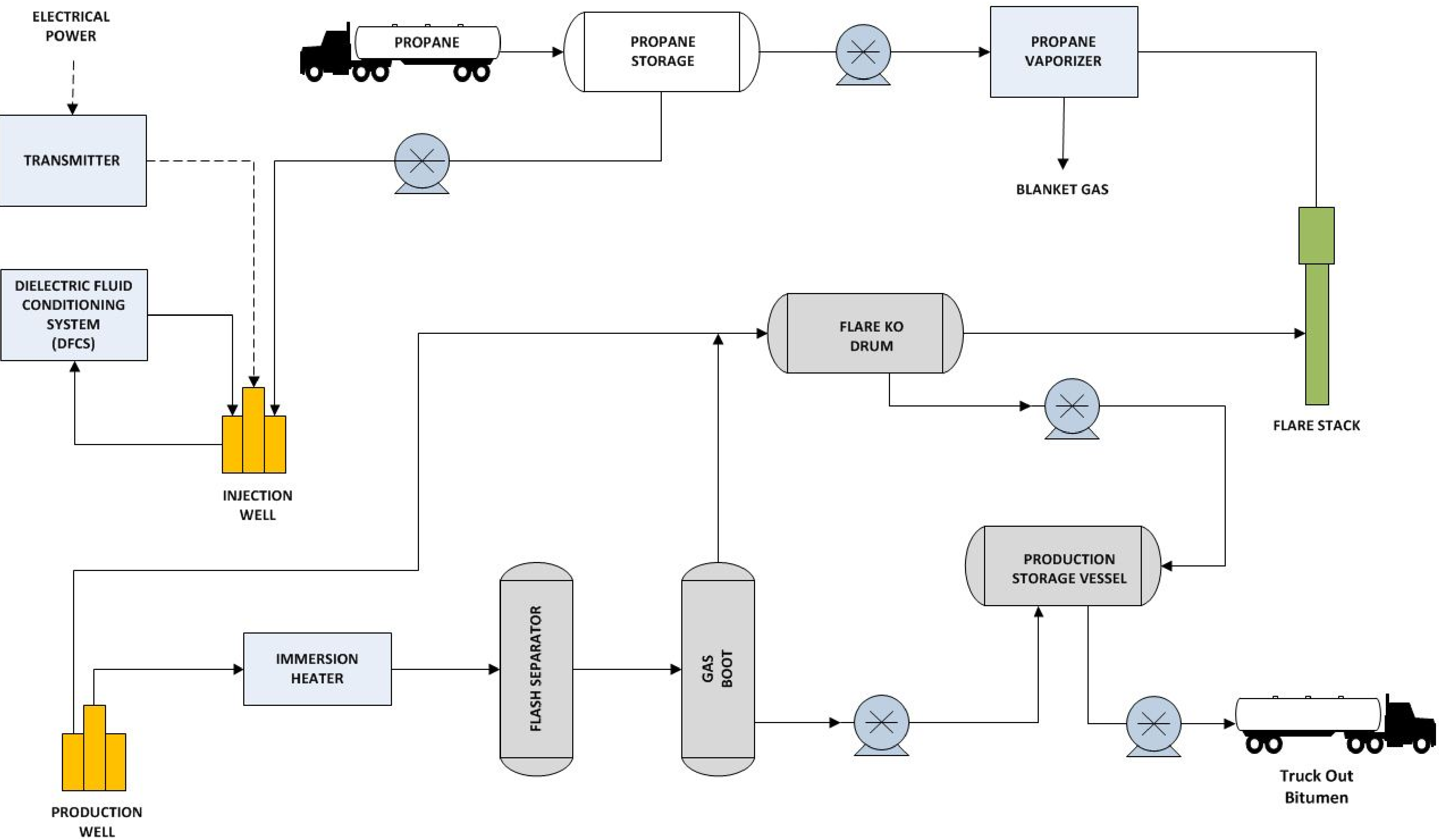

**EQUIPMENT LIST**

| ITEM# | EQP.# | DESCRIPTION | NORTH | EAST |
|---|---|---|---|---|
| 1 | EZ-P1 | PRODUCTION WELL | N 1+31.980 | E 0+29.080 |
| 2 | EZ-I1 | SOLVENT INJECTION WELL | N 1+26.410 | E 0+42.880 |
| 3 | 100-PK-102 | TRANSMITTER BUILDING | N 1+18.895 | E 0+68.000 |
| 4 | 100-PK-103 | DIELECTRIC FLUID CONDITIONING SYSTEM | N 1+03.700 | E 0+68.000 |
| 5 | 100-PK-106 | TRANSMITTER COOLER | N 1+24.800 | E 0+76.900 |
| 6 | 100-PK-101 | INSTRUMENT AIR PACKAGE | N 0+86.000 | E 0+68.000 |
| 7 | 100-PK-107 | PROPANE BULLET & PUMPS | N 0+54.300 | E 0+23.400 |
| 8 | 100-PK-104 | PRODUCT STORAGE VESSEL & BLDG | N 0+67.100 | E 0+25.000 |
| 9 | 100-PK-B792 | SOLVENT PROPANE CHARGE PUMP SKID | N 0+49.000 | E 0+33.800 |
| 10 | B-100 | DRILLING CONTROL CENTER | N 0+09.000 | E 0+12.600 |
| 11 | GEN-100 | EMERGENCY GENSET | N 0+54.600 | E 0+63.100 |
| 12 | | SEPARATOR BUILDING (EXISTING) | N 0+85.766 | E 0+46.260 |
| 13 | | VRU BUILDING (EXISTING) | N 0+76.275 | E 0+46.260 |
| 14 | | MCC BUILDING (EXISTING) | N 0+52.600 | E 0+47.300 |
| 15 | V-B781 | FLARE KNOCK-OUT DRUM (EXISTING) | N 0+44.600 | E 0+62.130 |
| 16 | S-B783 | FLARE STACK (EXISTING) | N 0+42.845 | E 1+00.805 |
| 17 | B-200 | EWH EQUIPMENT STORAGE AREA | N 0+29.100 | W 0+09.200 |
| 18 | TRANS-100 | TRANSFORMER | N 0+55.800 | E 0+47.450 |
| 19 | 100-PK-110 | DIESEL INJECTION PACKAGE | N 0+7[illegible] | E 0+2[illegible] |
| 20 | 100-PK-120 | METHANOL INJECTION PACKAGE | N 0+65.000 | E 0+38.000 |
| 21 | 100-PK-130 | THERMAL ACCUMULATOR PACKAGE | N 1+10.425 | E 0+58.930 |

# Surface Facilities – Plot Plan



# Surface Facilities – Simplified Schematic



# Summary of Facility Modifications

1. Diesel injection system:
   - In order to execute diesel injection it was recommended that a small volume (4-4.9m3) storage tank, with redundant pumping capability of 2.3$m^3$/hr (volume required to purge pump discharge tubing is 2.3$m^3$), with design pressure of 3600kPag at pump discharge, be added to the facility (with associated piping etc.) in order to conduct continuous diesel injection in production mode, and provide on-demand diesel immediately upstream of PSHH1000, in order to provide operational flexibility for the system

2. HX-101 Instrumentation:
   - Relocated TIT-1003 to the top of 100-HX-101 with high temperature shutdown and installed a pressure gauge.
   - Rev.1 add PSV as required by ABSA inspector

3. PK-103 DFCS Isolation Valves:
   - Added isolation valves on dielectic fluid supply and return lines

4. PK-103 DFCS PSV & PT:
   - Added block flow PSV's on di-electric oil supply and return lines with relief setpoints below level that would cause damage to downhole toolhead.
   - Added pressure transmitters on di-electric supply and return lines to alarm and then shutdown in the event of high pressures caused by blocked flow or thermal expansion. Setpoints needed to include safety margins to ensure no damage to downhole toolhead.

# Summary of Facility Modifications

5. EZ-I1 Bubble Tube on Propane Inj.:
   - Added tubing connection between nitrogen purge line and propane supply as shown on dwg# 133501-0000-05-031-0002 Rev.1

6. Mitigated JT across PV 1004:
   - Implemented a pressure reduction design change to ensure minimal impacts from hydrate formation as a result of JT effect across PV 1004. Produced casing gas pressure is controlled by PV 1004 as shown on dwg# 133501-0000-05-031-0001 Rev.2.

7. Thermal Accumulator Change:
   - Added a Thermal Accumulator package which will act as a Pulsation dampener for the DFCS skid.

8. Propane Pump Skid Re-design:
   - Replaced isolation valve downstream of P-B792A/B with a block and bleed valve.

9. Programming Automatic Operation of FKOD Pumps P-B782A/B:
   - Change of programming from manual to automatic operation of FKOD Pumps P-B782A/B

11. Vaporized Propane System Change:
    - Added heat trace and insulation to all of the piping

# Summary of Facility Performance

- As part of the root cause analysis, as well as the design changes to the subsurface completion, a number facility changes are planned for the ESEIEH facility.
- New modifications and additions to the existing facility (Antenna site)
  - Filter skids on the inlet to the IOB for FOD removal
  - DF2 – Dielectric Fluid System to fill the sealed liner and prevent fluid ingress
  - DFCS carbon steel pipe to be replaced with stainless steel pipe
  - Upgraded sample quills to be installed for more representative sampling
  - 2 new fuel gas tanks to allow for changing the solvent from propane to butane
  - Add new instrumentation in DFCS
- New facilities at the observation well pad to accommodate the vertical solvent injection well:
  - Glycol Heater
  - Nitrogen pack
  - FKOD Flare stack
- The existing facility and observation well pad will be connected via an underground 2 inch solvent pipeline and separate 600V cable



SUNCOR

# ESEIEH Pilot Performance Presentation

Regulatory and Environment

SUNCOR

# Regulatory Summary

- Regulatory Approvals and Licenses:
  - AER Experimental Scheme Approval No. 12074 issued May 1, 2013
  - EPEA Amending Approval No. 705-02-02 issued July 19, 2013
  - Measurement, Accounting and Reporting Plan (MARP) approved February 19, 2014
  - Facility License F-47236 issued March 24, 2014
  - Well License 0462395 (EZP1) issued December 13, 2013
  - Well License 0462501 (EZI1) issued December 16, 2013
  - RMWB Development Permit 2013-DP-01311 issued November 27, 2013
  - MARP was updated on February 27, 2015
  - AER Experimental Scheme Amendment No. 12074A issued July 27, 2015
    - Scheme approval extension granted until November 30, 2018
  - Waivers for placement of flare stack and spacing of flare stack obtained
  - D78 amendment not required for changes

# Regulatory Compliance

- AER Non-Compliance:
- Suncor Energy Inc. is in compliance with all regulatory approvals, decisions, regulations and conditions not otherwise identified in this presentation or otherwise disclosed.

# Environmental Summary

- Environmental:
  - Disturbance:  no new disturbance associated with the pilot facilities and horizontal well pair. These are within existing Dover well pad.
  - Storm water:  surface run-off contained on the site through the use of existing berms. Water collected, sampled and released if it meets EPEA requirements.
  - Domestic wastewater: contained and trucked to an approved treatment facility.
  - Spill containment:  consists of storage and secondary containment that complies with Directive 055 requirements. Other measures will include: collection of surface run-off; spill prevention and loss control systems ; groundwater monitoring ; proper maintenance, operating procedures and inspections ; spill contingency and response plans.
  - Air emissions:  monitoring and sampling as per the EPEA approval requirements
  - Groundwater:  monitoring and sampling as per the EPEA approval requirements



SUNCOR

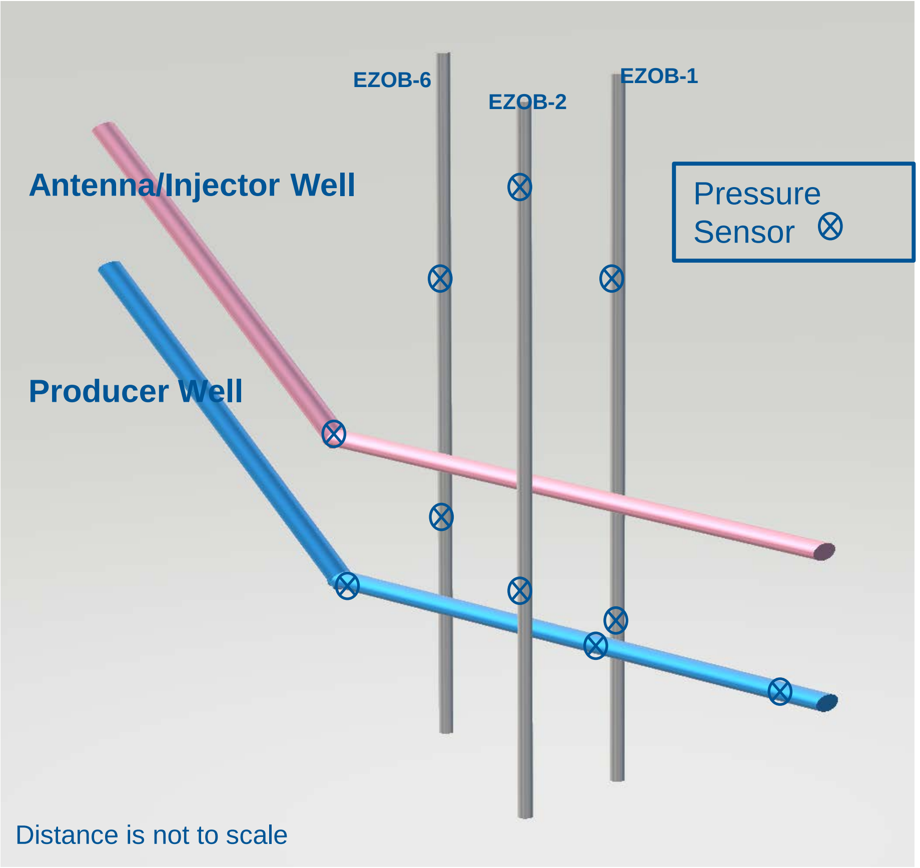
# ESEIEH Pilot Performance Presentation

Future Plans

# Future Plans

- Regulatory applications to be submitted to the AER for previously mentioned changes to the existing facility, well completions, and the addition of new well once designs have been finalized
- Install new liner with the finalized antenna well design
- Recomplete the antenna well with the finalized antenna well design
- Install the revised solvent injection configuration
- Evaluate the merits of changing the injected solvent from propane to an alternative solvent
- Facility upgrades related to the subsurface design changes
- Review and update the existing operating plan and make changes in light of learnings from previous operations and design changes
- Current schedule has antenna start up occurring in early 2018, with 12 to 24 months of operation to follow

# Reservoir Pressure Monitoring – Original Design



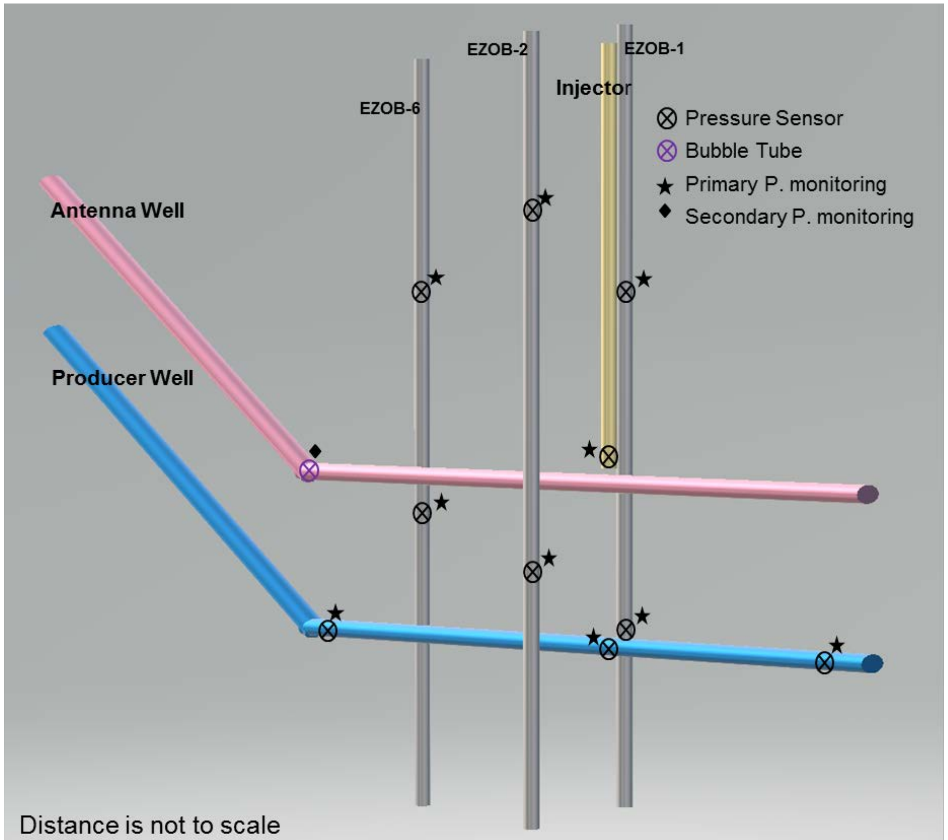

**EZOB-2 is ≈ 5m from EZ-WP1**
**EZOB-6 is ≈ 4m from EZ-WP1 (Heel Region)**
**EZOB-1 is ≈ 2m from EZ-WP1**

Original design included:

- Combination antenna & injection well,
- Heel pressure measurement on antenna/injector,
- Three (3) pressure measurements on the producer,
- Three OB wells in close proximity with multiple pressure sensors,
- OB and producer pressure sensors functioned to expectation during initial operations (May-December 2015),
- OB and Producer pressure sensor function confirmed during 2017 D-13 work on adjacent wells.

The changes in the configuration of the antenna/injector well resulted in minor modifications to the reservoir pressure monitoring scheme.

# Reservoir Pressure Monitoring – New Design




**EZOB-2 is ≈ 5m from EZ-WP1**
**EZOB-6 is ≈ 4m from EZ-WP1 (Heel Region)**
**EZOB-1 is ≈ 2m from EZ-WP1**

Antenna well re-designed as a sealed-wellbore

- Injection & pressure monitoring capability of the antenna removed.

Vertical solvent injector drilled & completed in:

- Close proximity to EZ-OB1 and EZOB2,
- Close proximity to the antenna mid-point,
- Vertical injector well equipped with downhole pressure gauge,
- Injector pressure sensor ~2 meters from antenna mid-point.

Bubble tube to be installed in the antenna well

- Bubble tube landed in intermediate annulus
- Low-rate, continuous N2 injection
- Landed 1-2 meters above antenna elevation
- 30-40 meters from ICP

Bubble tube designated as a secondary pressure monitoring sensor.

# Information Request:

***Provide more details about the cause of damage to composite liner and what changes will ESEIEH implement in a new liner***

Cause of damage:

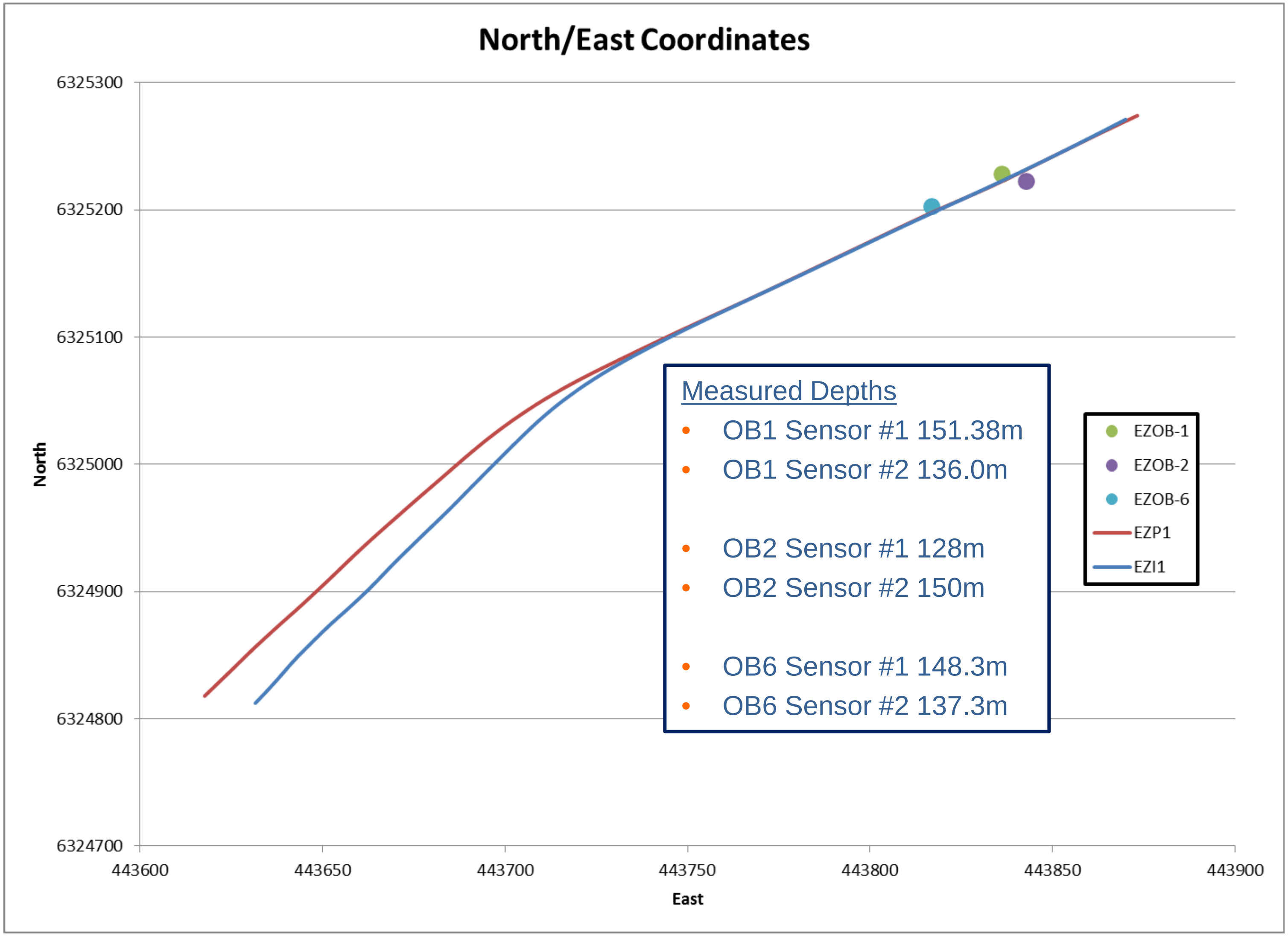
- The composite liner was exposed to a high-temperature event that compromised thermal, electrical and mechanical function of the isolator material. A comprehensive Root Cause Analysis (RCA) identified several contributing factors, principal of which was an unexpected accumulation of FOD (foreign object debris) within the composite segment. The FOD resulted in voltage breakdown across the composite segment and the high temperature event.
- The RCA also identified an isolator material flaw that would have compromised longevity of the component.

Changes to the ESEIEH project include:

- As a result of FOD
  - Sealed liner design to isolate the internal components of the antenna from reservoir fluids, and removed the solvent injection function from the antenna. A separate vertical well will inject the solvent.
  - Addition of a plastic sleeve over the exposed isolator assembly to optimize electrical performance and protect the isolator from wellbore FOD
  - Added surface and subsurface filters to the cooling circuits to ensure the dielectric fluid is not contaminated by FOD.
  - Replace carbon steel piping within the dielectric fluid circulation network with stainless steel pipe to prevent FOD accumulation.
  - Added a second dielectric fluid conditioning system to fill the sealed liner and prevent fluid ingress to the internal antenna components.

- Revised design has been rigorously tested for environmental breakdown.

# Appendix – Observation Well Instrumentation Location




Measured Depths

- OB1 Sensor #1 151.38m
- OB1 Sensor #2 136.0m

- OB2 Sensor #1 128m
- OB2 Sensor #2 150m

- OB6 Sensor #1 148.3m
- OB6 Sensor #2 137.3m