2018 Annual Performance Review

# Cold Lake Approvals 8558 and 4510

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2018 Annual Performance Review

## Table of Contents

**Electronic Attachments**

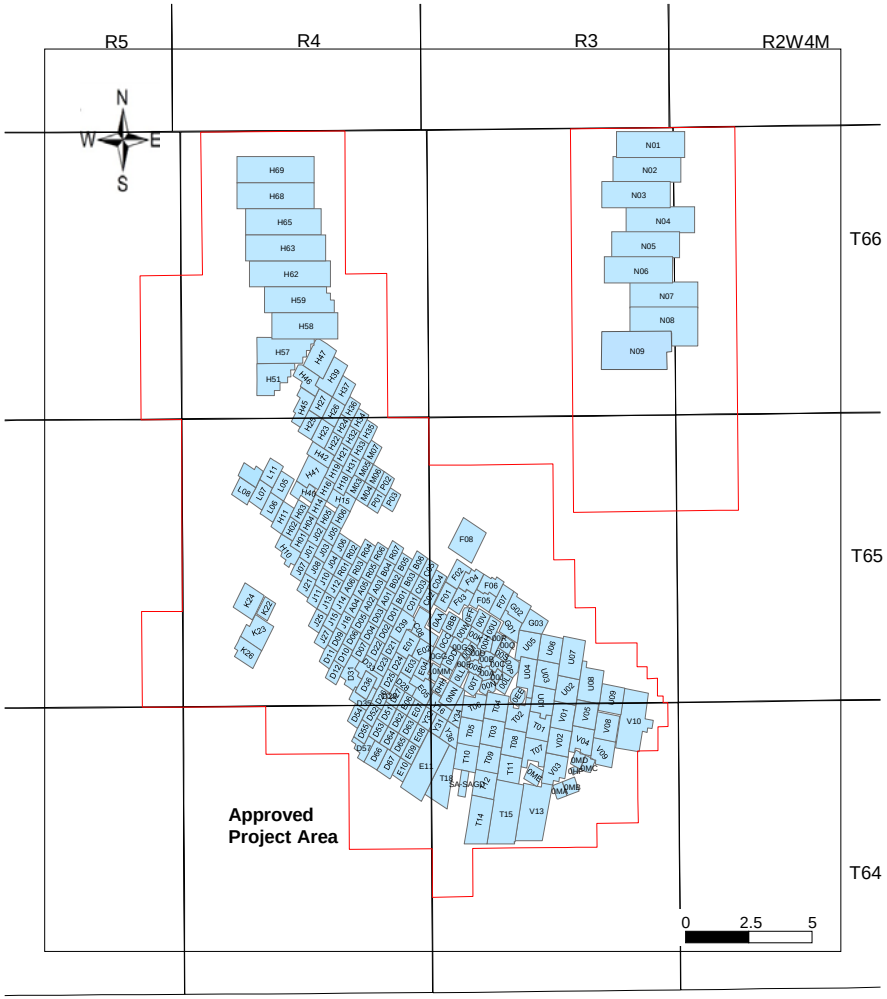
Piezometer Plots
Temperature Logs
Injection Pressures
Pad Production Plots

**Note: The following information covers the period from October 1st 2017 to September 30th 2018, unless otherwise stated.**

| Acronyms | Definitions |
|---|---|
| **BTEX** | Benzene Toluene Ethylbenzene Xylenes |
| **BIS** | Bitumen In Shale |
| **BHL** | Bottom Hole Location |
| **BTC** | Buttress Thread Collar |
| **CDWQG** | Canadian Drinking Water Quality Guidelines |
| **CW(T)** | Clearwater (Top) |
| **CLO** | Cold Lake Operations |
| **CS(T)** | Colorado Shale (Top) |
| **CEW** | Colorado Shale Evaluation Well |
| **CI** | Contour Interval or Casing Integrity |
| **(HP) CSS** | (High Pressure) Cyclic Steam Stimulation |
| **(O)EBIP** | (Original) Effective Bitumen in Place |
| **EUE** | External Upset Tubing |
| **FTD** | Final Total Depth |
| **FLIR** | Forward Looking Infra-red |
| **GM** | Gas Migration |
| **(U)/(L)GR** | (Upper)/(Lower) Grand Rapids |
| **GEW** | Groundwater Evaluation Well |
| **GW** | Ground Water |
| **HIP** | Horizontal Injector-Producer |
| **HW** | Horizontal Well |
| **HRSG** | Heat Recovery System Generator |
| **(H)PSW** | (Hybrid) Passive Seismic Well |
| **IOI** | Injector Only Infill |
| **LASER** | Liquid Addition to Steam for Enhanced Recovery |
| **LTC** | Long Thread Collar |
| **MD** | Measured Depth |
| **NS-CC** | Nippon Steel-Casing Connection |
| **OV** | Oilsand Valuation Well |
| **PIMFET** | Production Injection Management Fatigue Estimation Toolkit |
| **RFC** | Regulated Fill-up Cement |
| **STC** | Short Thread Collar |
| **ST** | Side Track |
| **(SA)-SAGD** | (Solvent Assisted) Steam Assisted Gravity Drainage |
| **SCVF** | Surface Casing Vent Flow |
| **TVD** | True Vertical Depth |
| **VOF** | Volume Over Fill-Up |

# Background of Scheme

# Background




## Development History

| | |
|---|---|
| 60's-70's | Lease acquisition<br>Small scale research pilots |
| 1975 | 10 kbd commercial pilot |
| '85-'94 | Phase 1-10<br>> Maskwa<br>> Mahihkan |
| 2002 | Phase 11-13 Mahkeses<br>> Cogeneration facility |
| 2004 | Approval area expanded<br>> Nabiye, Mahihkan North |
| 2015 | Phases 14-16 Nabiye<br>> Cogeneration facility |



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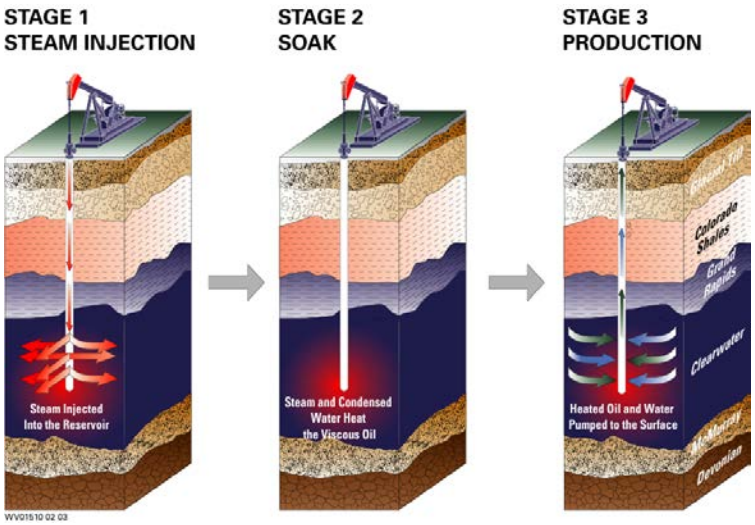
# CSS Process Overview




| | |
|---|---|
| Mobilizing Agent: | Heat |
| Mobilizing Agent Delivery System: | Steam |
| Drive Mechanisms: | Compaction, solution gas drive, gravity drainage |
| Wells Required: | 1 |
| Well Type: | Deviated or horizontal |
| Operating Pressure: | Above fracture pressure |

**Cyclic Steam Stimulation**

- High-pressure, high-rate, cyclic process with multiple drive mechanisms
  - > compaction
  - > solution gas drive
  - > gravity drainage
- Steam injection heats bitumen to reduce its viscosity (4 - 6 weeks)
- Brief soak phase to confirm casing integrity and control inter-well communication (3 days – several weeks)
- Length of the production period increases from a few months in early cycles to multiple years in late cycles
- Full well life: 8 -17 cycles and up to 50 years including follow-up processes



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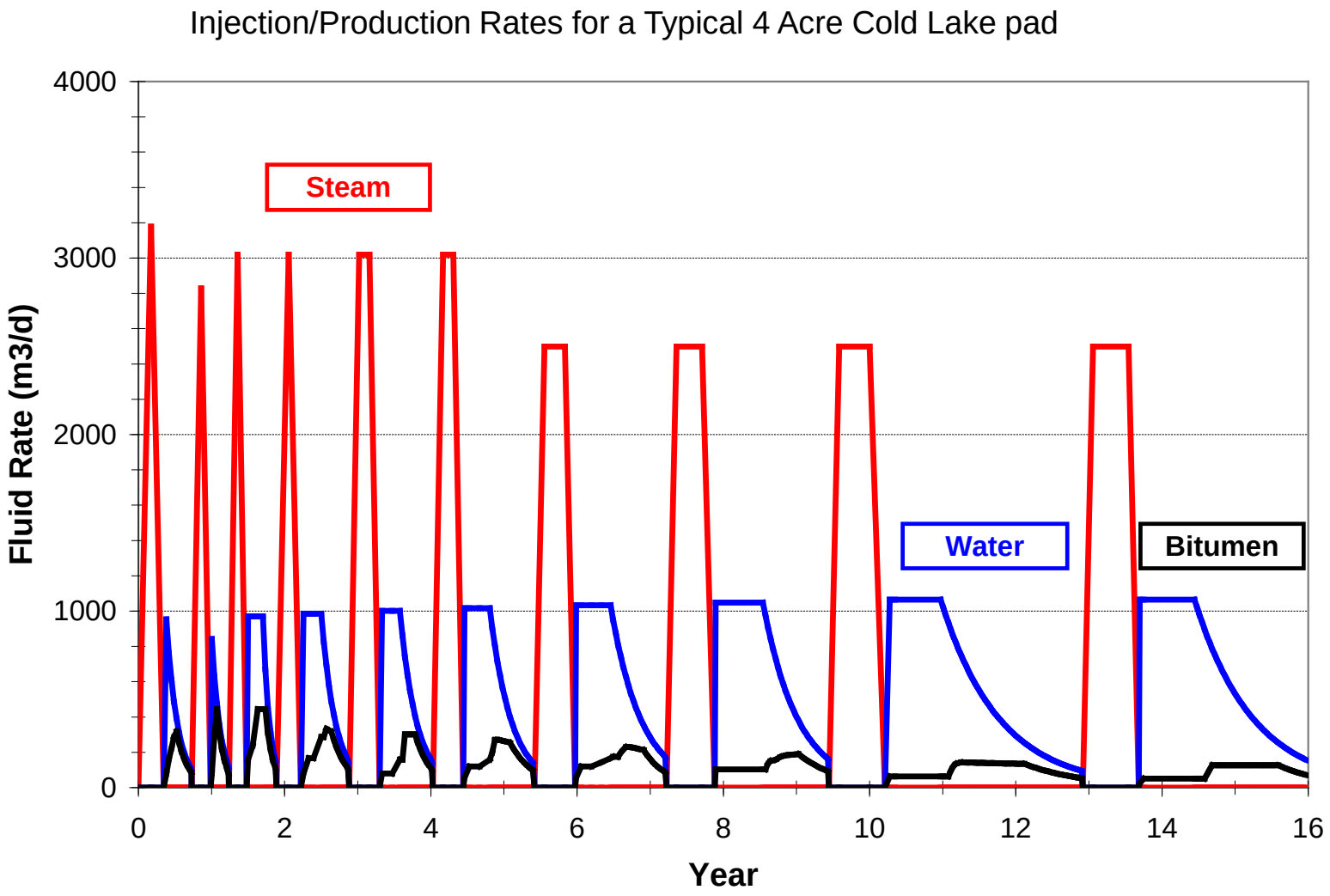
# CSS Process Overview



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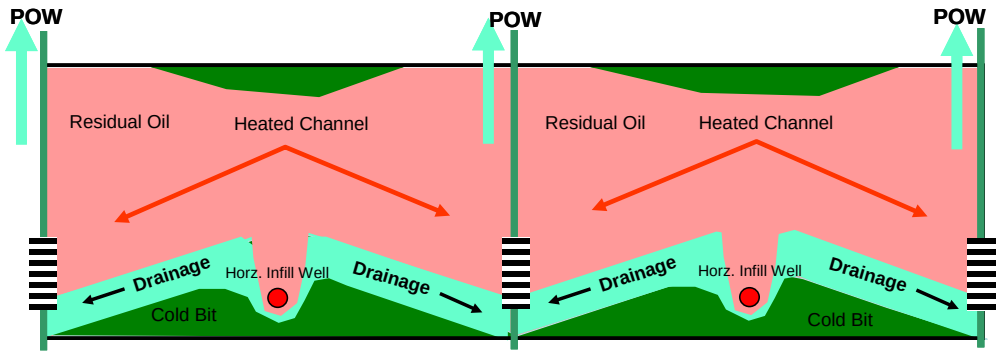
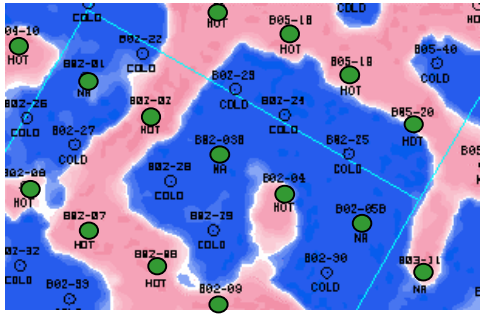
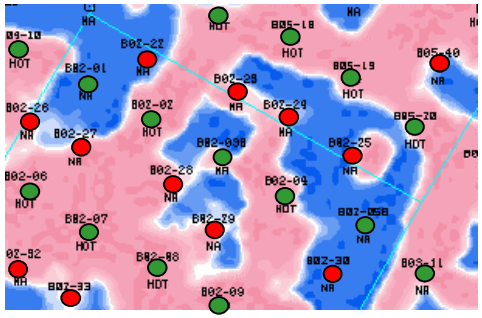
# Injector Only Infills (IOI)



Pre-Infill 3D Seismic



Post-Infill 3D Seismic

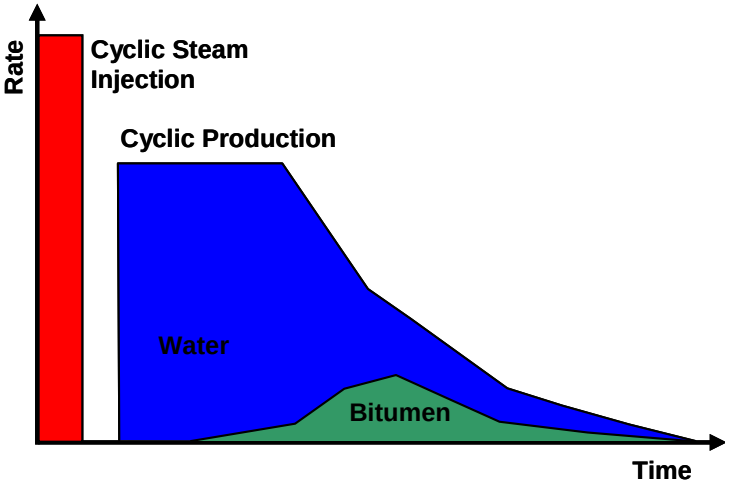
Hot reservoir (partially depleted)

Cold reservoir (undepleted)

CSS wells

Infill wells

- Injector only Infill wells direct cyclic steam to cold bitumen
- Steam distribution in horizontal wells controlled by limited entry perforations (~20 holes/1000 m well)
- Existing deviated wells operate as cyclic producers



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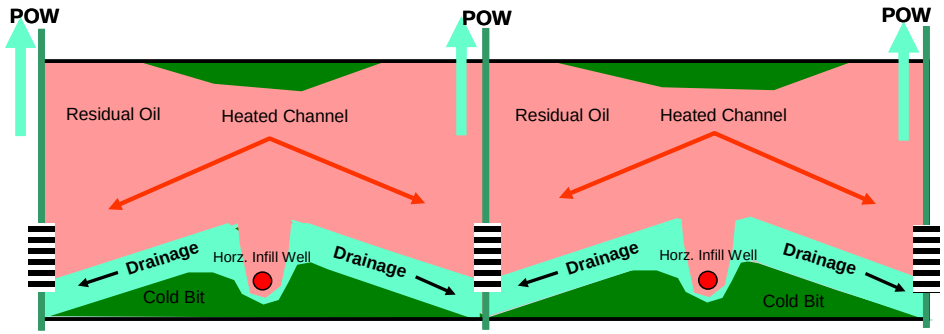
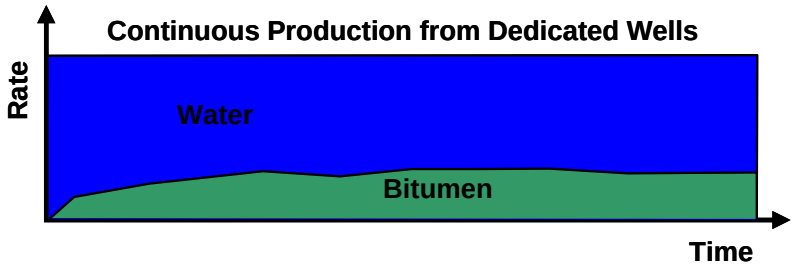
# Steamflood Process Overview








- Continuous steam injection, at low rates has the potential to:
  - > Lower operating costs
  - > Improve well operability
  - > Reduced casing stress
- Target reservoir pressure between 0.5 to 1.5 MPa
- Continuous rather than cyclical steam injection through dedicated injection-only and production-only wells



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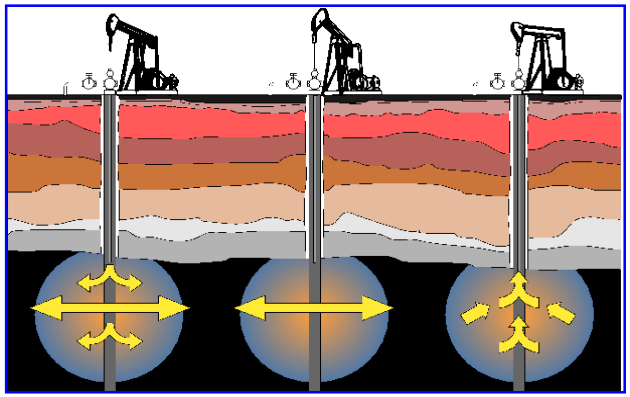
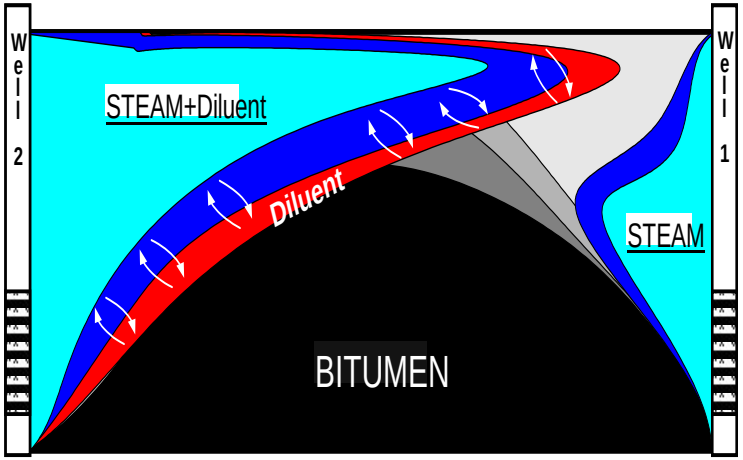
# LASER Process Overview



**CSS Thermal Process**




## Liquid Addition to Steam for Enhancing Recovery

- LASER is a late-life technology
  - > Follow-up process for CSS (cyclic steam stimulation)
  - > Implemented with 2-3 cyclic cycles remaining
  - > Alternative to purely thermal processes
- LASER is a cyclic steam process with the addition of a C5+ condensate to the steam during injection
  - > Enhances gravity drainage efficiency by reducing in-situ viscosity beyond thermal limit
  - > Potentially increases the recovery by >5% of EBIP
- Key process performance indicators
  - > Incremental OSR over a purely thermal baseline
  - > Fractional recovery of injected solvent



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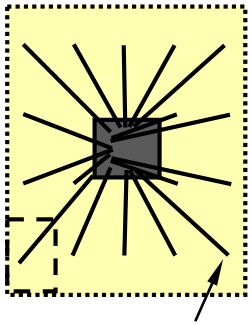
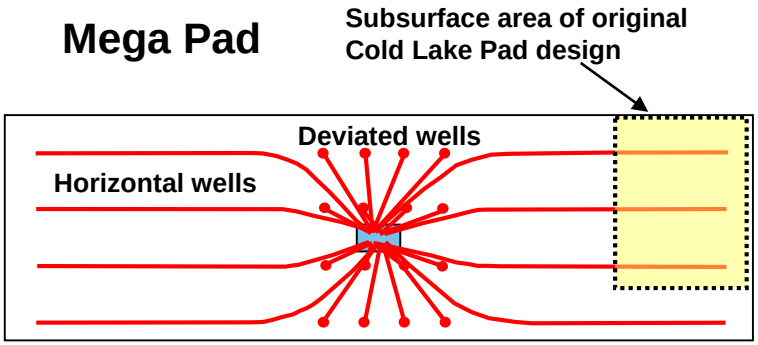
# Pad Design

Original Pad Design




**Mega Pad**




- Wells drilled directionally from central lease location
  - > Reduced environmental disturbance
  - > Improved development economics
  - > Increased operational efficiencies
- Original pad design 20 wells on 4 acre spacing
- Current pad designs
  - > Up to 35 wells on 4 or 8 acre spacing
  - > Mix of deviated and horizontal wells



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# Geoscience Overview

# Average Reservoir Properties and OBIP

Reservoir and Fluid Properties

| | |
|---|---|
| Depth | Clearwater @ 400M |
| Depositional Facies | Continental scale fluvial-deltaic system |
| Sands | Unconsolidated, reactive, clay clasts |
| Diagenetic Cements | Mixed-layer clays |
| Bitumen API Gravity | 10.2 |
| Bitumen Viscosity | 100,000 cp @ 13 C<br>8 cp @ 200C |
| Bitumen Saturation | Average 70% |

| | *Range* | *Average* |
|---|---|---|
| Porosity | 27 - 35% | 32% |
| Permeability | 1 - 4 Darcies | 1.5 Darcies |
| Bitumen Wt % | 6 - 14% | 10.5% |
| Total Net Pay | 0 - 60m | 30m |

Original-Bitumen-in-Place (OBIP)

| *Clearwater Fm* | *8 Wt %* | | *6 Wt %* | |
|---|---|---|---|---|
| | *(E6m3)* | *(MBO)* | *(E6M3)* | *(MBO)* |
| Entire Approval Area | 2,250 | 14,150 | 2,609 | 16,410 |
| Operating Portion[1] | 1,888 | 11,875 | 2,185 | 13,740 |

[1] Volume of main approved development area (i.e. excluding Nabiye)

CALCULATION METHOD

OBIP = A * H * V

A = area (m2)
H = Net pay (m)
V = Volumetric Factor = W * (2.64 – (1.64 * P))
W = Saturation (avg Wt %)
P = avg Porosity



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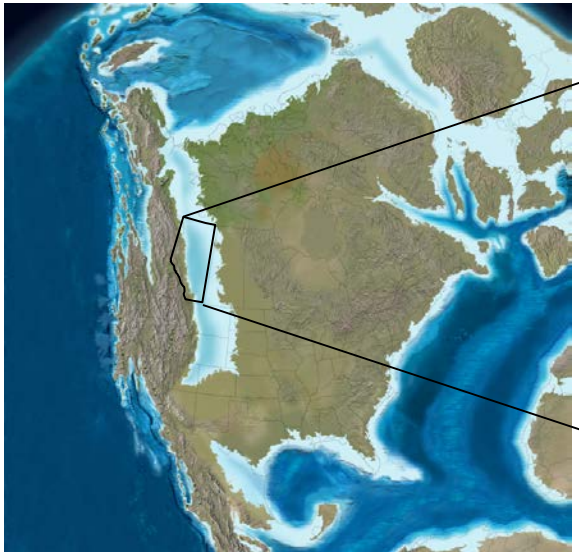
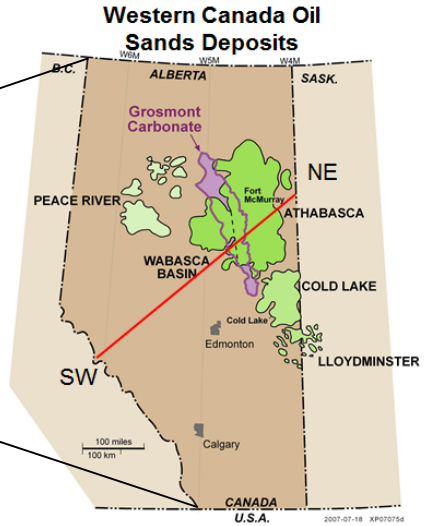
# Mannville Group: Geologic Setting

*Paleogeography (~100 Ma)*

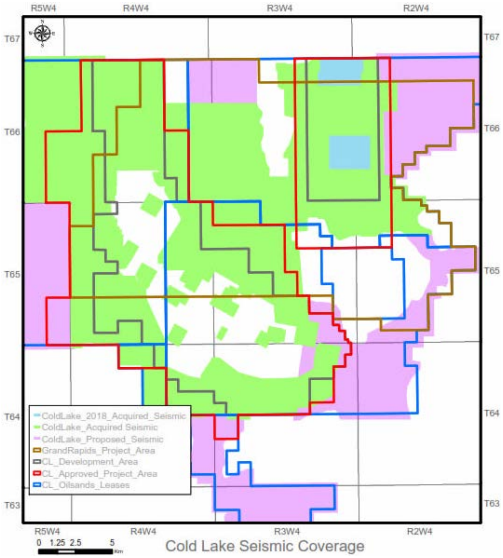


*Blakey*, www2.nau.edu/rcb7/index.html

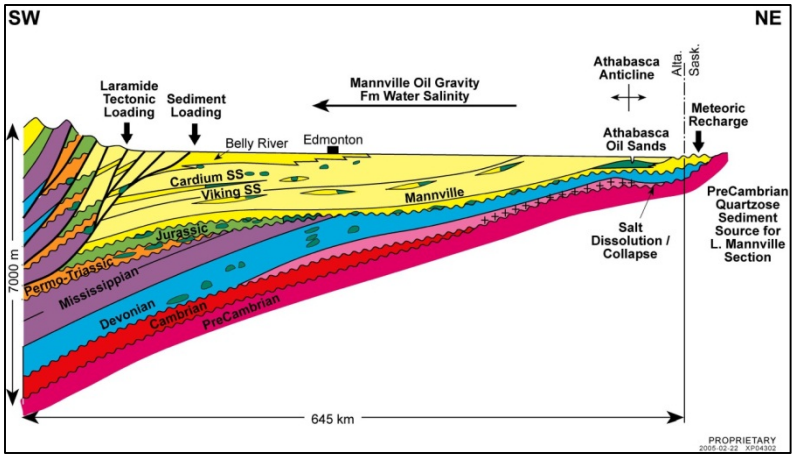



## *Depositional Environment*

- Mannville group deposited during Barremian to Albian time associated with fluvial drainage to the north toward the boreal sea (Western Interior Seaway)
- Western Canada Basin is a large foreland basin thickening to the west; marine & non-marine deposits
- Sub-divided into two lithostratigraphic units: 1) Lower tidally influenced fluvial (McMurray); and 2) Upper estuarine/shelf dominated (CLW & GR)
- Regional high to the east due to backbulge where salt dissolution and underlying Paleozoics likely controlled subsidence - Athabasca anticline




Cold Lake Seismic Coverage



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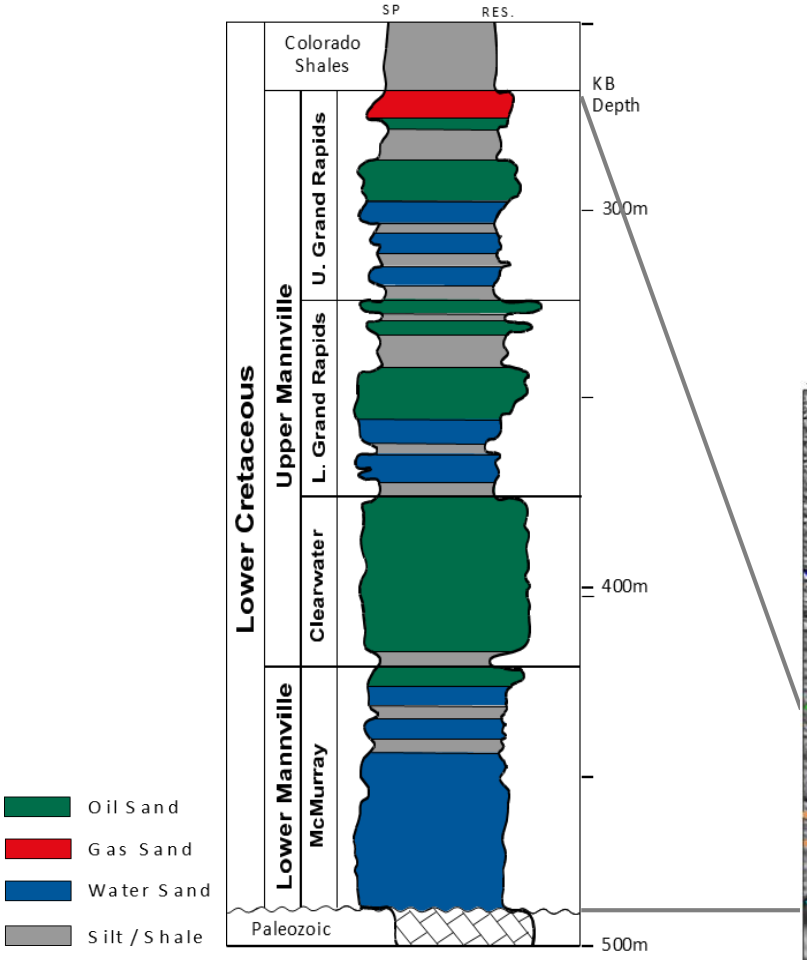
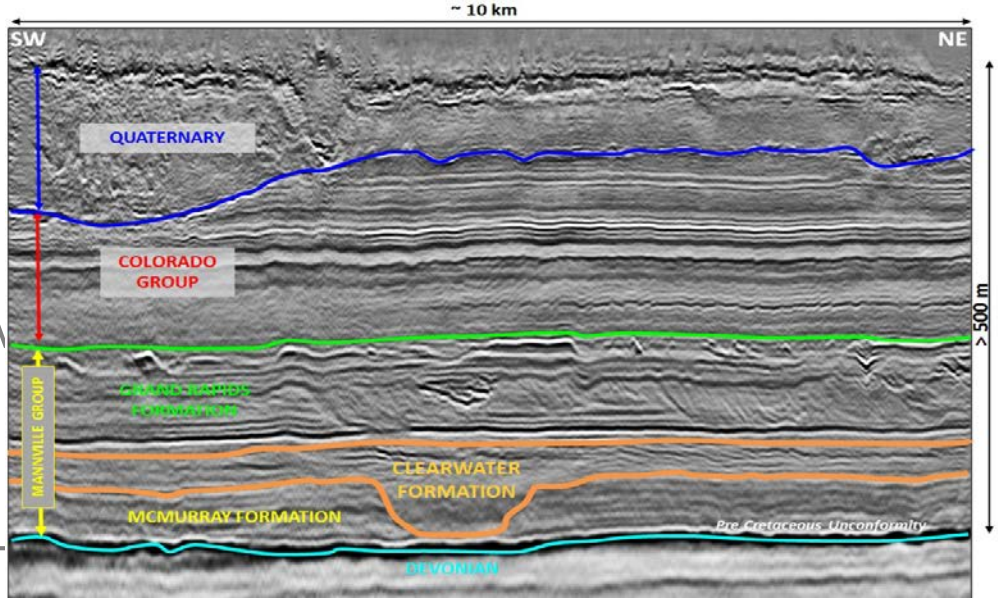
# Representative Type Log

**Representative Well Log Response – Mannville Group**




- Schematic type well log through the Mannville Group, (Albian) of Cold Lake field, Alberta
- Primary reservoir is the Clearwater Formation, secondary targets comprise the Grand Rapids and McMurray formations
- Clearwater Formation is a reservoir with a complex stratigraphic architecture that consists of a succession of deltaic and tidally influenced distributive fluvial systems
- Development to date has focused on the Clearwater in the central axis of the main fluvial valley complex

**Seismic Cross Section at Cold Lake (Surface to Top Devonian)**



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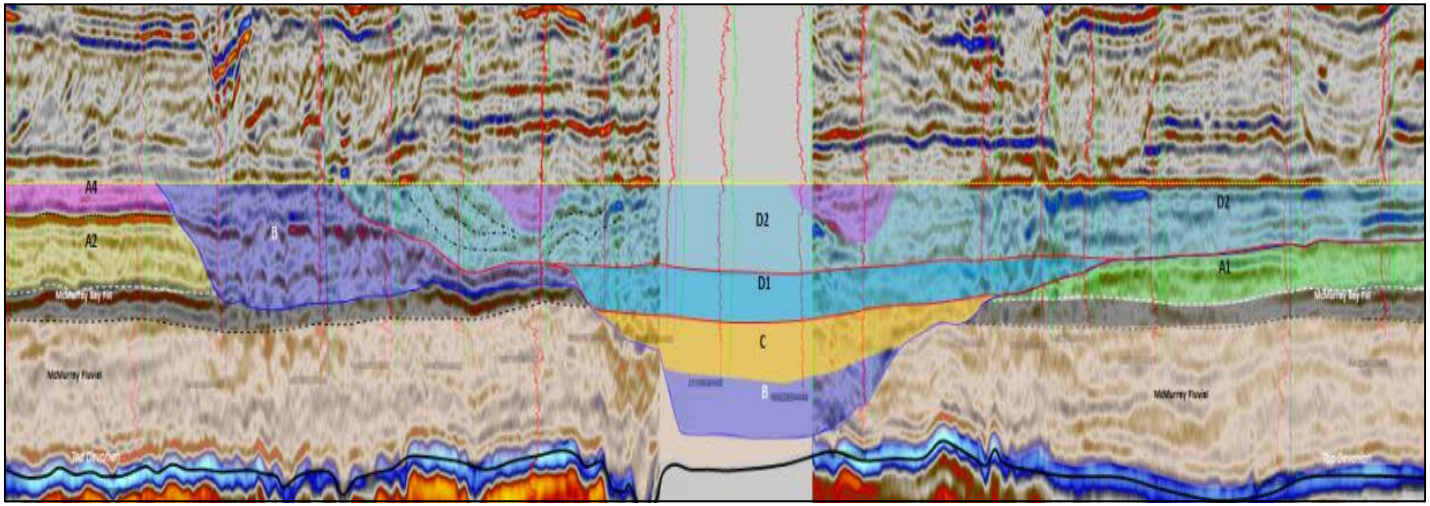
# Stratigraphic Framework

***History***

- Previous Cold Lake Clearwater stratigraphic framework developed in 1998
  - Adequate framework for majority of Cold Lake development projects
- Increasing complexity of recent & future development opportunities requires more predictive framework. Revised framework integrates 370 $km^2$ of hi-res 3D seismic and 1500 cores/logs
  - Identified four genetic units within the Clearwater that were mappable sub-regionally

***Ongoing Implementation***

- Application of framework to Nabiye is providing insights into pad performance variations
- Improved predictability of EOD distribution and impact on RQ has assisted with understanding production characteristics at Mahihkan North
- Broader application in the field is fundamental to assessing potential for future development opportunities



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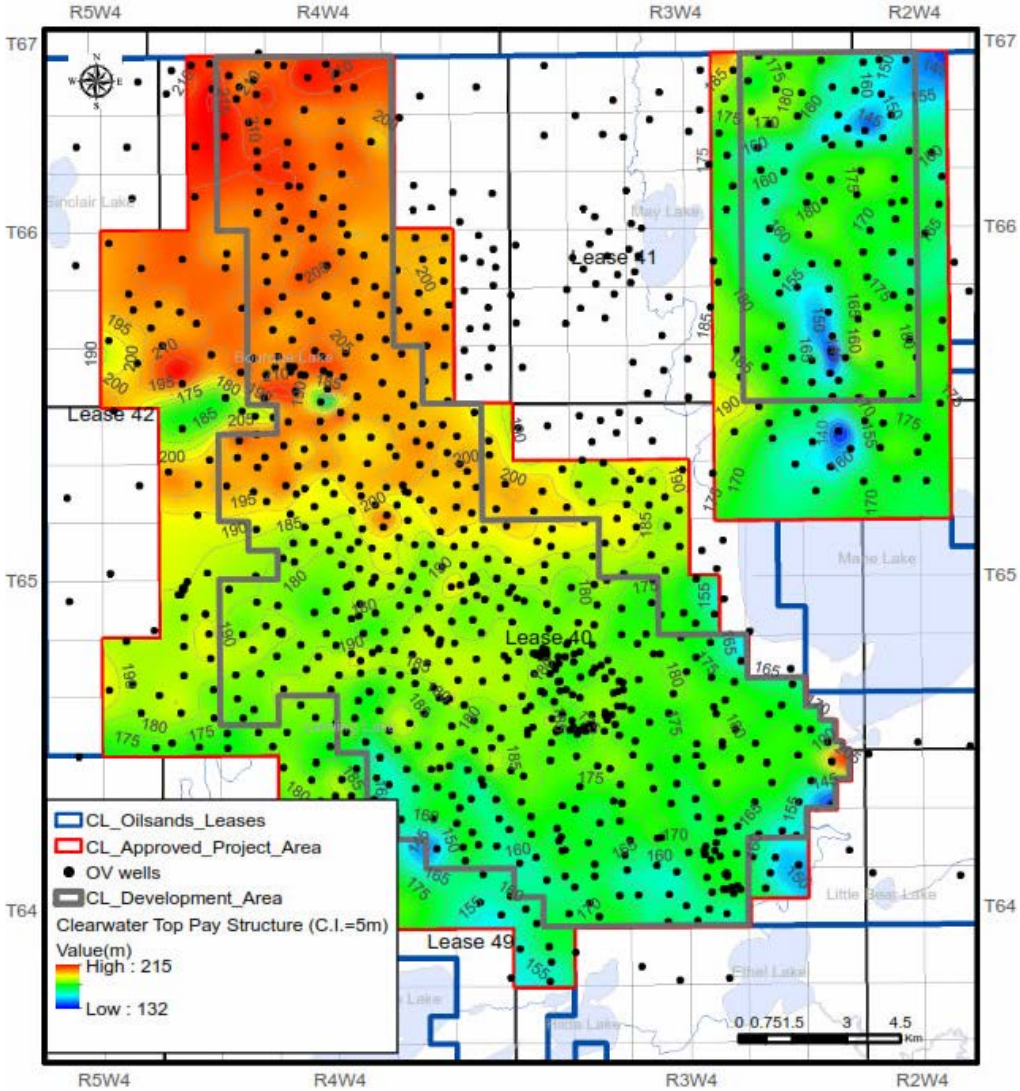
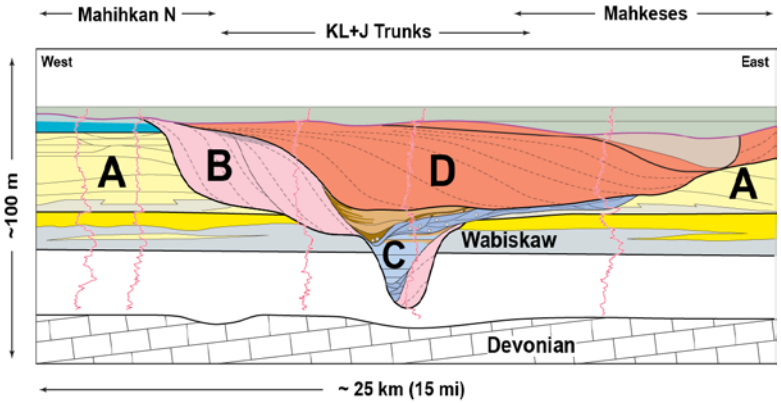
# Top Bitumen Pay Structure




- Top of bitumen pay is a smoothly varying surface which gently dips from a high of 220m above sea level (A.S.L.) in the NW to a low of 136m A.S.L. in the SE
- Top of bitumen structure varies more greatly in the Nabiye area
- Mapped surface is either a rock/bitumen or a gas/bitumen contact

**Clearwater Formation Stratigraphic Framework**



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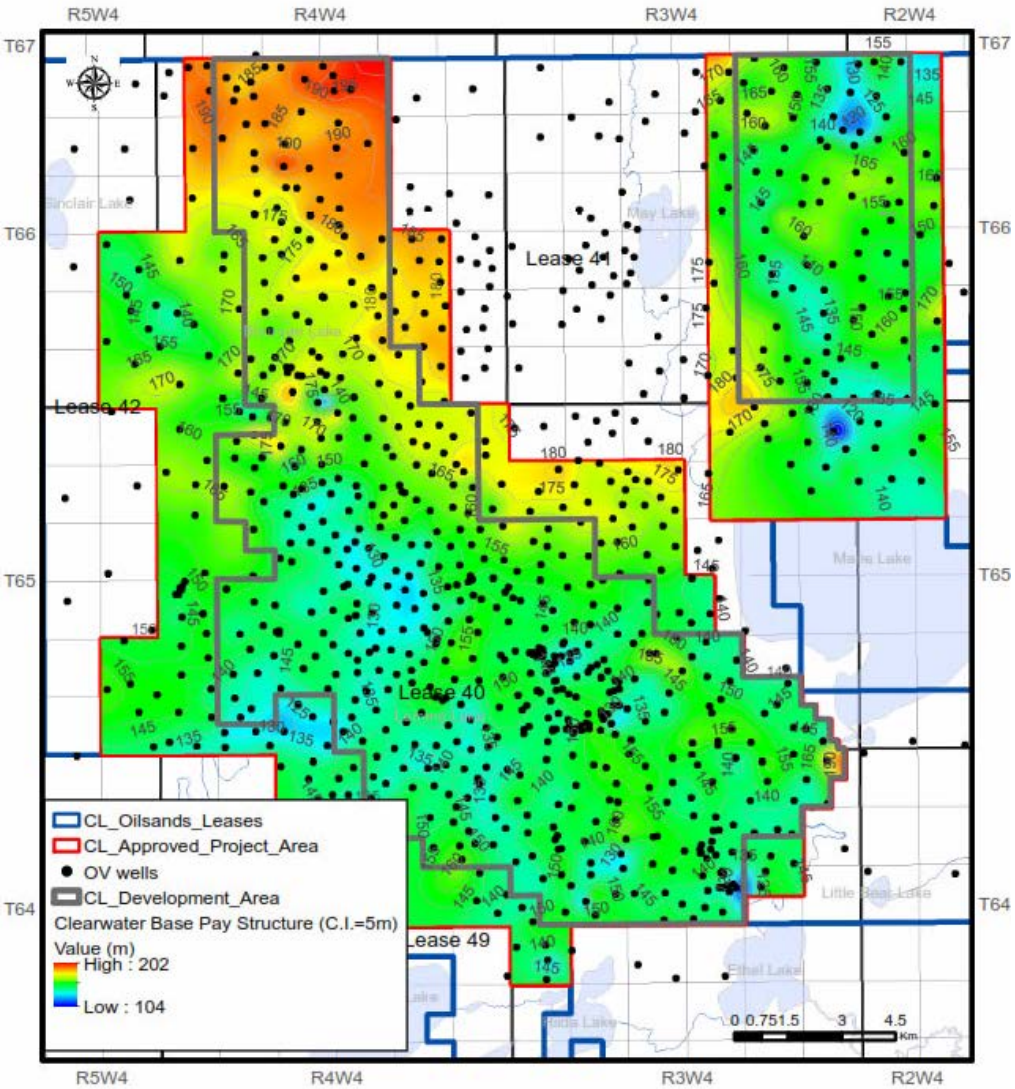
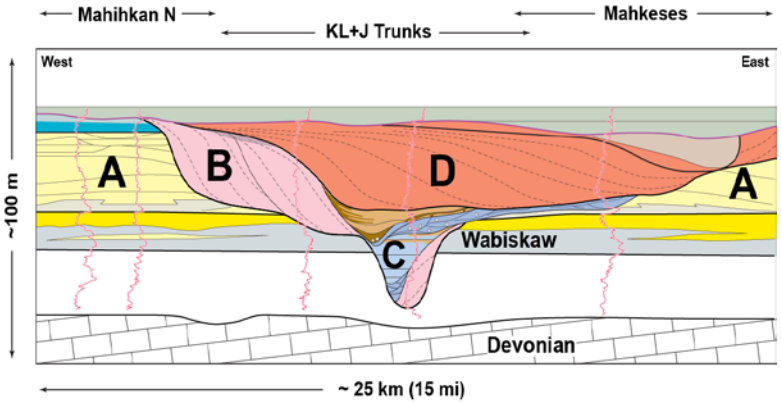
# Base Bitumen Pay Structure




- Mapped surface is either a bitumen/rock, a bitumen/water transition zone or a bitumen/water contact
- Different successions, depending on their depositional environment are filled with varying amounts of sand and shale.

**Clearwater Formation Stratigraphic Framework**



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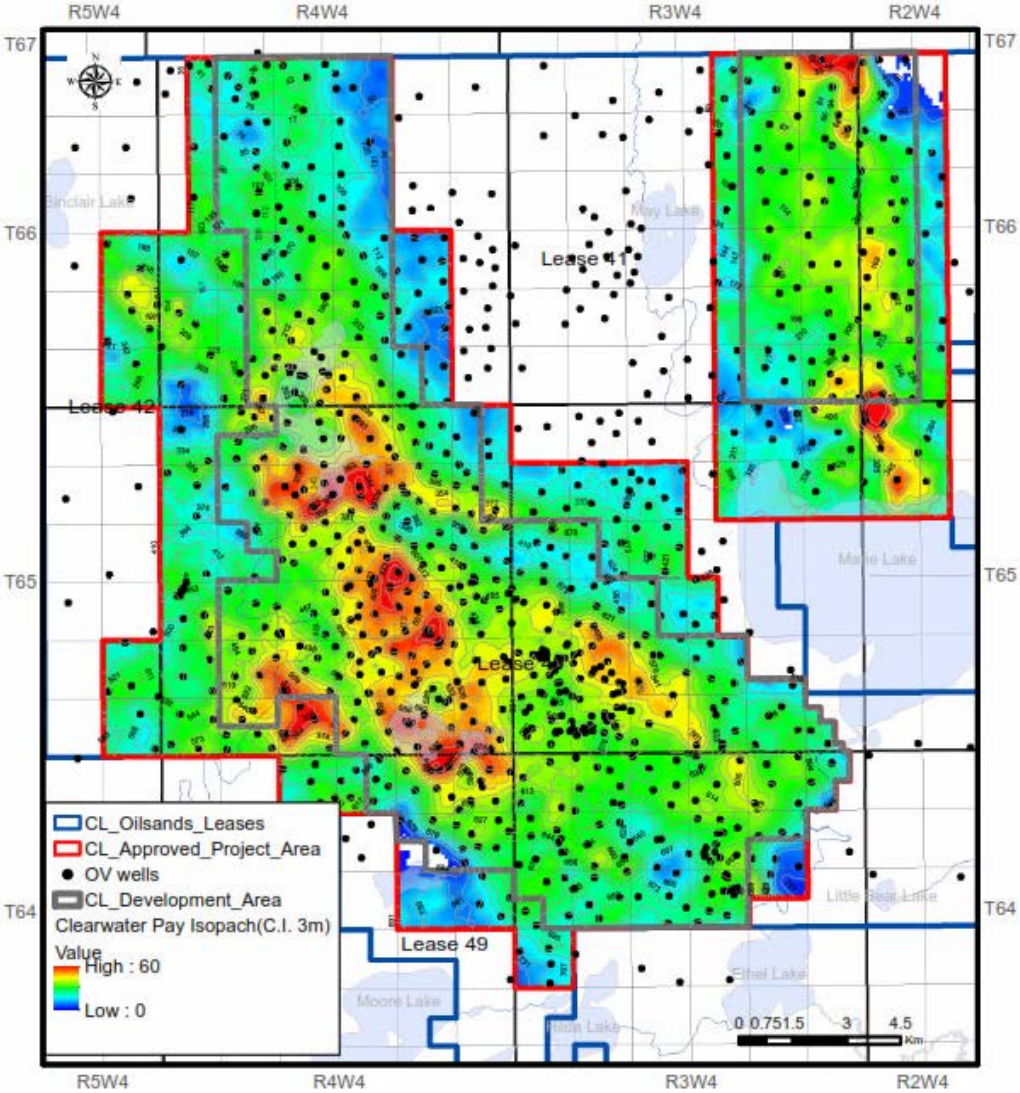
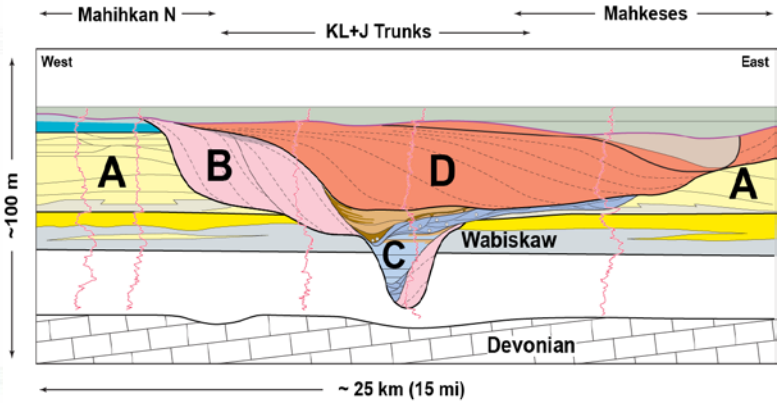
# Isopach of Net Bitumen Pay (>8 wt %)




- Map illustrates distribution of pay above 8 wt% saturation cut off
- Thin pay and pay immediately adjacent to water included in isopach calculation
- Thickness trend is consistent with orientation of main valley incision

**Clearwater Formation Stratigraphic Framework**



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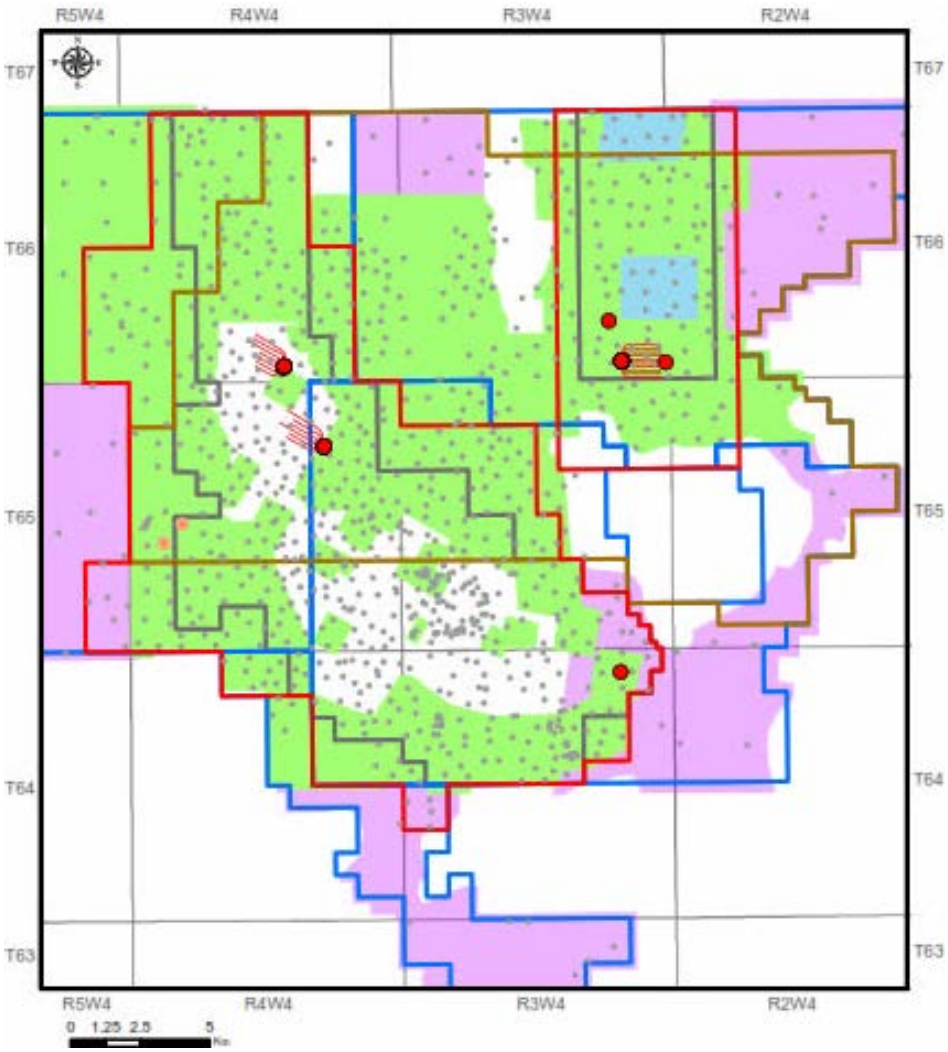
# Approved Development Area




**Map Illustrates:**

- Approved Project Area
- Approved Development Area
- Location and extent of existing development pads
- Distribution of OV core holes
- Wells drilled in 2017/ 18
- Current 3D seismic coverage
- Future 3D Proposals

- 2018 OV Wells
- OVwells before 2018
- 2018 winter drilled wells
- ColdLake_2018_Acquired_Seismic
- ColdLake_Acquired Seismic
- ColdLake_Proposed_Seismic
- GrandRapids_Project_Area
- CL_Development_Area
- CL_Approved_Project_Area
- CL_Oilsands_Leases



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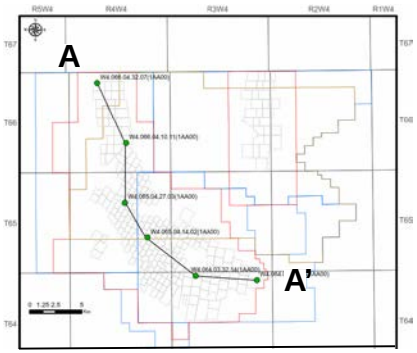
# Representative Structural Well Log Cross Section

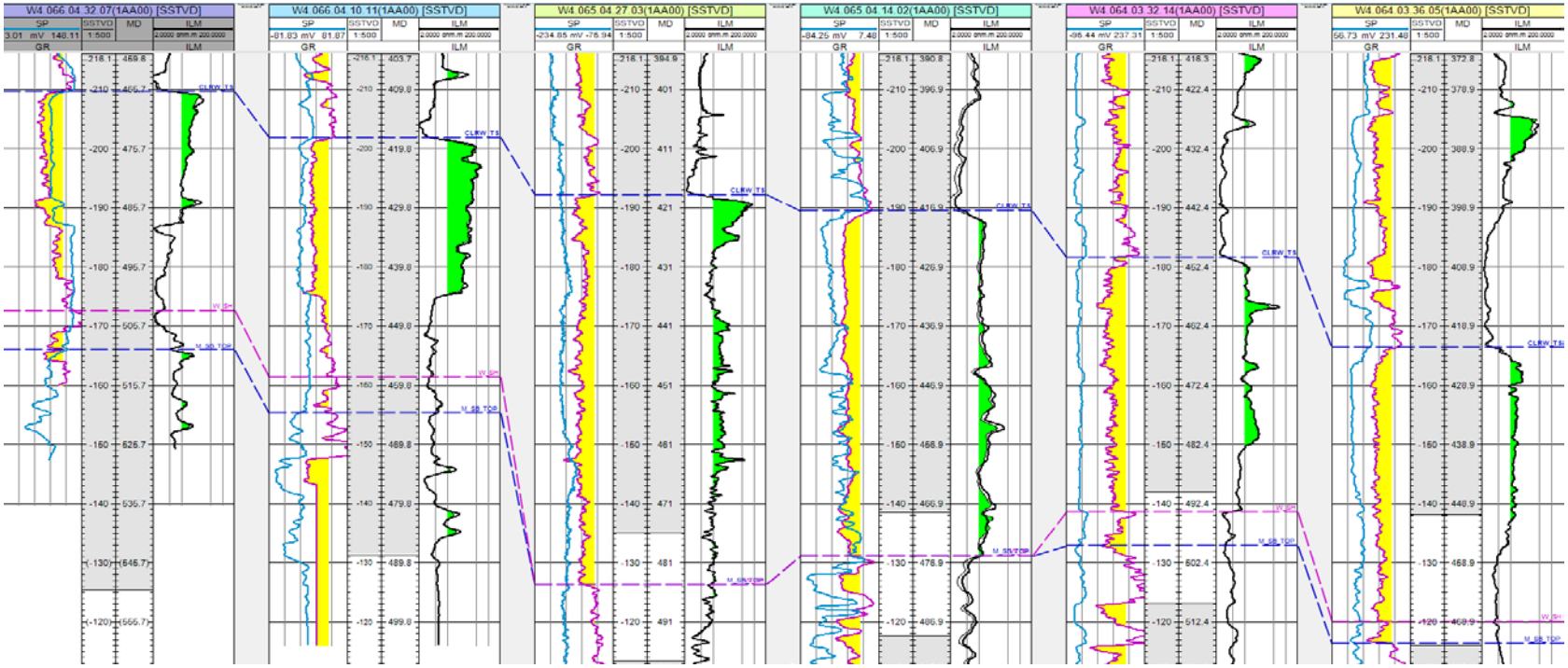
Cross section represents stratigraphic and structural variability within the Clearwater Formation from northwest to southeast .




- Cold Lake Leases
- Approved project boundary
- Developed pads
- Grand Rapids project boundary

A

A'



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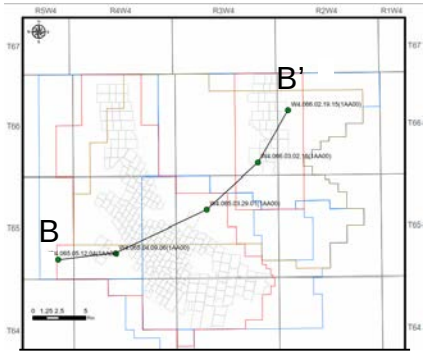
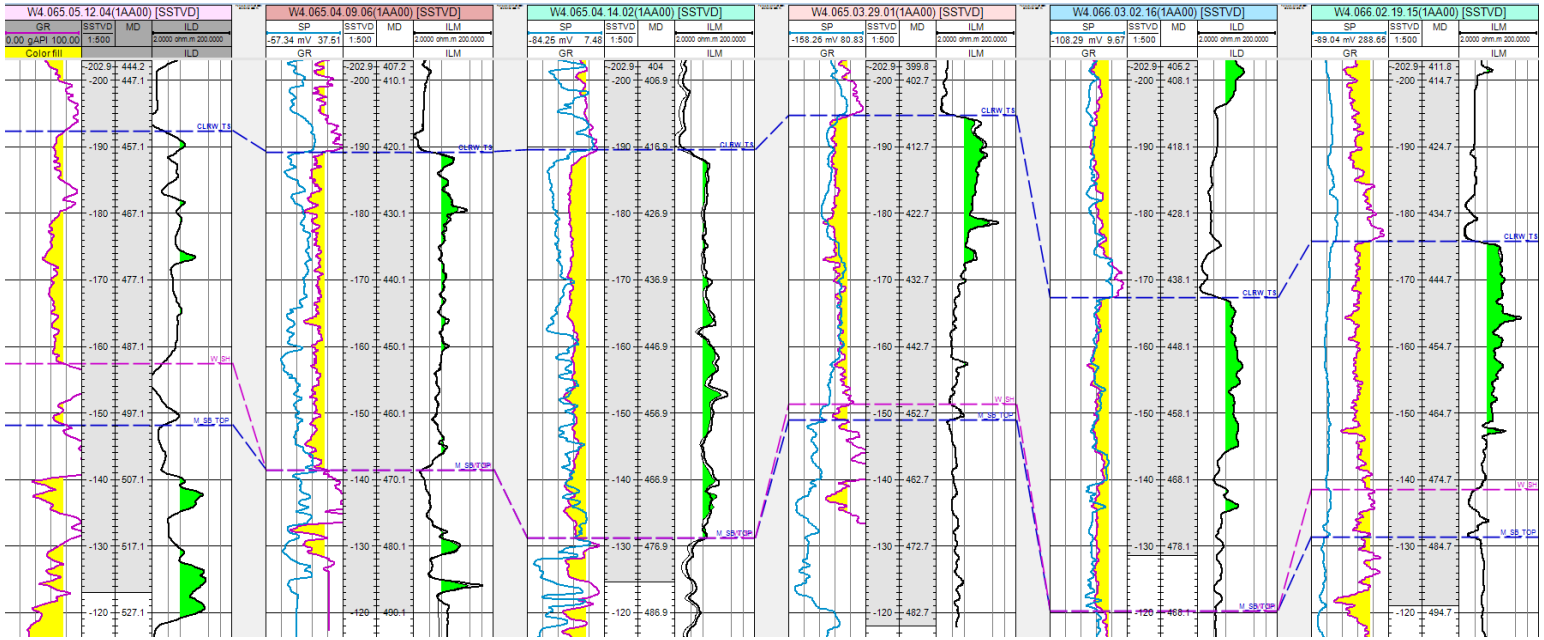
# Representative Structural Well Log Cross Section

Cross section represents stratigraphic and structural variability within the Clearwater Formation from southwest to northeast.




- **Cold Lake Leases**
- **Approved project boundary**
- **Developed pads**
- **Grand Rapids project boundary**

B




B'



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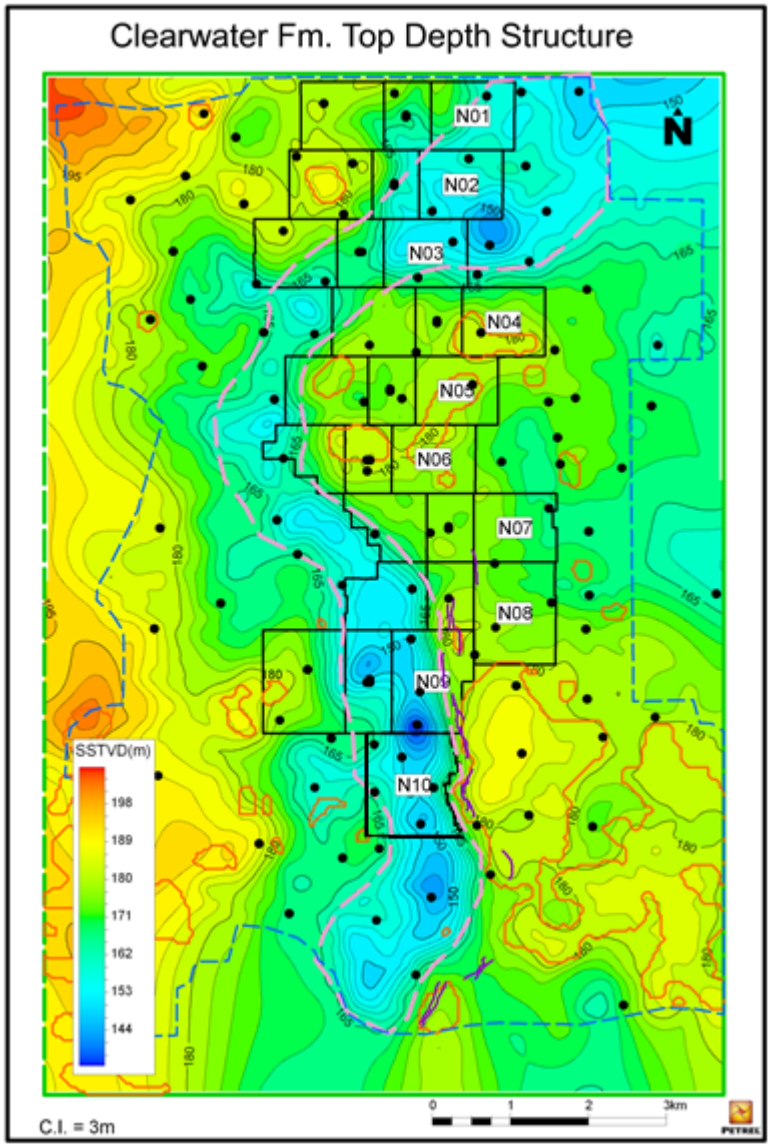
# Nabiye: Top Clearwater Structure

**Map illustrates:**

- Depth (Elevation) of the Top Clearwater Formation across the greater Nabiye Development area
  - Clearwater Top structure map integrates 3D seismic surveys and all well data
  - Significant structural change from 200 m asl to 140 m asl due to underlying salt dissolution of Paleozoic evaporites
  - Salt dissolution in the area occurred pre-, syn- and post-deposition of the Mannville Group
  - Structural deformation generated extensional faults within the Clearwater, Grand Rapids, and lower Joli Fou formations along the southeastern edge of the salt-dissolution valley
- Presence of top gas/water areas
- Distribution of the OV wells used in GeoModel
- Current production pads

- Cored OV Wells used in updated GeoModel
- Production Pads N01-N10
- Seismic Surveys combined outline (3D)
- Top Gas/Water Areas (From Seismic and Wells)
- Salt Dissolution
- Faults in Clearwater Formation



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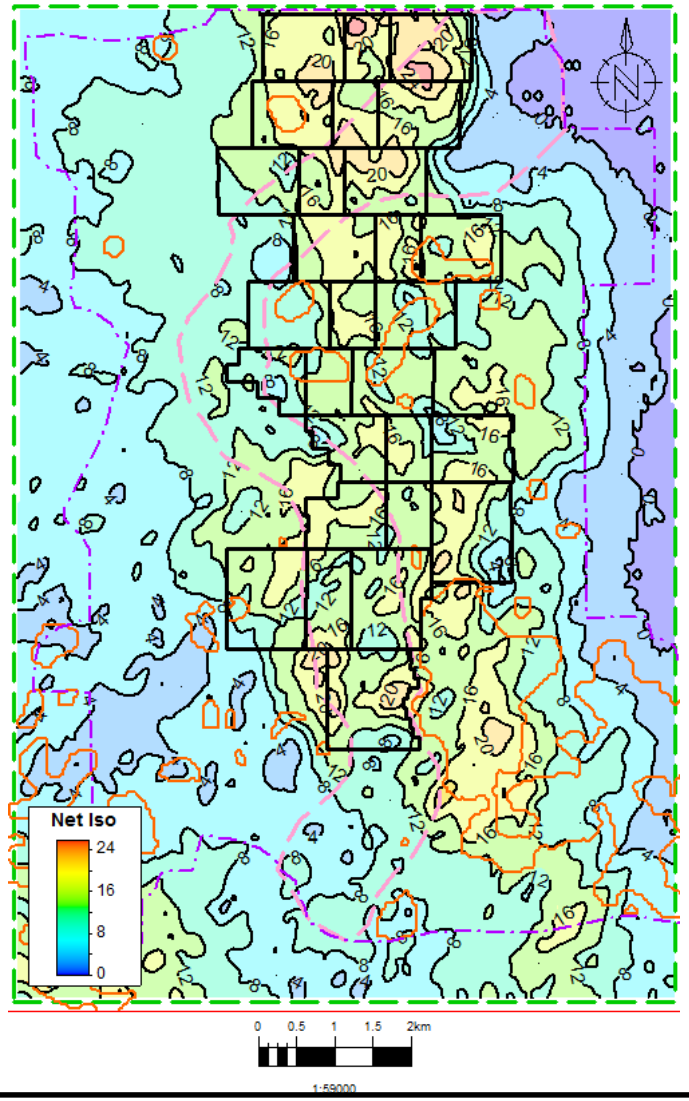
# Nabiye: Isopach of Net Effective Bitumen Pay

**Map illustrates:**

- Distribution of Net Effective Pay Thickness across the greater Nabiye Development area
  - Calculated from well top picks (top and base effective pay) that account for top gas/water and bottom water standoff
  - Effective Pay defined as >8 wt% bitumen saturation; thin pay not included
- Current production pads
- Presence of top gas/water areas
- Salt Dissolution Feature

Production Pads N01-N10
Seismic Surveys combined outline (3D)
Top Gas Areas (From Seismic and Wells)
Salt Dissolution

Clearwater Net Effective Pay (>8wt%) Thickness



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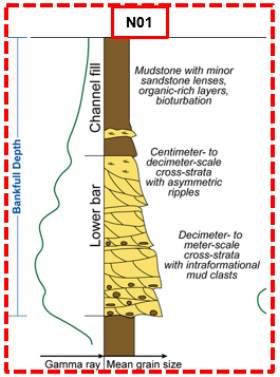
# Nabiye: Geoscience Summary & EOD Interpretation

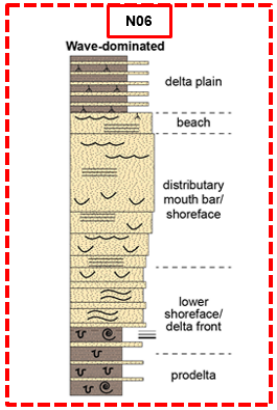
Nabiye genetically related to older deltaic “A” units rather than younger fluvial “D” units

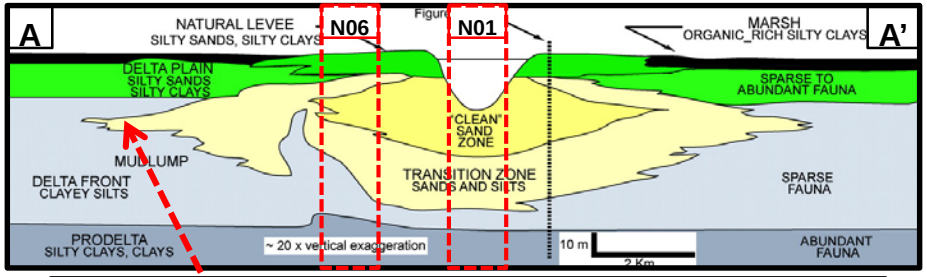
Nabiye subdivided into 3 main Geobodies (*A6a; A6b; Regional Deltaics*):

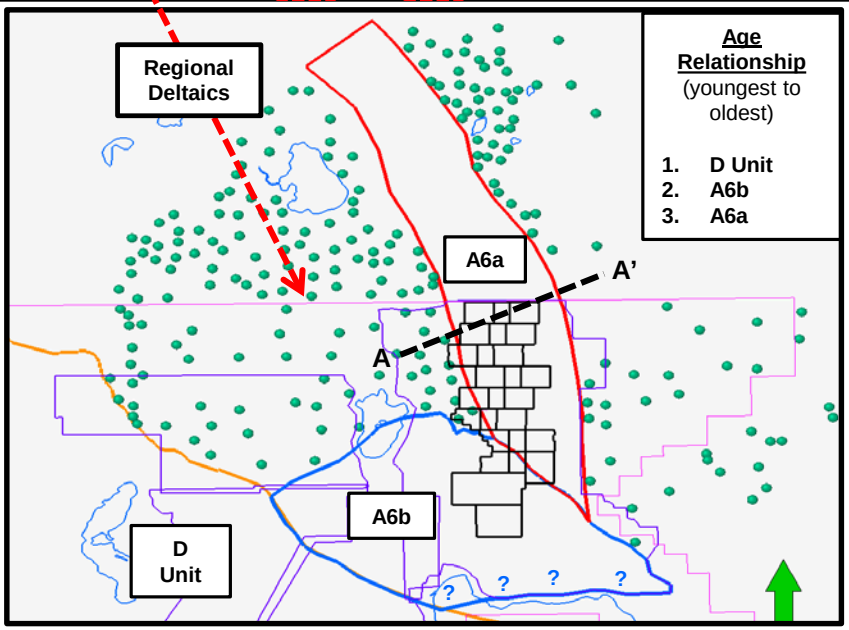
Age-relationships resolved and tied to OSC framework based on cross-cutting relationships

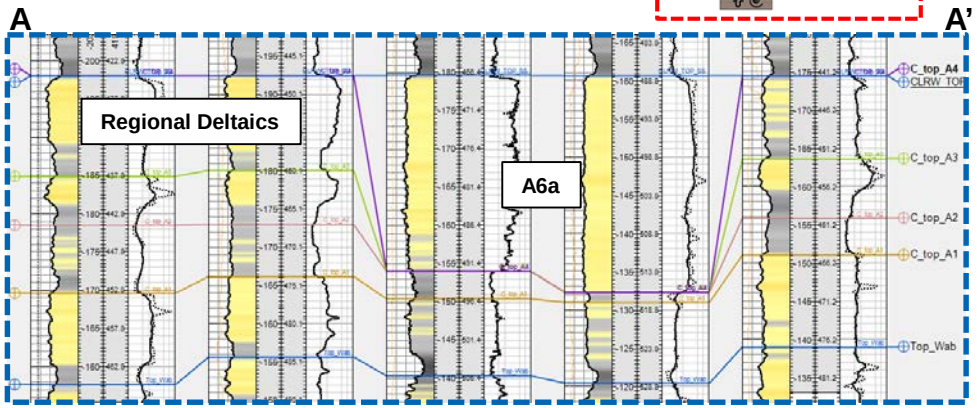
Reservoir differences may represent down-dip and lateral facies changes relative to the main axis of deposition within individual lobes (*e.g. distributary channel vs. terminal distributary channel/mouth-bar vs. proximal and distal delta-front EODs)*




Well log cross section datumed on Top Clearwater surface displaying the internal stratigraphy across Nabiye field (pad N01/N02 area)



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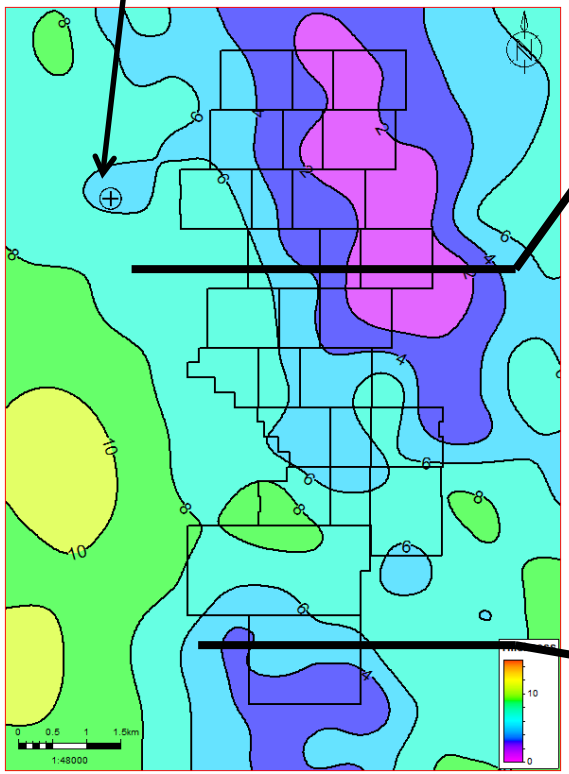
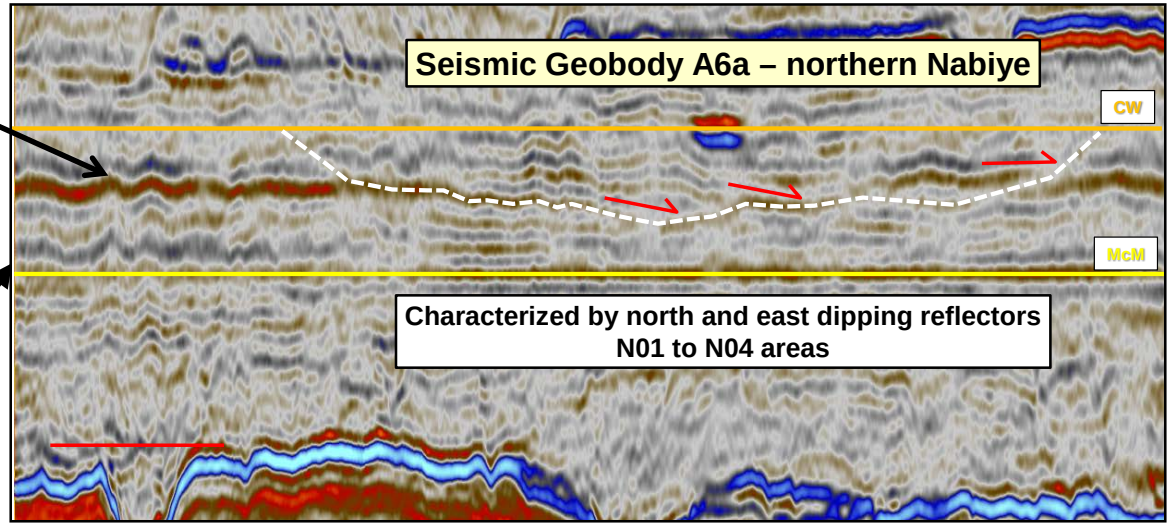
# Nabiye: Geobodies Seismic Mapping

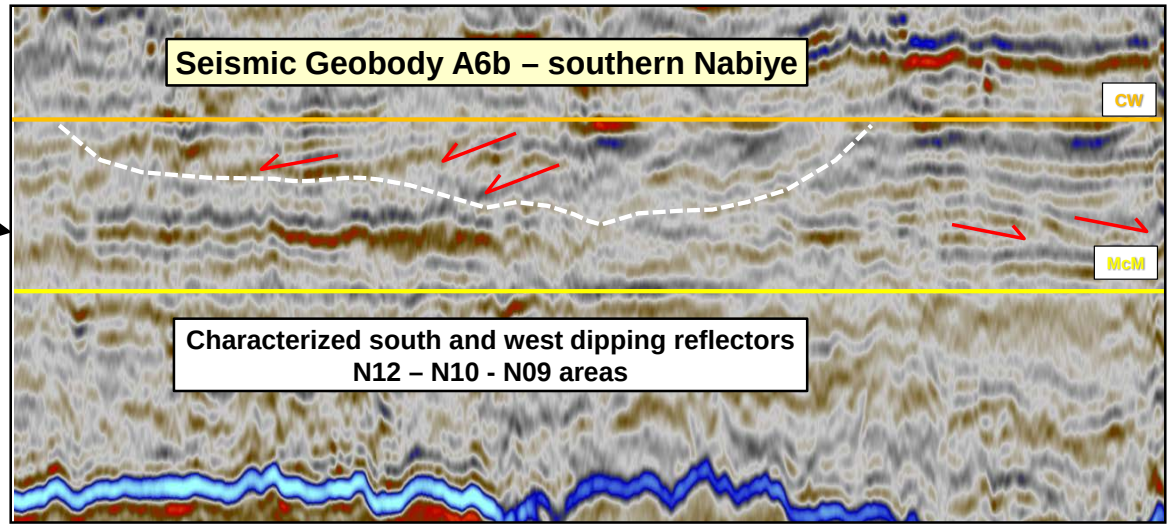
**Regional Deltaics**

**A2 Isopach**




**Time Seismic Volume Double-flattened on Clearwater and McMurray Tops**



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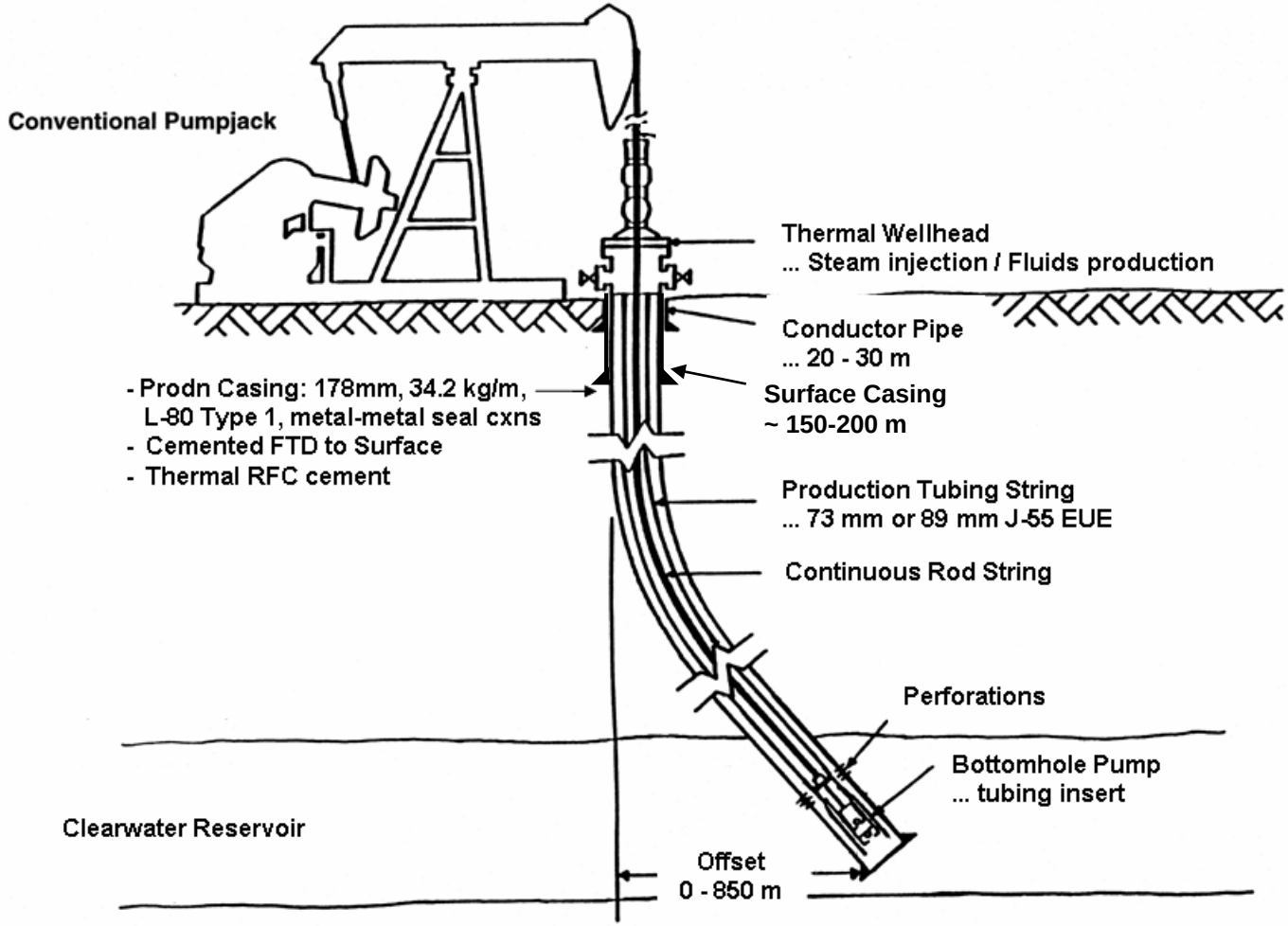
# Drilling and Completions

# Typical Deviated CSS Well Design



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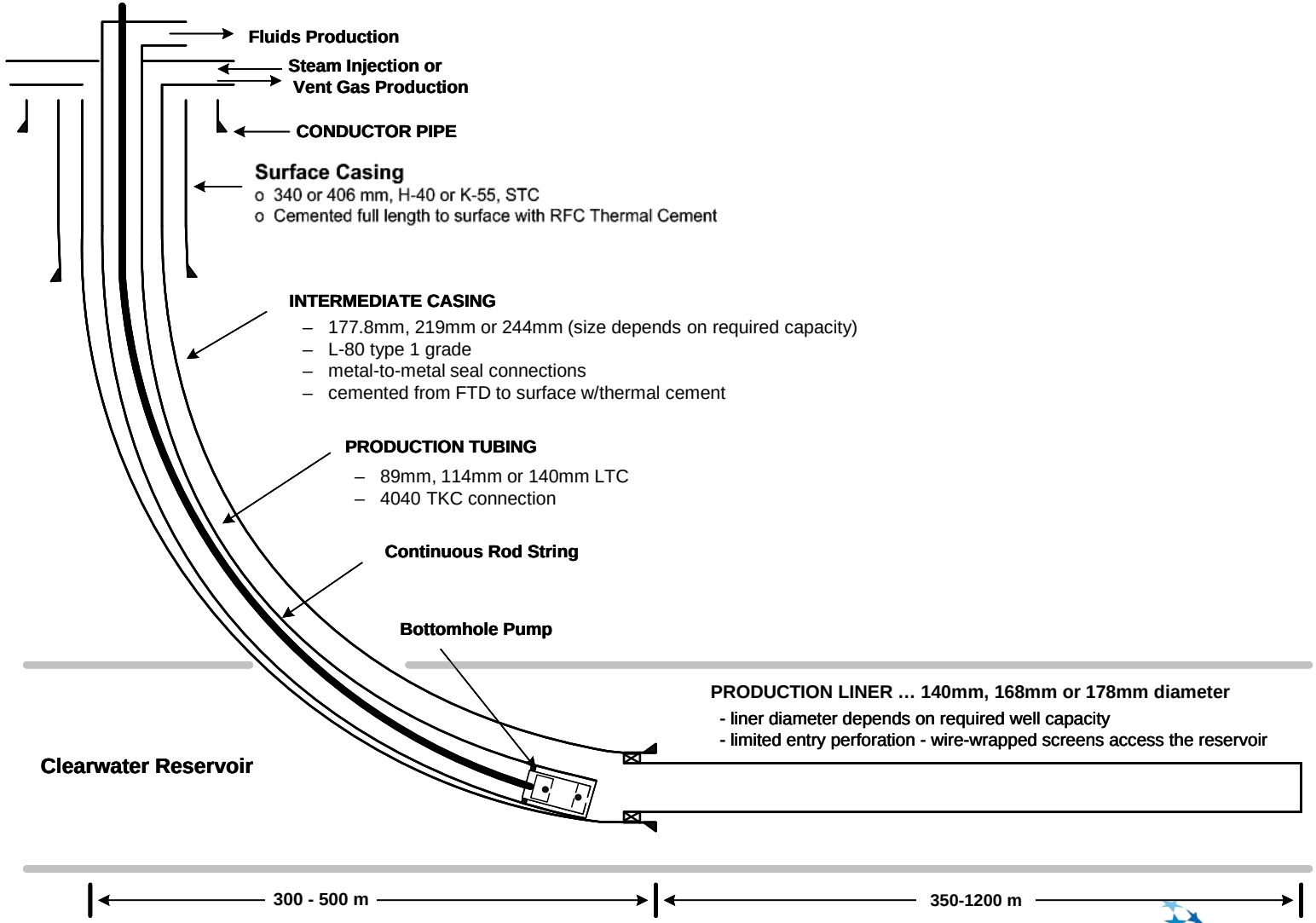
# Horizontal CSS or HIP Well Design



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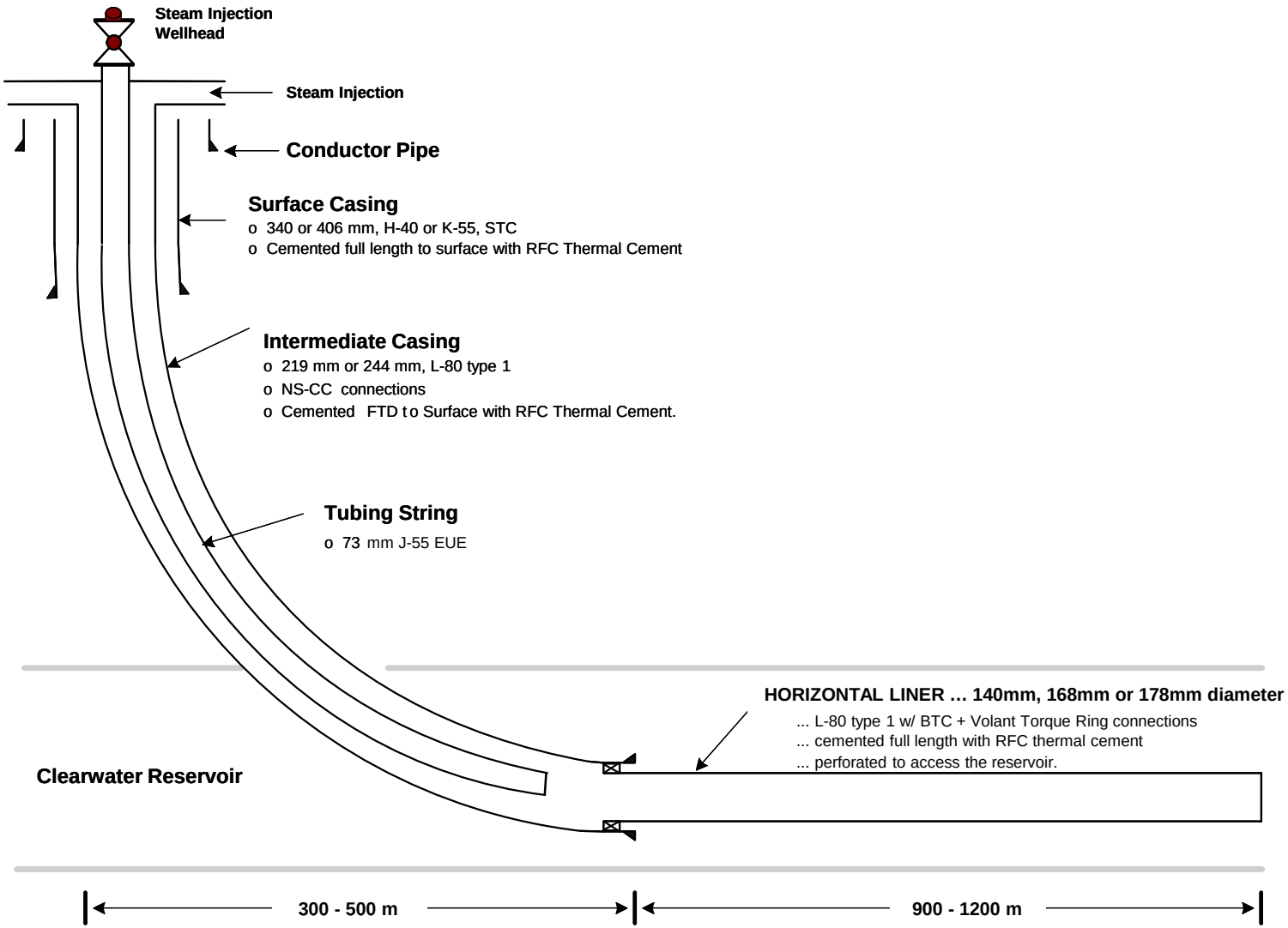
# Horizontal Steam Injection Well Design



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# Artificial Lift

# Artificial Lift

| Pumpjack | Bottom Hole Pump | Speed | Design Rate |
|---|---|---|---|
| 160 - 173 - 86 | 50.8 mm | 7 SPM | 38 m3/d |
| | | 11 SPM | 60 m3/d |
| | | 16 SPM | 87 m3/d |
| 228 - 173 - 86 | 63.5 mm | 7 SPM | 60 m3/d |
| or | | 11 SPM | 93 m3/d |
| 320 - 213 - 86 | | 16 SPM | 135 m3/d |
| 456 - 213 - 144 | 63.5 mm | 4 SPM | 55 m3/d |
| | (long stroke) | 7 SPM | 100 m3/d |
| | | 14 SPM | 200 m3/d |
| 912 - 305 - 192 | 82.6 mm | 4 SPM | 130 m3/d |
| | | 7 SPM | 225 m3/d |
| | | 11 SPM | 350 m3/d |
| 1280 - 305 - 240 | 95.3 mm | 4 SPM | 210 m3/d |
| | | 7 SPM | 370 m3/d |
| | | 10 SPM | 530 m3/d |
| 1824-365-240 | 108 mm | 4 SPM | 250 m3/d |
| | | 7 SPM | 450 m3/d |
| | | 10 SPM | 640 m3/d |

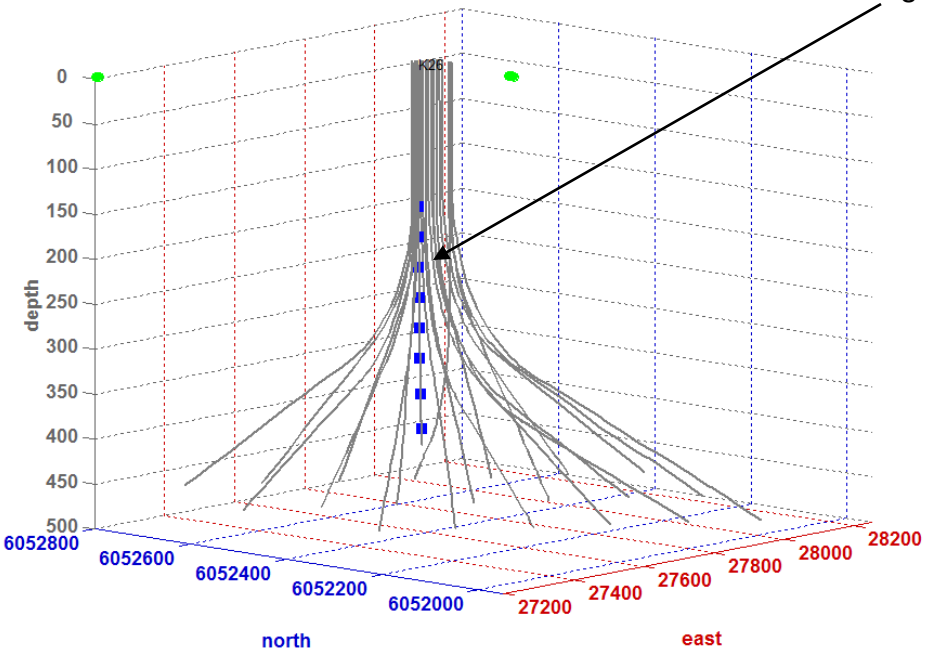
- Insert rod pumps used across field
- Size of lift system depends on:
  - Offset to reservoir target
  - Well deliverability: deviated versus horizontal wells
- Operating Conditions
  - Pumping temperature 75 – 220°C
  - Pump Intake pressure 6 MPa to less than 500 kPa
  - Average run life of rod pumps is between 350-450 days
- Corpac Variable Frequency Drive (VFD) Program
  - Installing VFD's on all new producing wells
  - Using VFD controllers for inferred measurement, speed control, pumping unit shutdown and optimization

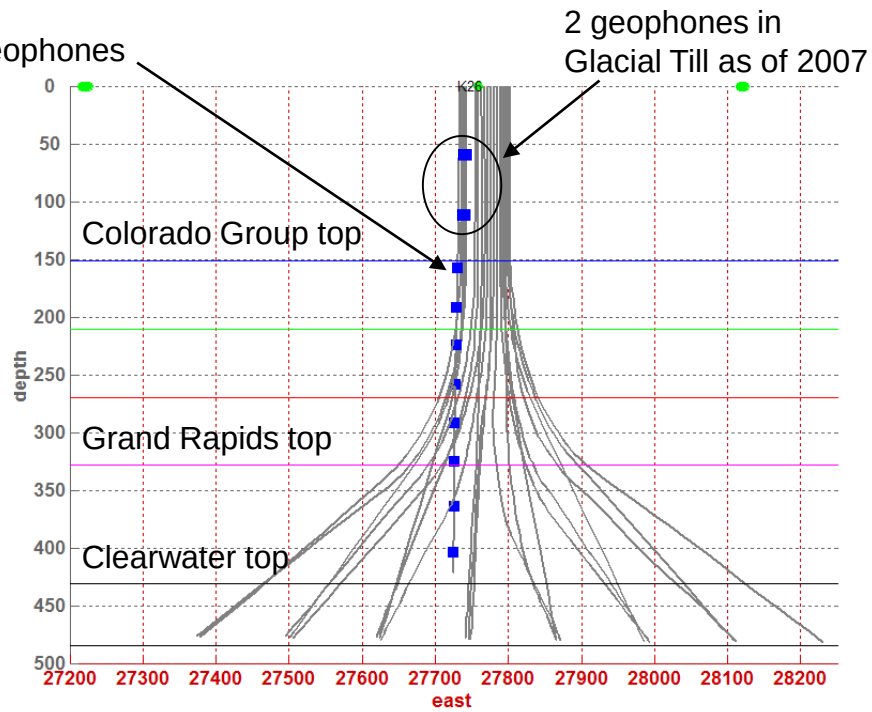
# Instrumentation in Wells

# Instrumentation in Wells

- A passive seismic well with permanent omnidirectional geophones is installed at all new high pressure pads at Cold Lake since 1998
- Seismicity is monitored to detect fluid incursion and casing failures in uphole zones

**Typical Passive Seismic Configuration**



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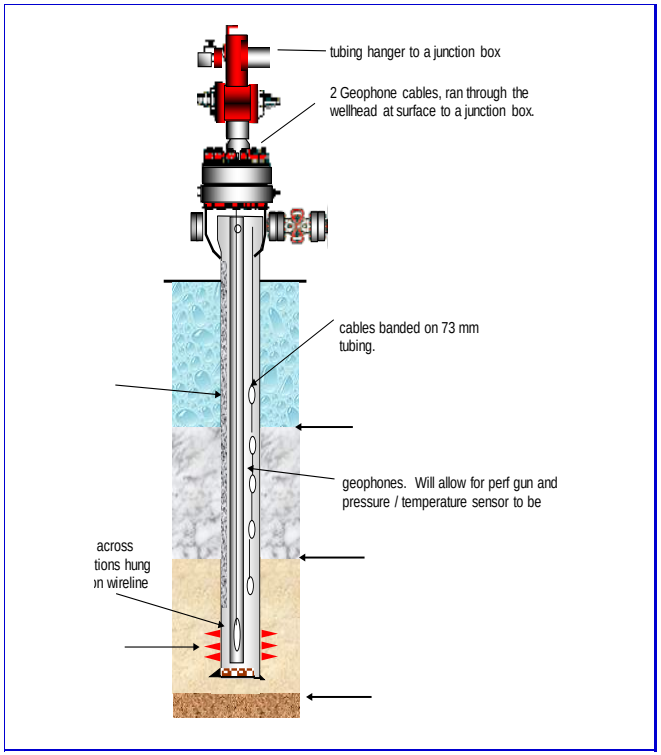
# Instrumentation in Wells

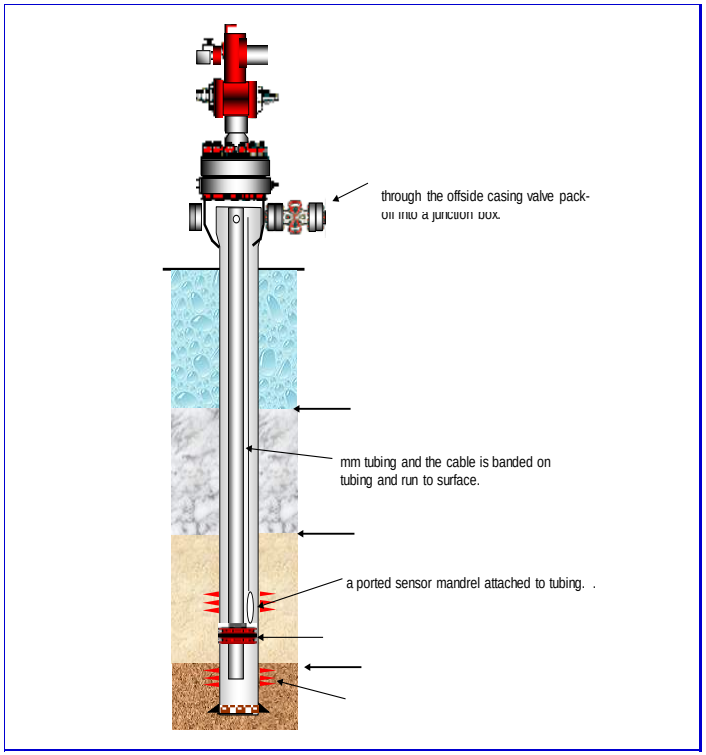
### Hybrid Passive Seismic Well

- A hybrid Passive Seismic well design allows pressure monitoring in the Grand Rapids and passive seismic monitoring with cemented geophones in the same well.




### Grand Rapids Pressure Monitoring Well

- There are several wells in the field used to monitor Grand Rapids pressure. These wells often monitor more than one interval. The configuration below provides pressure monitoring in one Grand Rapids interval and one Clearwater interval.



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# Well Integrity

# Well Integrity Measures and Mitigations

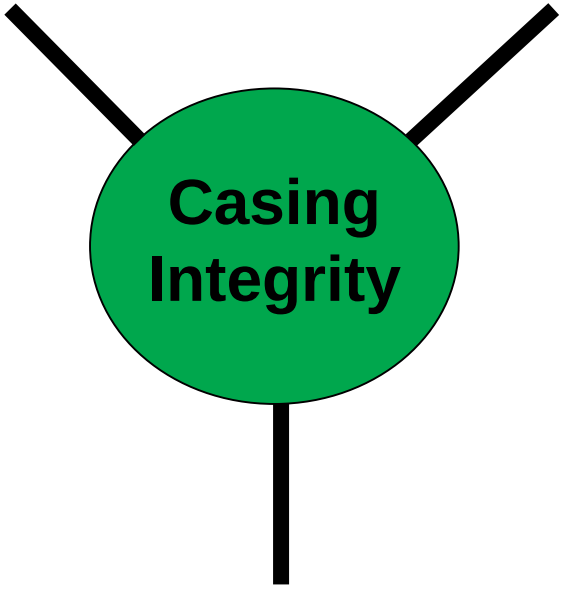
Well Integrity managed with strong Prevent, Detect, Respond & Respond processes.

**Prevention**

- Well Design & Construction Best Practices
- Well Operation & Inspection Best Practices
- Well Casing Repairs

**Detection**

- Multiple, complimentary automated monitoring systems




**Response & Recovery**

- Defined Protocols for Assessing and Controlling Consequences



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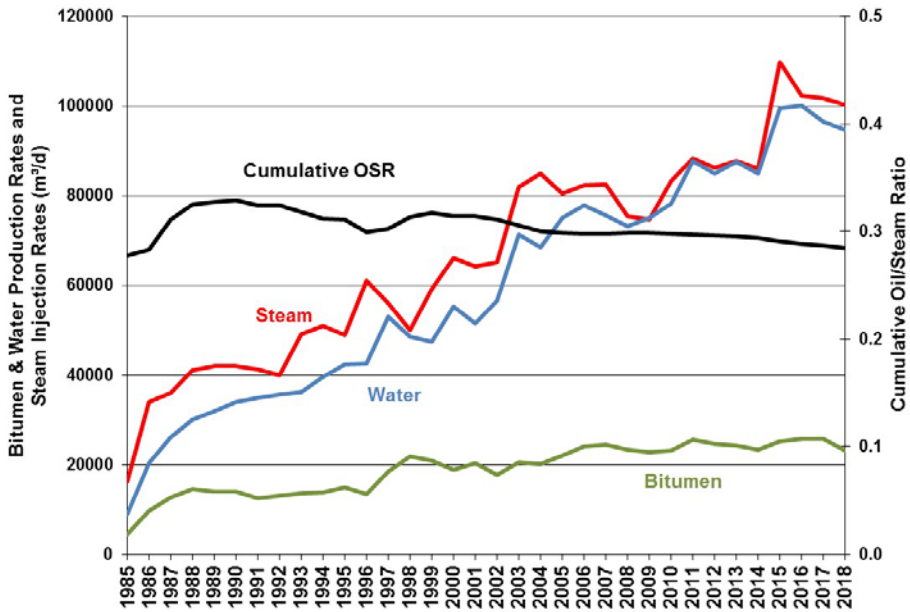
# Scheme Performance

# Cold Lake Recovery Determination

- Bitumen recovery from the CSS process in the Clearwater zone is a function of effective pay thickness and bitumen saturation
- Effective pay and bitumen saturations are determined from facies based descriptions of logs and cores obtained from the Clearwater zone at an 8 wt% cutoff
  - Shale and clay content are considered in the determination of effective pay
- Recovery predictions are based on performance type curves derived from field performance and reservoir simulation
- Adjustments are made for other factors impacting recovery such as:
  - Bottom water
  - Clearwater gas cap
  - Split pay
  - Adjacent reservoir depletion
  - Well spacing

# Cold Lake Production Performance

## Cold Lake Approval 8558 Area Production




- Maximum daily bitumen production under approval 8558 is 40,000 $m^3$/d

| | Bitumen Production $10^3$ $m^3$/d | Steam Injection $10^3$ $m^3$/d | Cumulative | |
|---|---|---|---|---|
| | | | OSR | SOR |
| 2017 | 25.8 | 101.8 | 0.29 | 3.5 |
| 2018 YTD Sep | 23.1 | 100.3 | 0.28 | 3.5 |

Notes
- Production data includes CSP and SA-SAGD pilot projects
- SOR on wet steam basis



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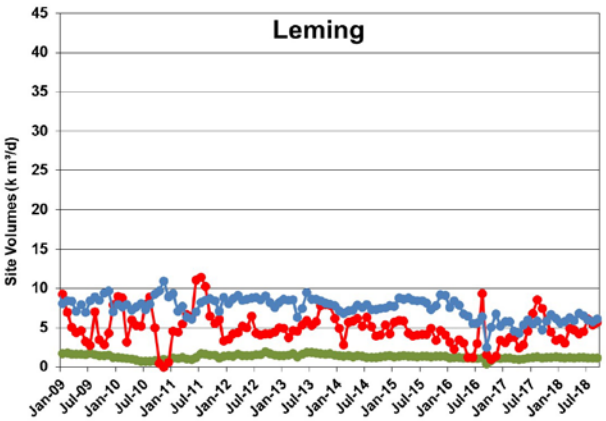
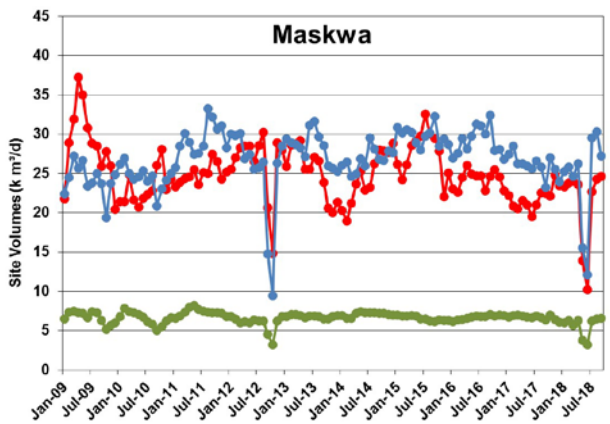
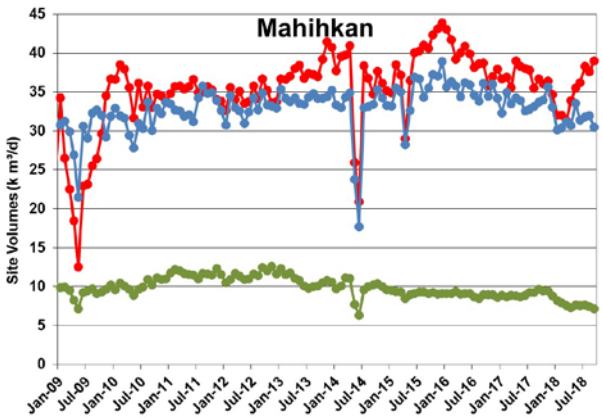
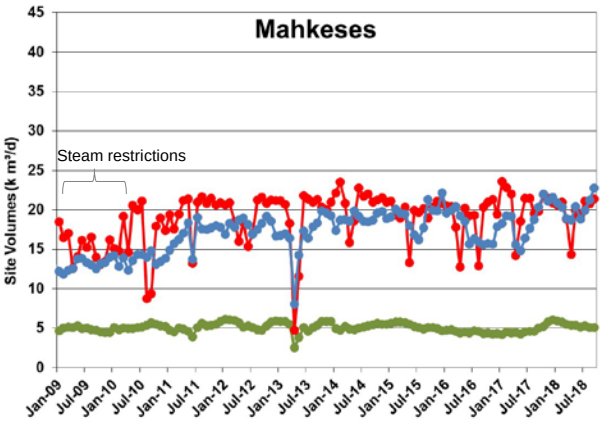
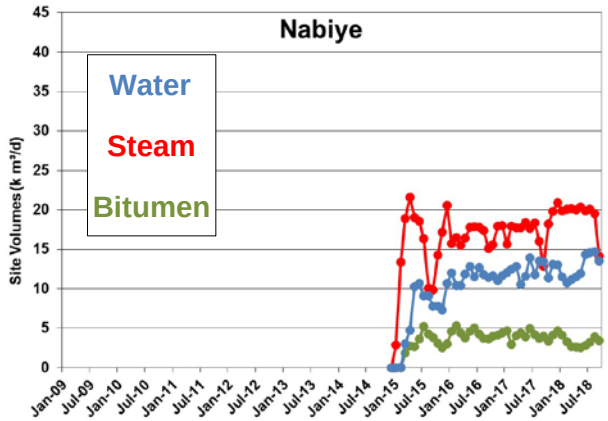
# Individual Site Performance




| Plant | 2018 Average | |
|---|---|---|
| | OSR | SOR |
| Leming | 0.25 | 4.0 |
| Maskwa | 0.28 | 3.6 |
| Mahihkan | 0.23 | 4.4 |
| Mahkeses | 0.24 | 4.1 |
| Nabiye | 0.17 | 6.1 |

**Steam Transfers ($10^3$ $m^3$)**

| | | |
|---|---|---|
| **Maskwa to Mahihkan:** | **530** | **D04 Infills (Oct 2017 – Sep 2018), A06 Infills (Oct 2017 – Sep 2018)** |
| **Mahihkan to Maskwa:** | **63** | **J10 Infills (Oct 2017 – Dec 2017, Jun 2018 – Sep 2018)** |
| **Leming to Maskwa:** | **906** | **0FF Infills (Oct 2017 – Sep 2018), 00U Infills (Oct 2017 – Sep 2018)** |
| **Mahkeses to Leming:** | **919** | **T05 Infills (Oct 2017 – Sep 2018)** |



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# Abandonment Outlook

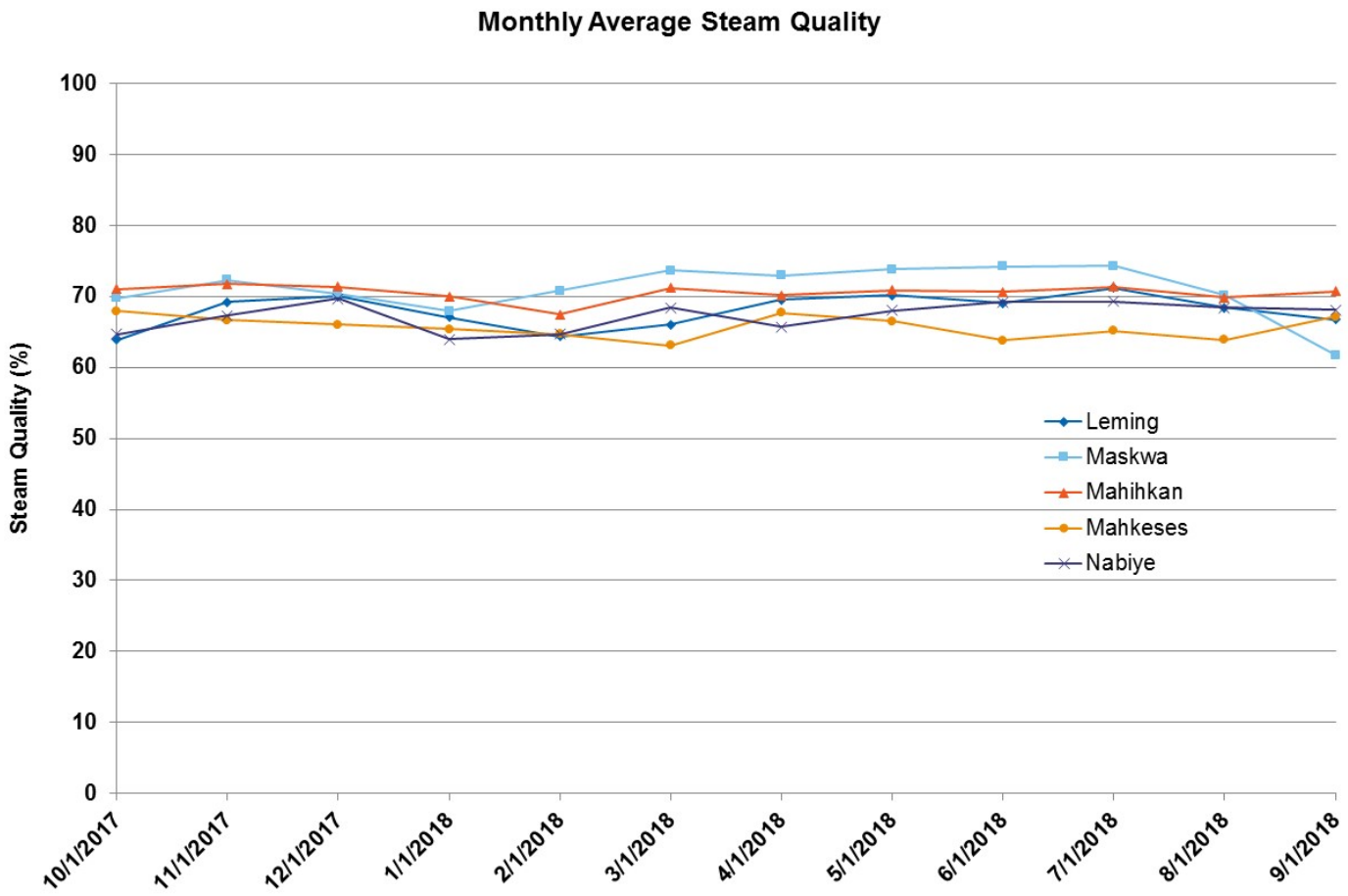
- 5 year outlook for pad abandonment
  - 'Flow Behind Pipe' assessment (inc. E07 pad testing) confirms hydraulic isolation behind casing on Cold Lake wells.
  - Assessment also demonstrates that post-steam cement bond logs do not reflect degree of hydraulic isolation behind casing
  - Aquifer isolation study completed in 2016 confirms that isolation of aquifers at the time of full subsurface abandonment is not necessary
  - E07 pad wells have been fully abandoned except for two wells which have been retained for monitoring of adjacent D29 pad high pressure steaming operations
  - CC/GG pad abandonment progressed; 43 wells fully or partially abandoned, targeted to have subsurface abandonment complete by year end 2018
  - DD, Q and S pad scheme approval in place, abandonments to follow CC, GG
  - Discontinue monitoring for Q-01 approved by AER in 2016
  - B03 pad abandonment progressed, 18 wells partially abandoned, 2 fully subsurface abandoned, remainder will continue 2019+
  - 20 Shale monitoring wells in low pressure areas as per AER approval abandonments progressed, 14 fully subsurface abandoned, remainder will continue 2019+
  - Pads with support from adjacent pads will continue operation
- Individual wells that are uneconomic will be zonally abandoned to meet Directive 13:
  - 11 individual wells had appropriate abandonment work completed in 2018

**Pads not steamed in prior 48 months**

| Pad | Plans |
|---|---|
| 00N | Operating as water storage pad |
| 00Q | All wells zonally abandoned in the Clearwater |
| 00S | All wells zonally abandoned in the Clearwater |
| 00U | Operating with support from adjacent pads |
| 00V | Operating with support from adjacent pads |
| 00W | Operating with support from adjacent pads |
| 0AA | Operating with support from adjacent pads |
| 0BB | Operating with support from adjacent pads |
| 0CC | Abandonment process started |
| 0DD | Abandonment process started |
| 0FF | Operating with support from adjacent pads |
| 0GG | Abandonment process started |
| 0HH | Operating with support from adjacent pads |
| 0LL | Operating with support from adjacent pads |
| A01 | Operating with support from adjacent pads |
| A02 | Operating with support from adjacent pads |
| A03 | Operating with support from adjacent pads |
| A05 | Operating with support from adjacent pads |
| B01 | Operating with support from adjacent pads |
| B02 | Operating with support from adjacent pads |
| B03 | Abandonment process started |
| B04 | Operating with support from adjacent pads |
| B05 | Operating with support from adjacent pads |
| B06 | Operating with support from adjacent pads |
| C03 | Operating with support from adjacent pads |
| C05 | Operating with support from adjacent pads |
| D26 | Operating with support from adjacent pads |
| D27 | Operating with support from adjacent pads |
| D52 | Operating with support from adjacent pads |
| D54 | Operating with support from adjacent pads |
| D55 | Operating with support from adjacent pads |
| D57 | Abandonment process started, all wells zonally abandoned |
| D66 | Abandonment process started, all wells zonally abandoned |
| E10 | Operating with support from adjacent pads |
| H03 | Operating with support from adjacent pads |
| H19 | Operating with support from adjacent pads |
| H24 | Operating with support from adjacent pads |
| H34 | Operating with support from adjacent pads |
| H36 | Operating with support from adjacent pads |
| J27 | Operating with support from adjacent pads |
| K24 | Operating with support from adjacent pads |
| L08 | Operating with support from adjacent pads |
| M03 | Operating with support from adjacent pads |
| M04 | Operating with support from adjacent pads |
| M06 | Operating with support from adjacent pads |
| P01 | Operating with support from adjacent pads |
| P02 | Operating with support from adjacent pads |
| P03 | Operating with support from adjacent pads |
| T11 | Operating with support from adjacent pads |

# Steam Quality

- Average district steam quality of 68% from Oct 2017 – Sep 2018



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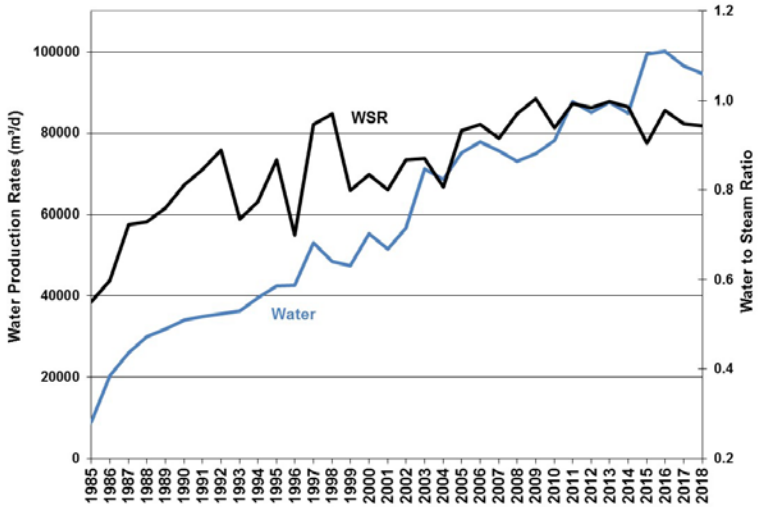
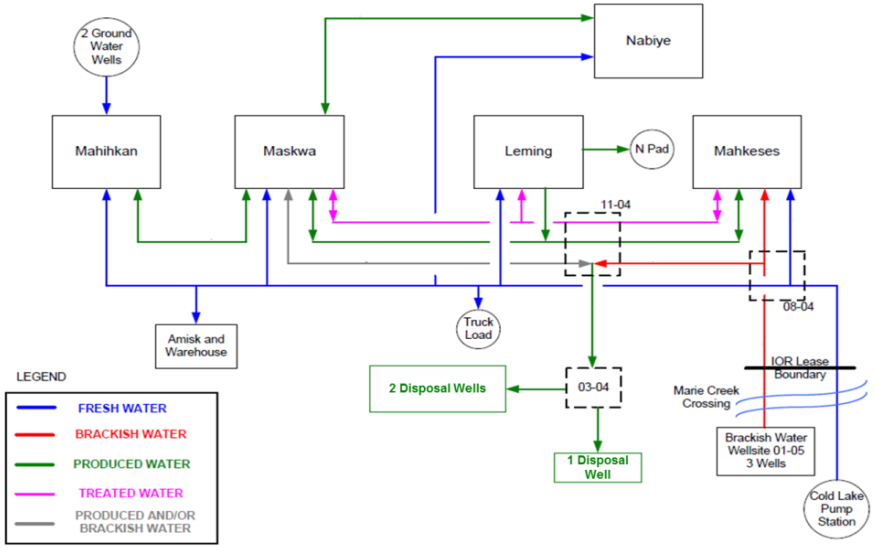
# Cold Lake Water Management

- **Cold Lake Water Production**
  - Water to steam ratio has increased as pads move into later cycle production (late life CSS / steamflood)
  - Typically field water deliverability is in excess of facility water handling capacity, requiring production shut-in

- **Operating Strategies**
  - Production shut-ins prioritized based on water to oil ratio to maximize oil production
  - Maximize steam injection quality
  - Minimize bringing water into the system
    - Freshwater and brackish water
  - Utilize out of zone disposal

**Cold Lake Water Production**



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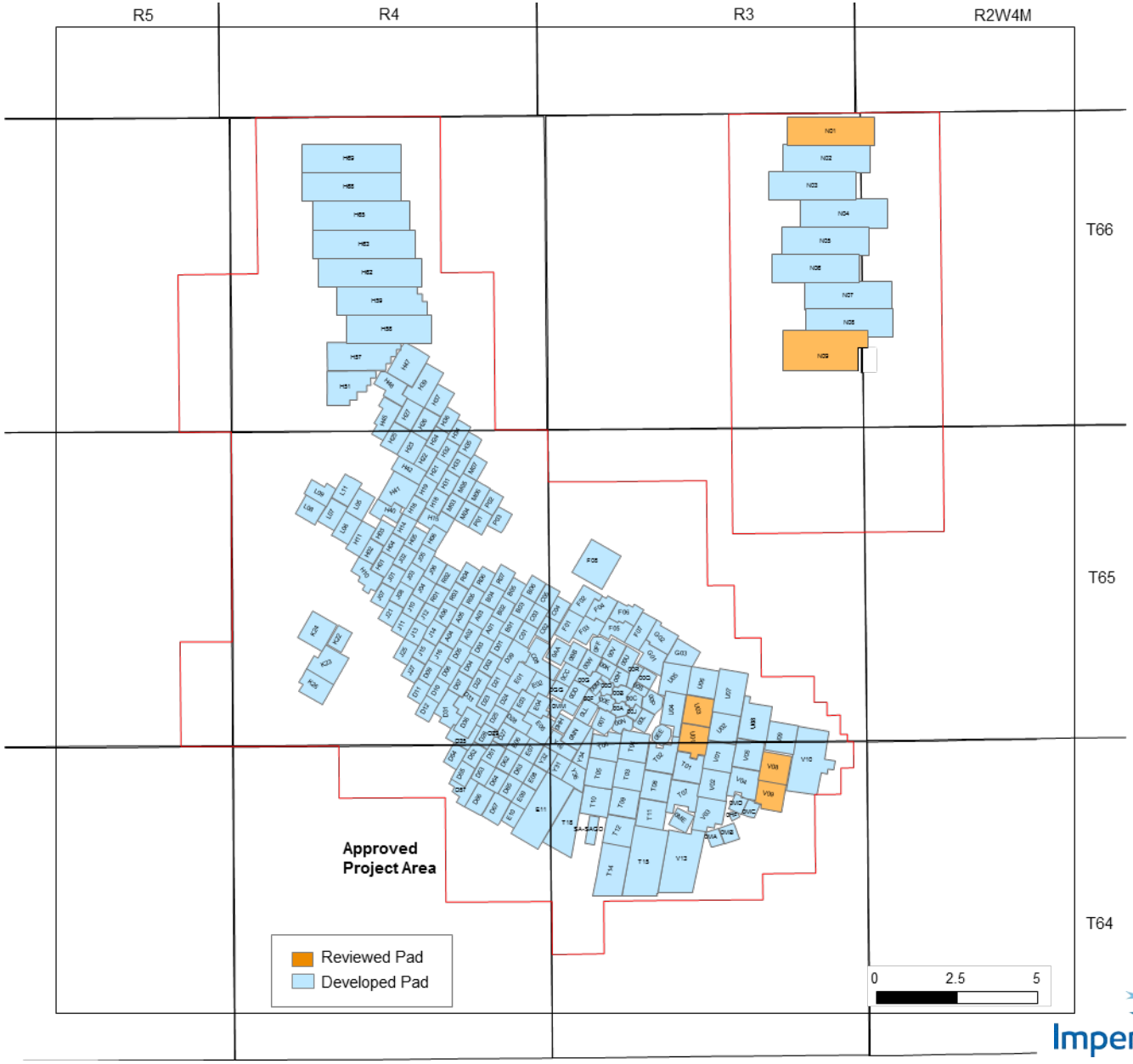
# Pad Performance Reviews



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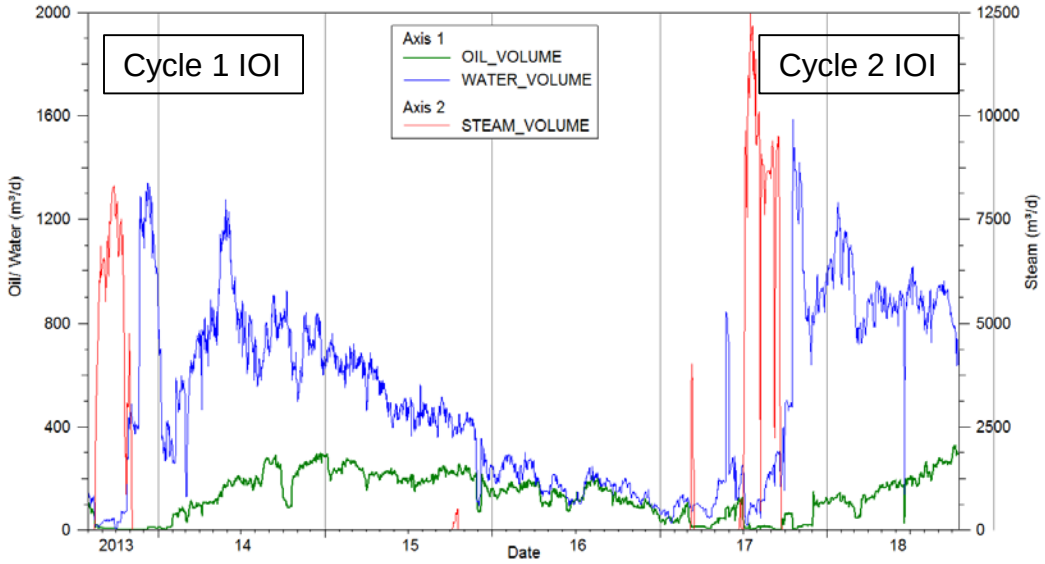
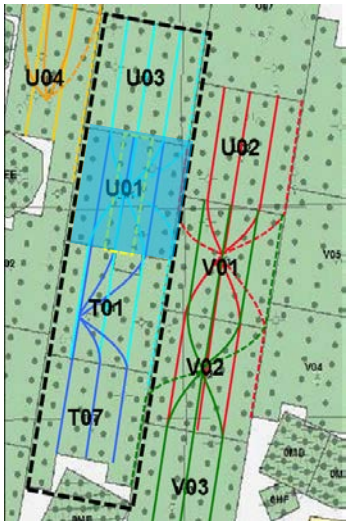
# Mahkeses T01 IOIs under U01 Pad

- U01 is an 8 acre 25 well pad infilled by T01 Injector-Only-Infills (IOIs)
- Cycle 1 IOI steamed August – November 2013
  - Steamed fill-up volume through CSS wells, over fill-up volume through IOIs
  - Cycle 1 OSR performance as expected
- Cycle 2 IOI steamed June – September 2017
  - Steamed fill-up and over fill-up volume through both CSS wells and IOIs
    - Greater steam volume injected into IOIs in Cycle 2 vs Cycle 1
  - Oil ramp continues, peak production rate expected to be greater than in Cycle 1

**U01 Pad & T01 IOIs under U01**




**Pad Layout**



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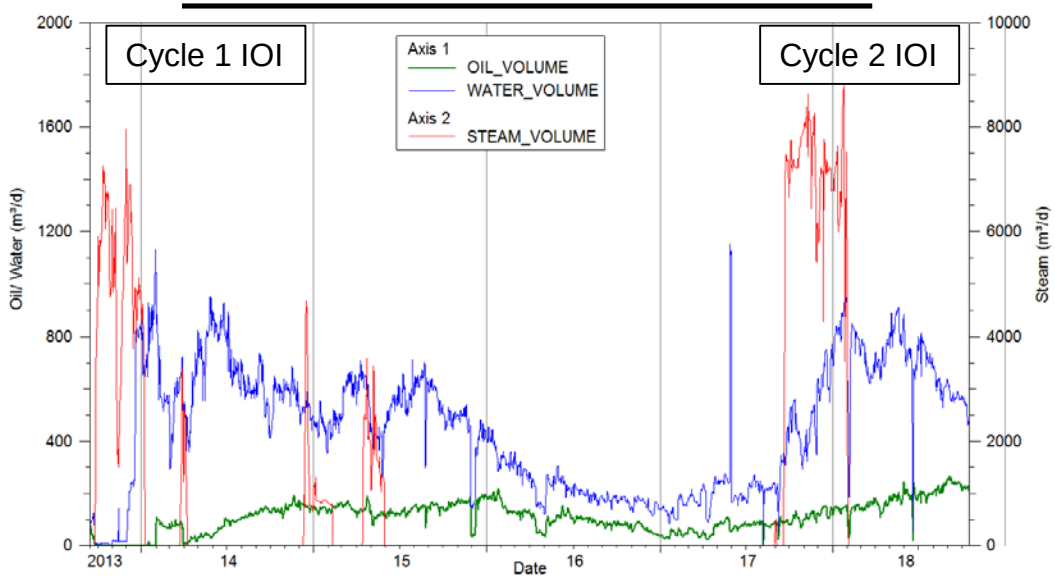
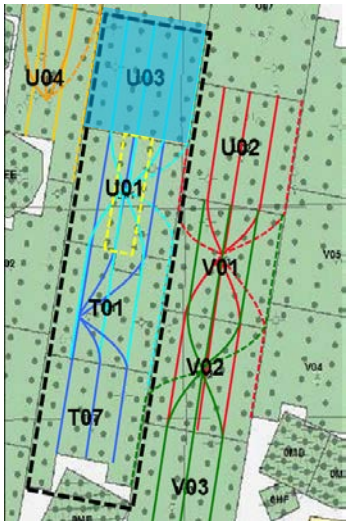
# Mahkeses U01 IOIs under U03 Pad

- U03 is an 8 acre 24 well pad infilled by U01 Injector-Only-Infills (IOIs)
- Cycle 1 IOI steamed September 2013 – January 2014
  - Steamed fill-up volume through CSS wells, over fill-up volume through IOIs
  - OSR performance below expectation
- Cycle 2 IOI steamed September 2017 – February 2018
  - Steamed through IOI wells only, CSS wells did not steam
  - Oil ramp began earlier in the cycle and peak production rate was greater vs. Cycle 1 performance

**U03 Pad & U01 IOIs under U03**




**Pad Layout**



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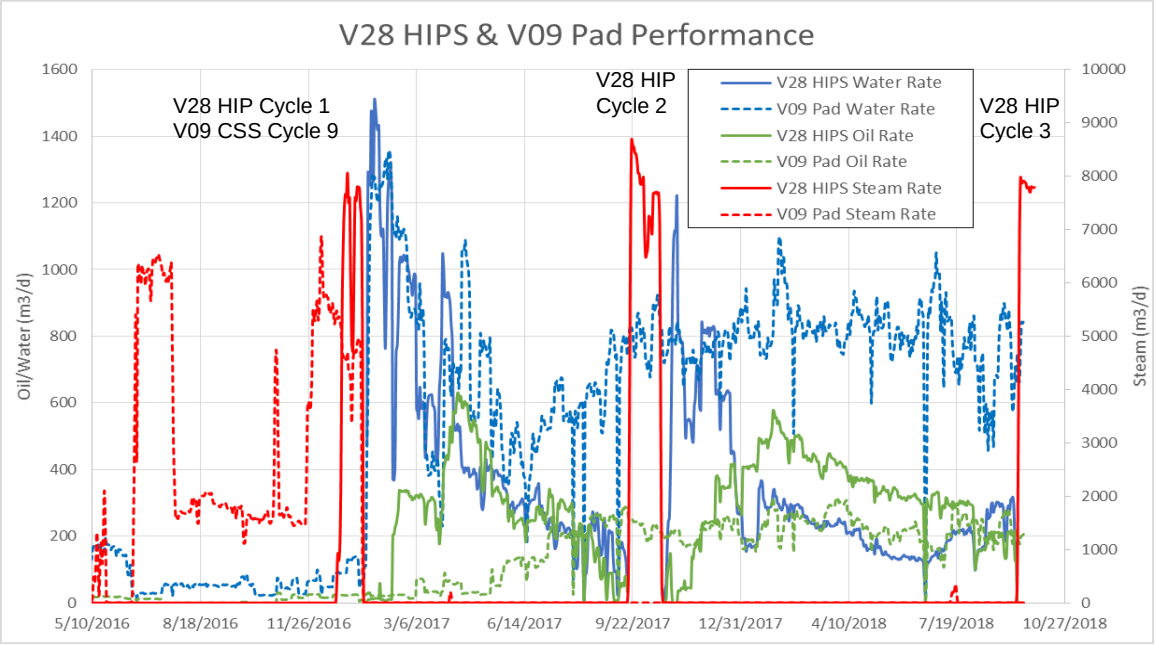
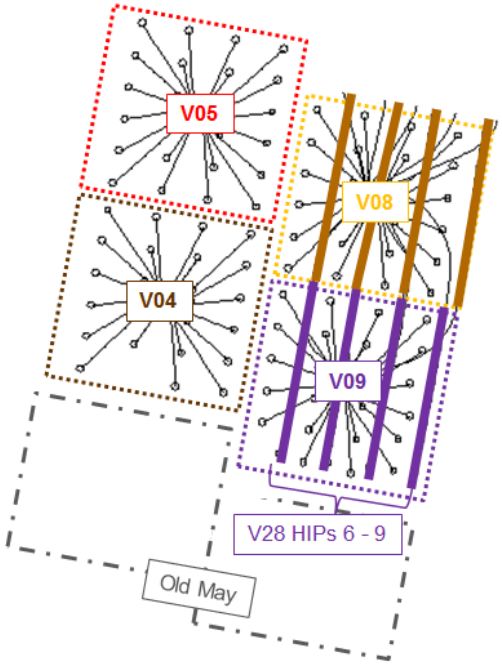
# Mahkeses V28 HIPs under V09 Pad

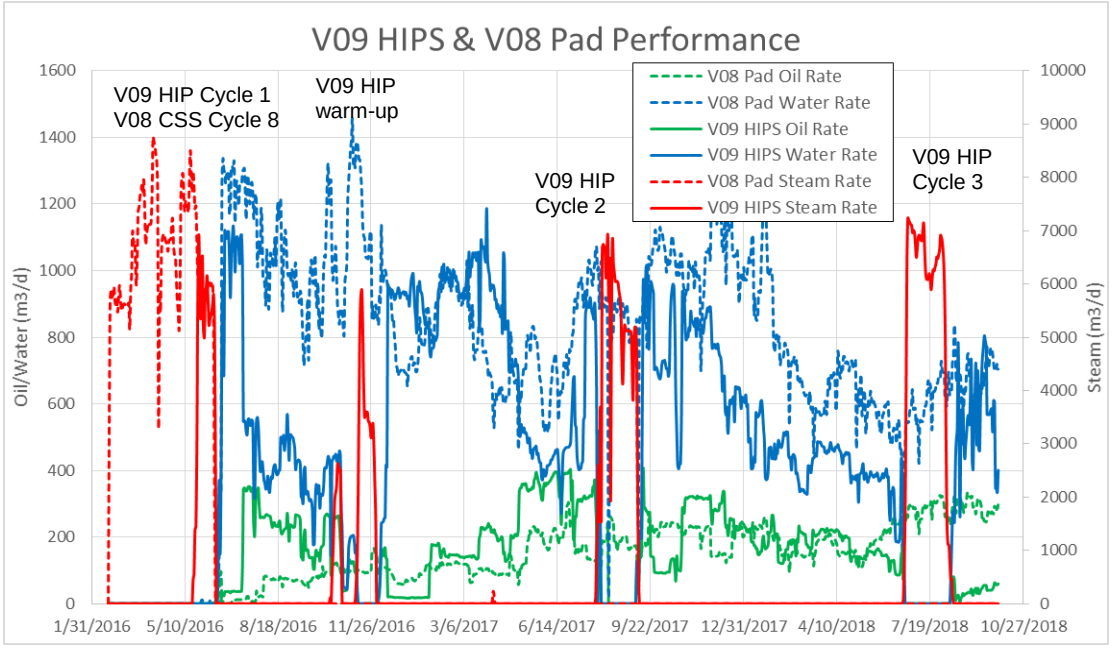
- V09 is an 8 acre 23 well pad infilled by V28 HIPs
- HIP Cycle 1 steamed in December 2016 to January 2017
  - Steamed concurrently with V09 Pad Cycle 9
  - V09 Pad performance on track with Cycle 9 expectations
  - V28 HIPs reflect early-cycle performance vs. mature cycle performance of base CSS pad
- HIP Cycle 2 steamed in September to October 2017
  - Steam injected into HIP wells only to better reflect cycle timing of early-cycle wells
  - V09 Pad production is holding steady since oil ramped post HIP Cycle 1 steam
  - V28 HIPs continue to perform as an early cycle pad
- HIP Cycle 3 steamed September to October 2018

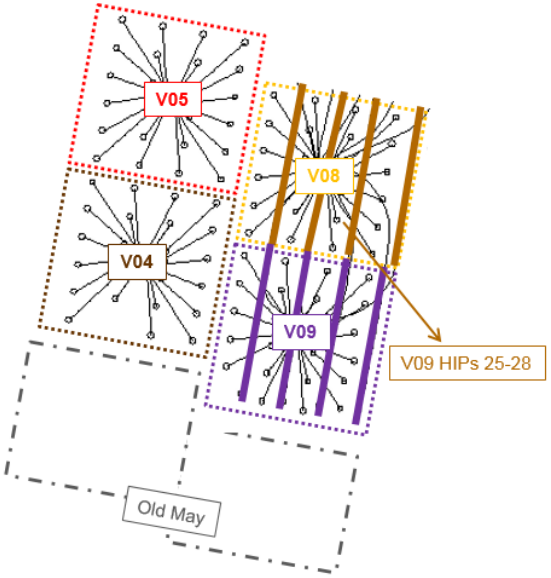


# Mahkeses V09 HIPs under V08 Pad

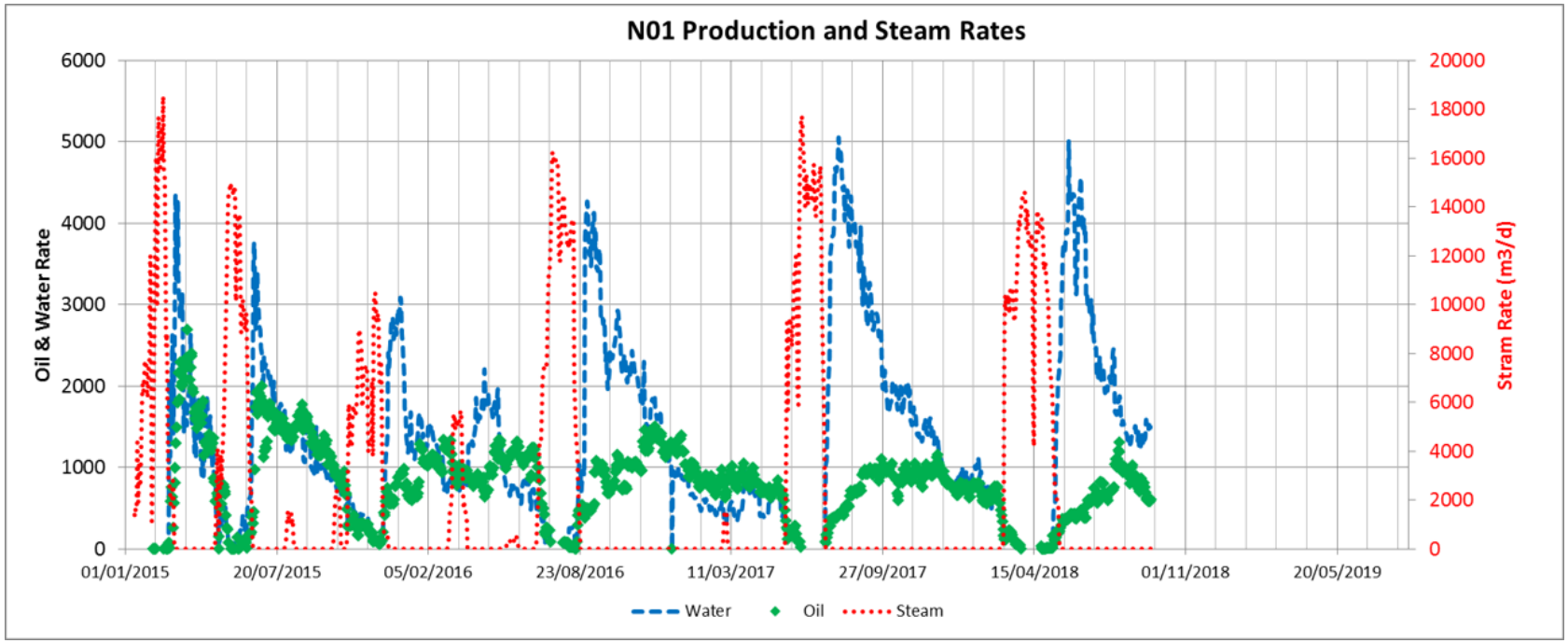
- V08 is an 8 acre 24 well pad infilled by V09 HIPs
- HIP Cycle 1 steamed in May to June 2016
  - Steamed concurrently with V08 Pad Cycle 9
  - V08 Pad performance on track with Cycle 9 expectations
  - V09 HIPs reflect early-cycle performance vs. mature cycle performance of base CSS pad
- HIP Cycle 2 steamed in July to September 2017
  - Steam injected into HIP wells only to better reflect cycle timing of early-cycle wells
  - V08 Pad production is continuing to ramp since combined V08 and V09 HIP Cycle 1 steam
  - V09 HIPs continue to perform as an early cycle pad
- HIP Cycle 3 steamed June to August 2018



# Nabiye N01 Pad

- Nabiye N01 is a 24 well pad (16 deviated, 8 horizontal), accessing 70 bottom-hole locations on 8 acre spacing
- Currently in the production phase of cycle 6
- Steam volumes have been reduced from Cold Lake best practices to manage pressure responses in the Grand Rapids
- Production performance is typical for CSS at Cold Lake



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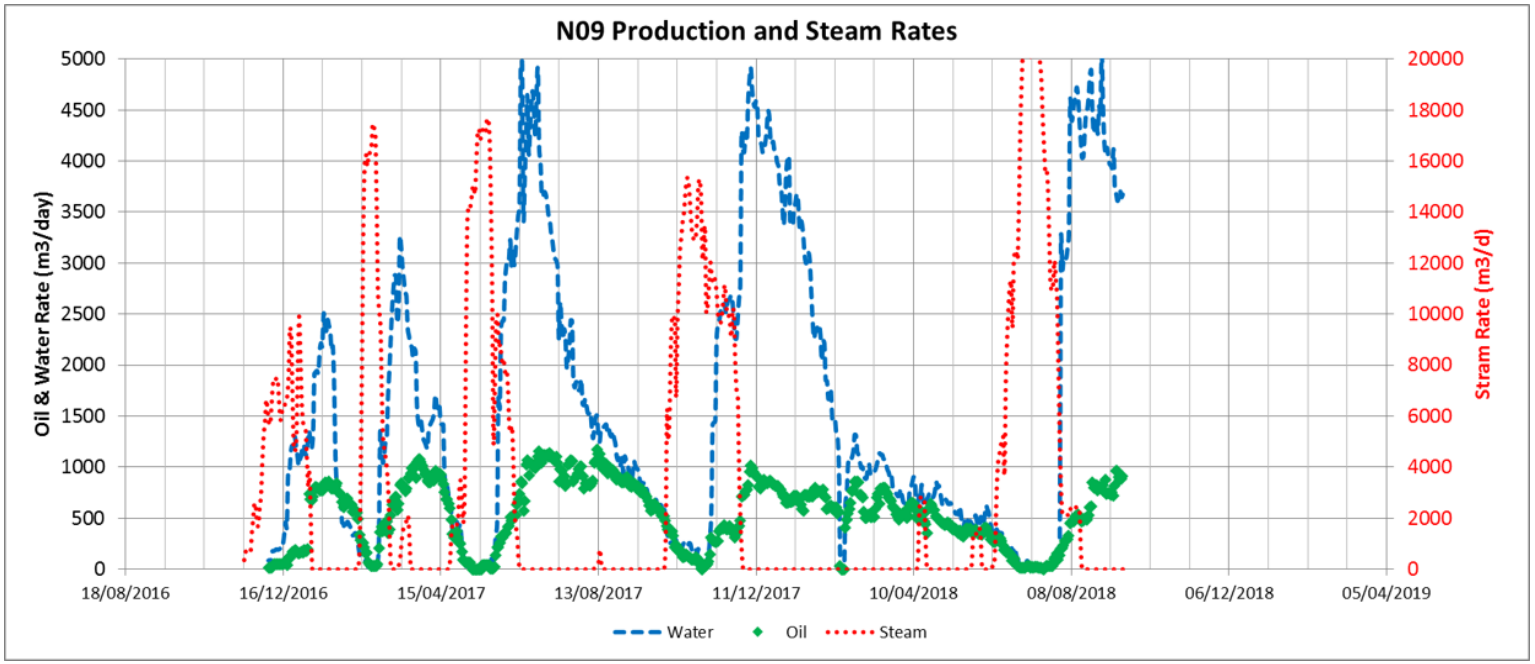
# Nabiye N09 Pad

- Nabiye N09 is a 36 well pad (24 deviated, 12 horizontal), accessing 101 bottom-hole locations on 8 acre spacing
- Currently in the steam injection phase of cycle 4
- Cycle 1 was split into two smaller injection cycles to mitigate the risk of pressure responses in the Grand Rapids formation. Steam volumes for each injection were roughly half of the typical first-cycle steam volume.
- Fewer Grand Rapids responses have been observed compared to other Nabiye pads



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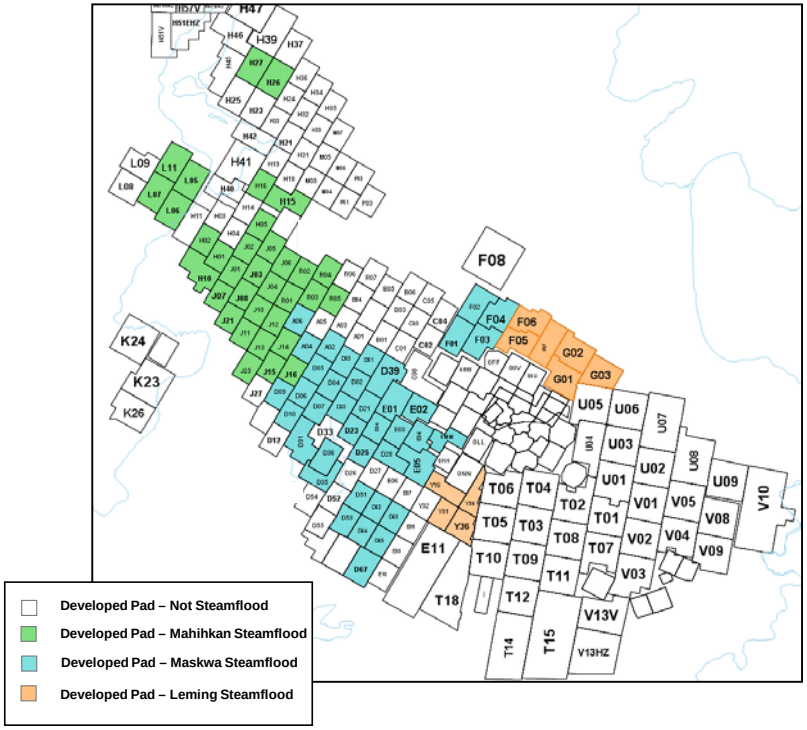
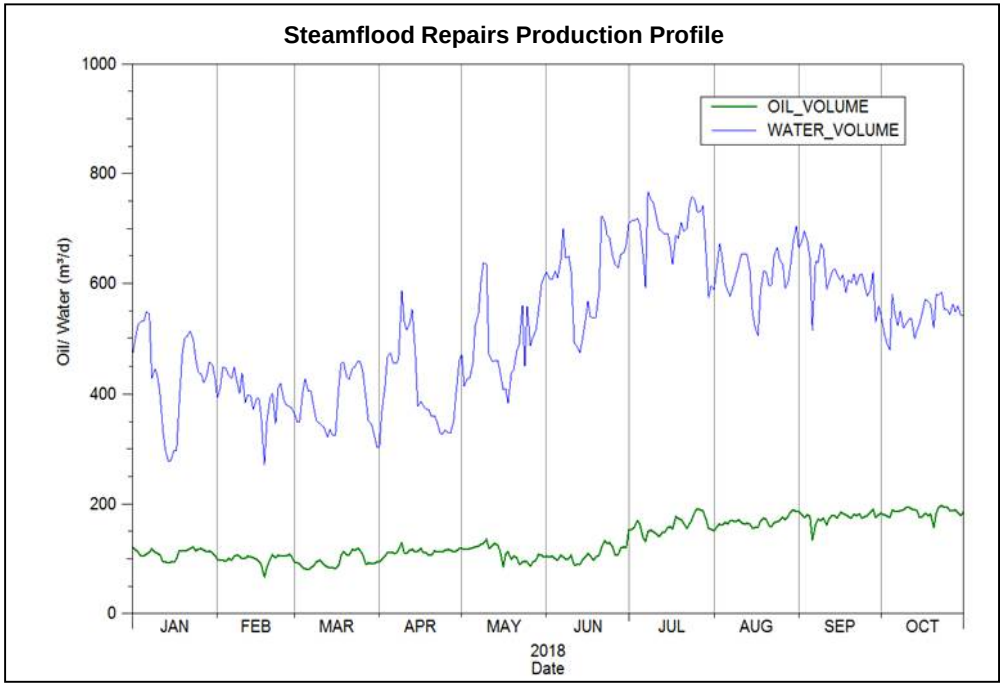
# Late Life Steamflood Performance

# Late Life Steamflood

- Steamflood approved for entire Cold Lake Development Area
- Currently ~123 infills on steamflood into 82 producing pads (~1,500 wells)
- Workover program undertaken to reactivate/improve steamflood wells in 2018 – 42 wells repaired to date
  - Production was increased 61 m³/d and wells continue to improve with IOI support
- Steamflood continues to be an important process for Cold Lake performance and long term recovery
  - Attempting to optimize steamflood performance by trialing different steam strategies including injecting at higher rates (1,000 – 2,000 m³/d) to ensure steam distribution
    - Reservoir pressure to remain less than 6 MPa as per approval
  - Investigating further optimization through machine learning



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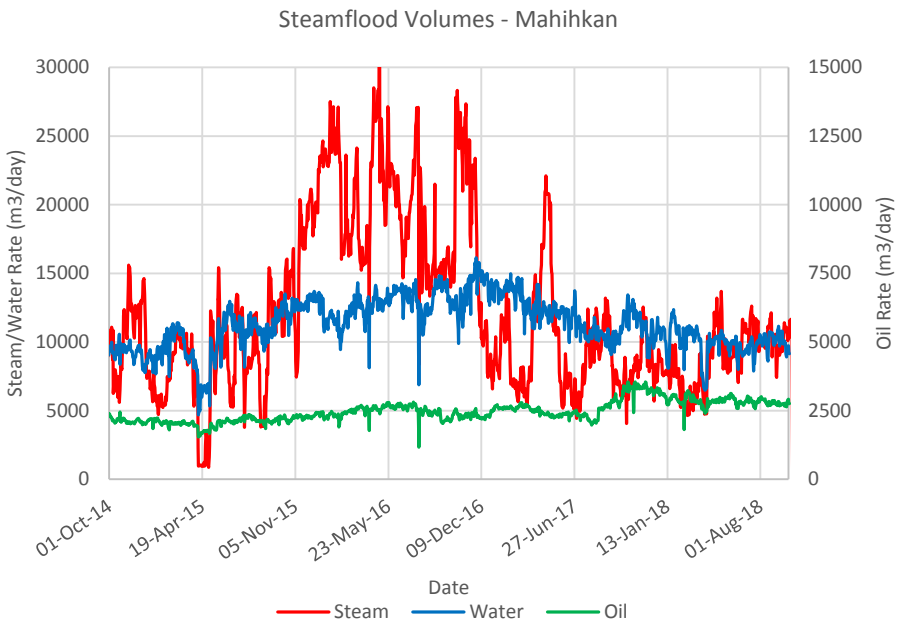
# Late Life Steamflood

**Mahihkan Steamflood Area**

34 Pads: H01, H02, H05, H15, H16, H18, H26, H27, J01-J08, J10-J16, J21, J25, L05-L07, L11, R01-R05

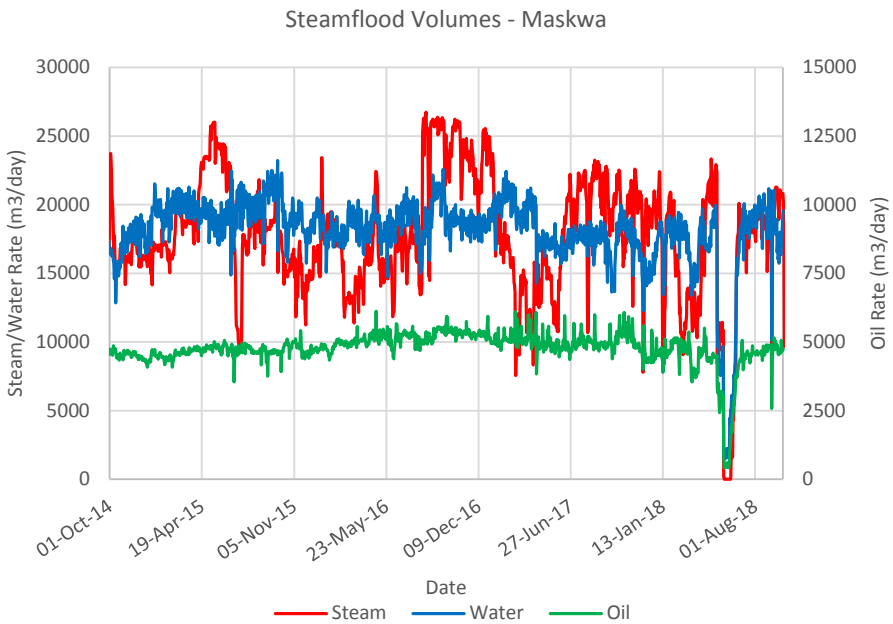
- Steamflood performance at Mahihkan as expected
- Low steamflood injection rates end of 2017, back to target rates as of Q2 2018
- Oil rates have increased in the past year
- Recovery factors as high as 70-85% for pads in this area




**Maskwa Steamflood Area**

38 Pads: A02, A04, A06, D01-D07, D09, D10, D21-D25, D28, D31, D33, D35, D39, D51, D62-D65, D67, E01-E05, F01-F04, 0MM

- Steamflood performance at Maskwa as expected
- Steady steamflood injection rates in the past year
- Quicker than expected production recovery from the shut down
- Recovery factors in the range of 30-70% for pads in this area



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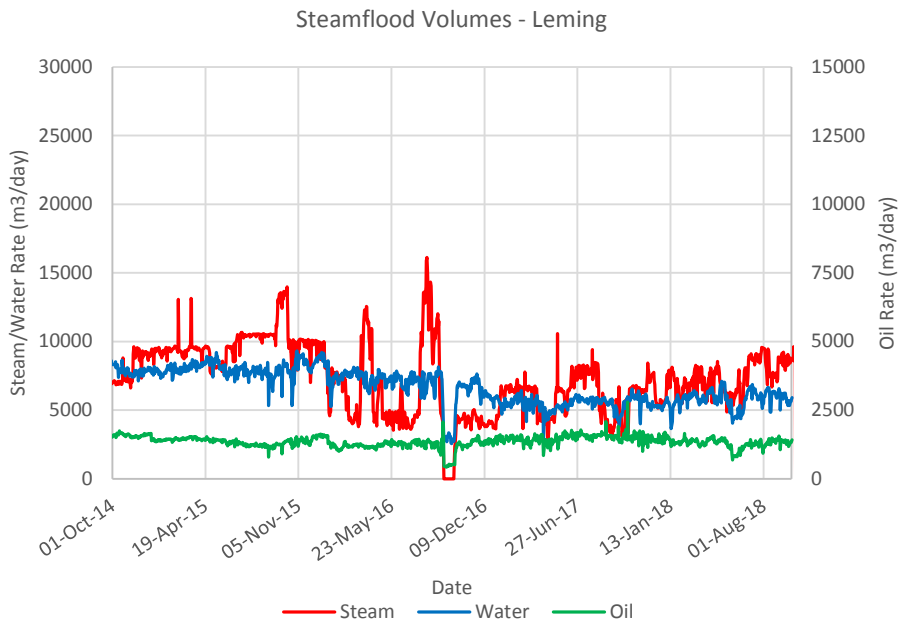
# Late Life Steamflood

**Leming Steamflood Area**

10 Pads: F05, F06, F07, G01, G02, G03, Y16, Y31, Y34, Y36

- Steamflood performance at Leming as expected
- Steamflood injection rates increased from prior year
- Oil rates have decreased slightly in the past year
- Recovery for pads in this area ranges from 35-60%



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# LASER Recovery Process

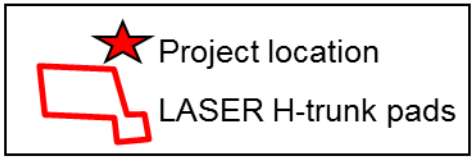
# LASER H Trunk Project- Cycle 1 Summary

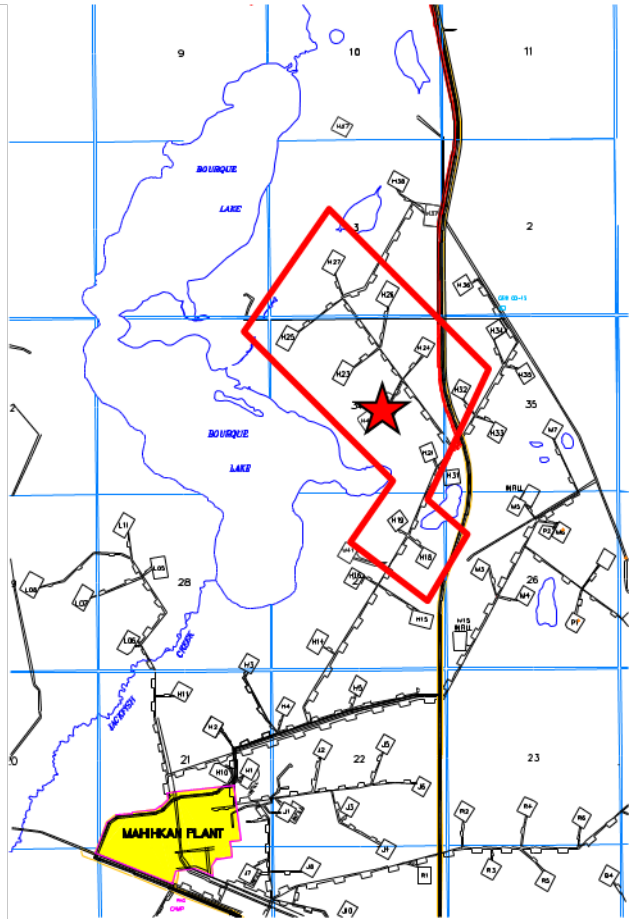
## Background

- 10 pads in Mahihkan H-trunk – diluent injection complete
  - First cycle diluent injection began in Q3 2007 and was completed April 2009
- Diluent management
  - Distributed to pads via dedicated distribution pipeline
  - Produced back to Mahihkan Plant as part of common production stream
    - Produced diluent reduces future blend requirement
- Recovery equipment minimizes burning of flashed diluent in steam generators
  - Started up August 2008

## Performance

- Overall first cycle LASER performance was in line with expectations
  - Average 0.10 OSR uplift was achieved compared to no LASER implementation, due to the 5% v/v diluent injected with the steam in this first LASER cycle. This is approximately a 50% improvement in oil production performance.
  - Range of 0.04 to 0.18 OSR uplift for the 10 pads
  - 59% of the injected diluent was recovered in LASER cycle 1, in line with expectations
  - Range of 30% to 90% recovery of injected diluent for the 10 pads
  - Some fluid migration from the LASER pads was observed, primarily to other pads in the north and east, with the most significant impact being reduced OSR uplift and lower diluent recovery at H26, H27, H24, and H32 pads
  - LASER has been demonstrated to be effective in CSS, IOI, and CSS POW situations
  - Higher diluent concentration at H23 pad (8.6%) compared to other pads resulted in an increase in incremental bitumen production and OSR uplift for the cycle, but with an apparent lower diluent recovery. An estimated 0.18 OSR uplift and 49% diluent recovery was achieved at H23 pad, but with uncertainty in the high concentration assessment due to fluid migration between pads.
  - LASER has been demonstrated to be successful across a wide range of diluent concentrations at the H trunk project, but identification of an optimal diluent concentration for LASER from the field data is difficult due to the pad-to-pad fluid migration experienced in the cycle
  - Sustainability of LASER performance uplift has been demonstrated by the third cycle of LASER at H22 pad, with an estimated 0.14 OSR uplift in the cycle



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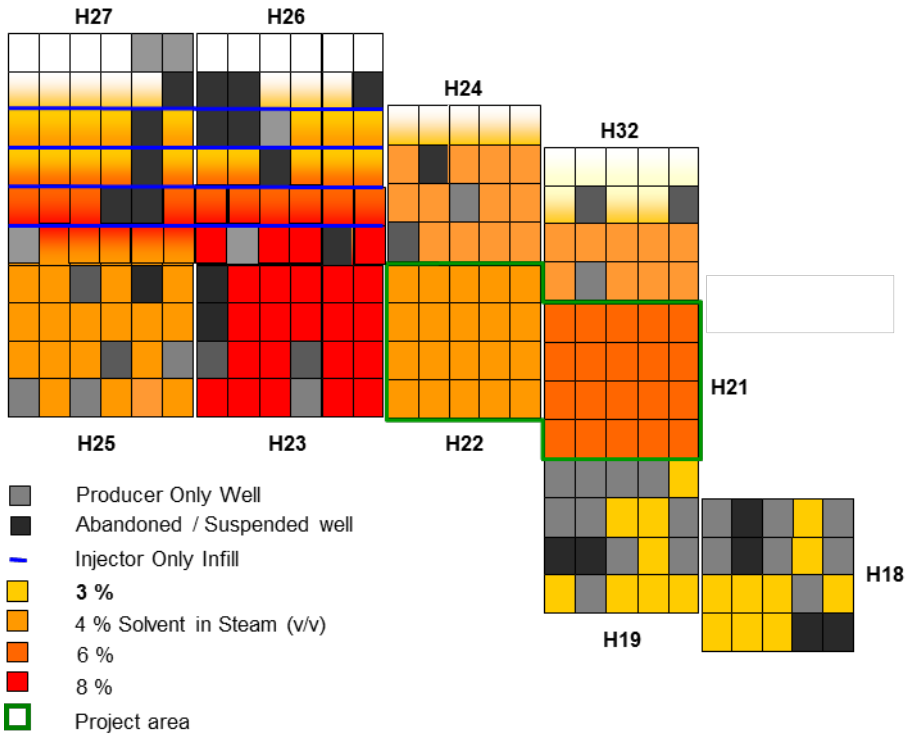
# Cycle 1 Laser H Trunk Project- Diluent Injection

**Diluent injection complete in all 10 pads**

| Key Learning Initiative | # of Pads Location | Target (% v/v) | Actual (% v/v) |
|---|---|---|---|
| LASER POW | 2 | | |
| 9 injectors | H18 | 3% | 3.2% |
| 8 injectors | H19 | 3% | 3.0% |
| LASER CSS | 6 | | |
| Standard | H21 | 4% | 6.1% |
| 3rd LASER Cycle | H22 | 4% | 4.5% |
| High Diluent | H23 | 8% | 8.6% |
| Standard | H25 | 4% | 4.4% |
| Potential Last Cycle | H24 | 3.5% | 3.9% |
| Potential Last Cycle | H32 | 3% | 3.9% |
| LASER IOI | 2 | | |
| After 1 IOI cycle completed | H26 | 5% | 4.4% |
| After 1 IOI cycle completed | H27 | 5% | 4.6% |




- Original LASER Pilot at H22 pad had 6% v/v of diluent injected in 8 wells (equivalent to ~2.4% v/v across a 20-well pad)
- Based on successful results at H22 Pilot, increased diluent to nominal average of 5% v/v for commercial implementation in 2007
- 8% v/v injected at H23 to test theory of increased benefits with higher concentration
- Remaining pads received diluent concentrations between 3-6% v/v
    - Lower diluent concentrations injected into pads with lower performance expectations

**Injection Data for First LASER Cycle (10 pads)**

| Cumulative ($km^3$) | to 09/30/2012 |
|---|---|
| Steam Injection | 6,246 |
| Diluent Injection | 297 |



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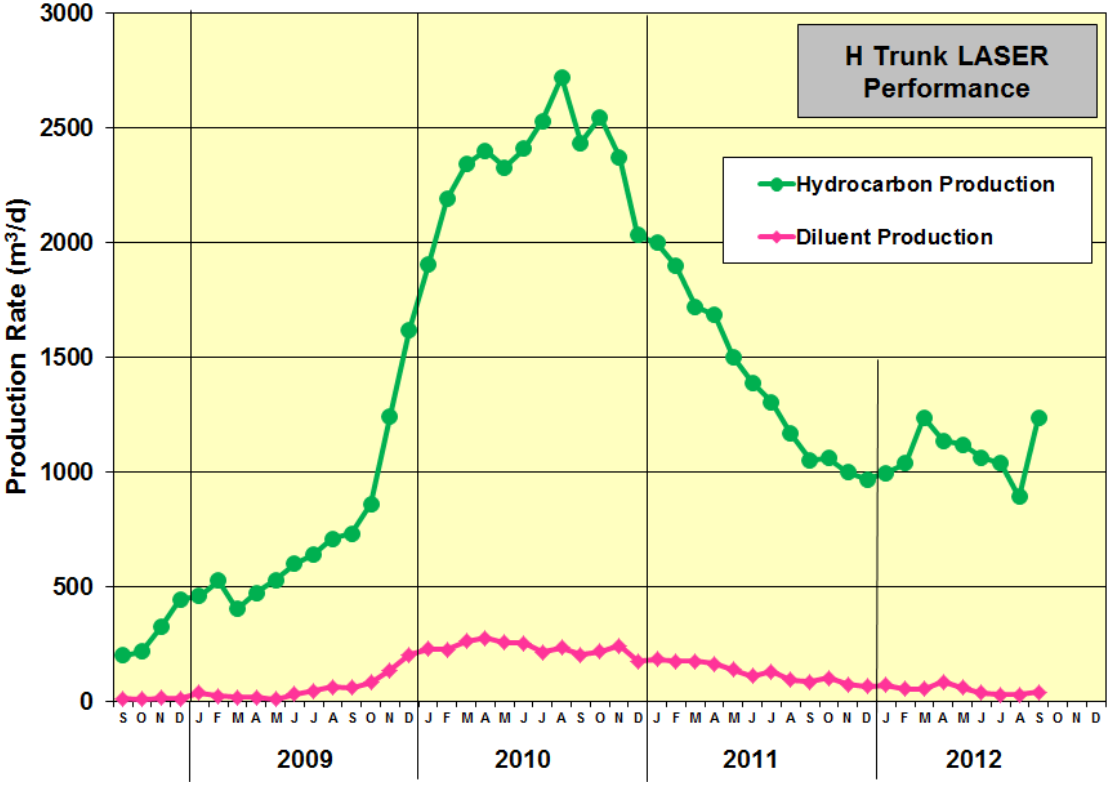
# Cycle 1 LASER H Trunk - Production Performance

**Production**

- Steam injection cycle at the 10 pad H Trunk LASER implementation was completed in early 2009
- Oil production and diluent reproduction increased to peak rates in 2010 as expected
- Production has declined throughout the remainder of the cycle, through 2011 and into 2012
- With the first H Trunk LASER cycle now at an end, the performance is encouraging. The overall incremental oil production and diluent recovery are in line with expectations.

- H18 and H19 began the production cycle in Q2 2008
  - Peak oil production rates were achieved in 2010 and wells on oil decline during 2011 & 2012
- H21, H22, H23, H25 began the production cycle in Q4 2008
  - Peak oil production rates were achieved in 2010 and wells on oil decline during 2011 & 2012
- H24, H26, H27, H32 began the production cycle in Q1 2009
  - Peak oil production rates were achieved in 2010 and wells on oil decline during 2011 & 2012




**Production Data for First LASER Cycle (10 pads)**

| Cumulative ($km^3$) | to 09/30/2012 |
|---|---|
| Hydrocarbon Production | 1,886 |
| Diluent Production | 174 |



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# Cycle 2 LASER H Trunk - Production Performance

## Background

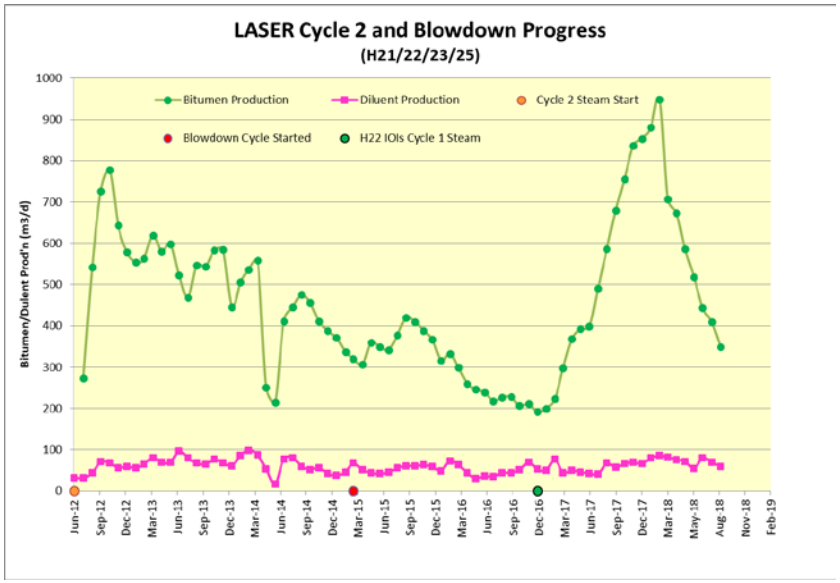
- H21, H22, H23 and H25 steamed with diluent for cycle 2
- 2nd Cycle injection focus strictly on CSS strategy
- Focus on longer term performance understanding

## Cycle 2 Injection

- Steamed with diluent from Sept - Dec 2012
- Total steam injection - 1638 $km^3$
- Total diluent injection – 77 $km^3$ (4.7% dil. v/v)
- Pressures of ~1.0 - 2.0 MPa achieved
  - Lower reservoir pressures compared to 1st LASER cycle
  - Higher level of depletion and inter-well communication across all pads

## Production Performance

- Oil produced in Cycle 2: 534 $km^3$
- Diluent recovery to date: 307 $km^3$
- Cycle 2 production ended in Mar 2015. At the end of the cycle, the four pads averaged OSR increases of 0.12, exceeding the original expectation.
- Diluent production rates peaked in July 2013 and trended as expected, to a cumulative of 62% by the end of the cycle
- The four pads went into a blowdown cycle (March 2015) in which steam with no diluent was injected. Diluent reproduction continues to be tracked as recovery under blowdown will be a key learning for future LASER projects. The current cumulative recovery for cycle 1 & 2 is 82%.
- H22 infills into H21, H23, H25 pads were first steamed in late 2016 and are currently in their 2nd cycle of steam. Increased bitumen and diluent production due to the infill steam is evident during the early 2017 through 2018 period shown the chart above.




**Production Data to Date:**

| Updated to 10/01/2018 | **Cycle 1** | **Cycle 2** | **Blowdown** |
|---|---|---|---|
| Cycle Start | May 2007 | Jul 2012 | Mar 2015 |
| Diluent Injection | 297 | 77 | 0 |
| Diluent production | 174 | 58 | 73 |
| Cumulative Diluent Recovery | 59% | 62% | 82% |



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# Mahihkan North LASER – Cycle 1

**Background**

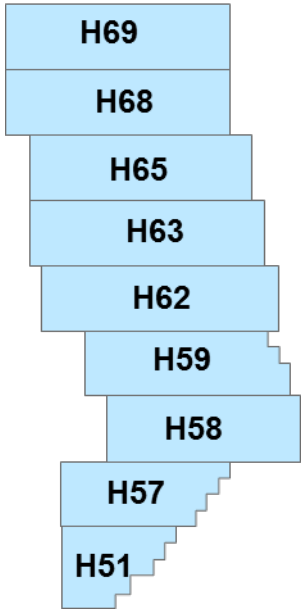
- Cycle 1 of LASER on 9 Mahihkan North pads (H51, H57, H58, H59, H62, H63, H65, H68, H69) has commenced
- First application of LASER on 8-acre spacing pads

**Injection**

- Diluent injection started May 15, 2017 at H65 and H68 pads
- A total of 6,487 $km^3$ of steam and 265 $km^3$ of diluent has been injected across H65, H68, H69, H51, H57, H58 and H59 pads through the end of September 2018.
- The average diluent concentration to date has been 4.1% (by volume).

**Production Performance**

- It is still too early in the production cycle to evaluate the uplift in production due to LASER
- Diluent production sampling to quantify the amount of reproduced diluent is occurring as planned



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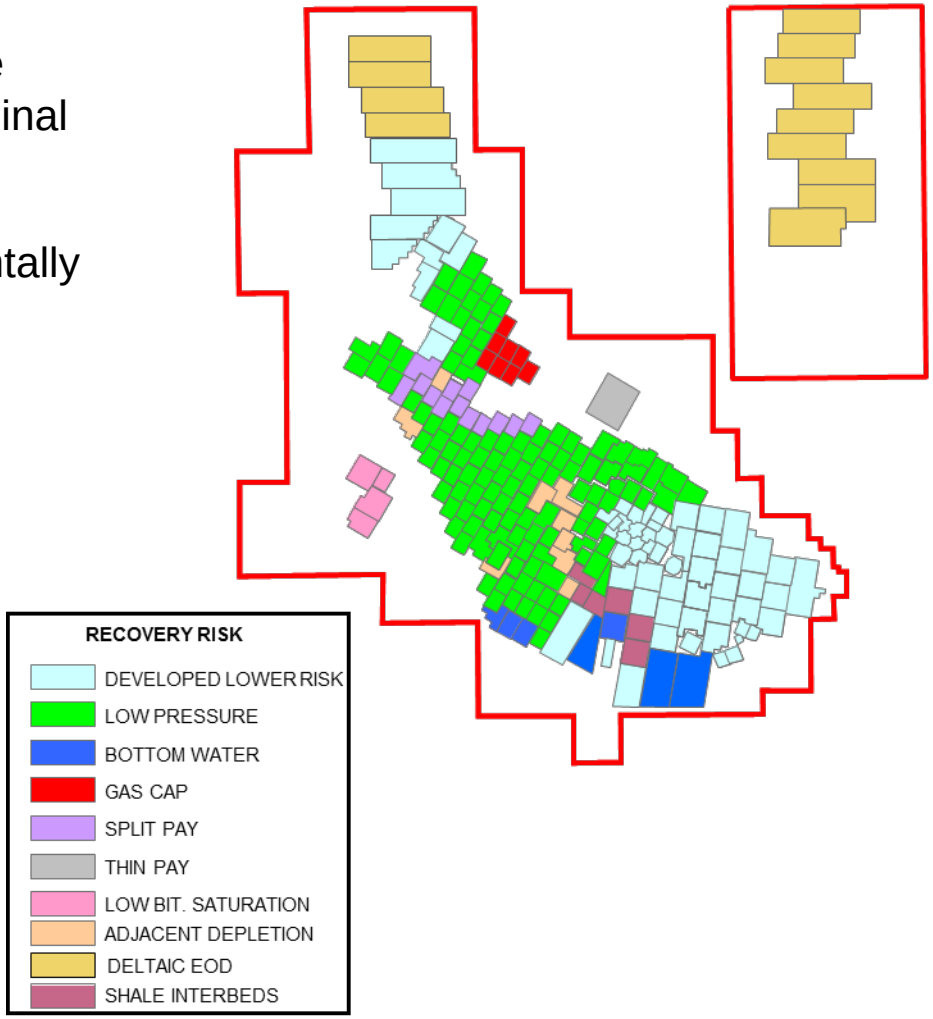
# Factors Impacting Recovery

# Factors Impacting Recovery

- Individual pad recovery expectations range from less than 10% to over 60% of the original effective bitumen in place
- The variation in recovery level is fundamentally a function of bitumen saturation and shale structure/distribution
- Additional reservoir challenges include:
  - Bottom water
  - Clearwater gas cap
  - Split pay
  - Adjacent reservoir depletion
  - Well Spacing



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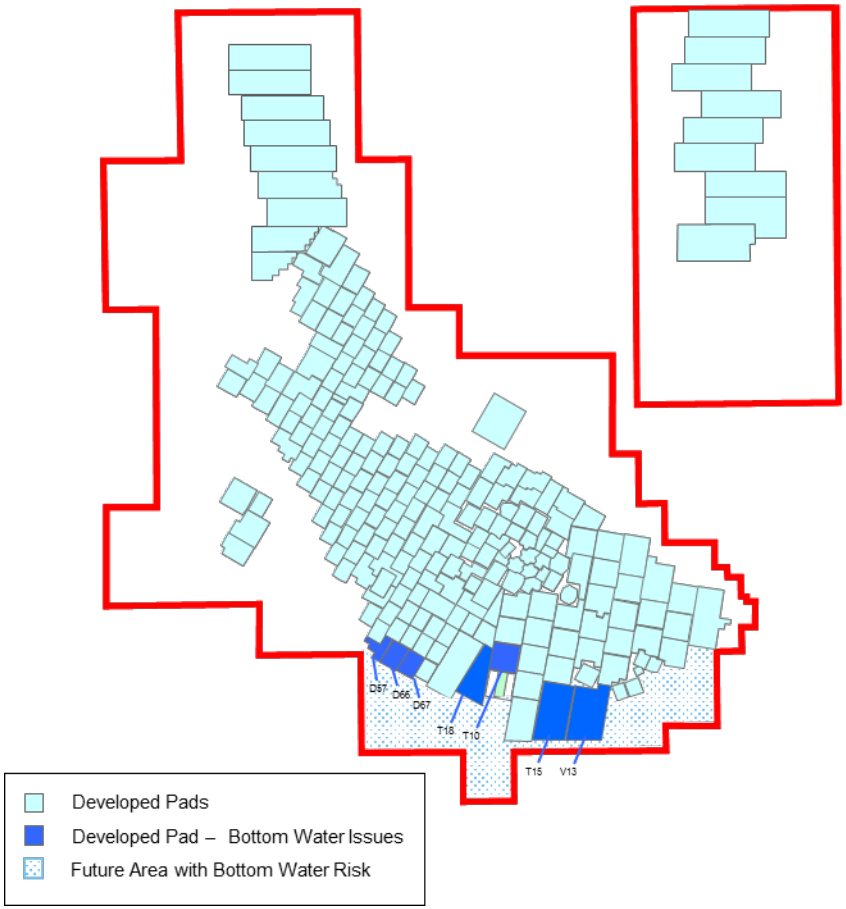
# CSS Performance - Bottom Water




- Performance issues:
  - Bottom water is a thief zone for steam injection
  - High mobility water excludes bitumen production
- Mitigation
  - Basal Wabiskaw shale provides seal for much of CLPP 1-13
  - Perforation standoff from transition zone and thin bottom water
  - Additional standoff required for thick bottom water in clean sand
  - Uphole recompletions of wet wells can be effective if sufficient separation is left between old and new perforations



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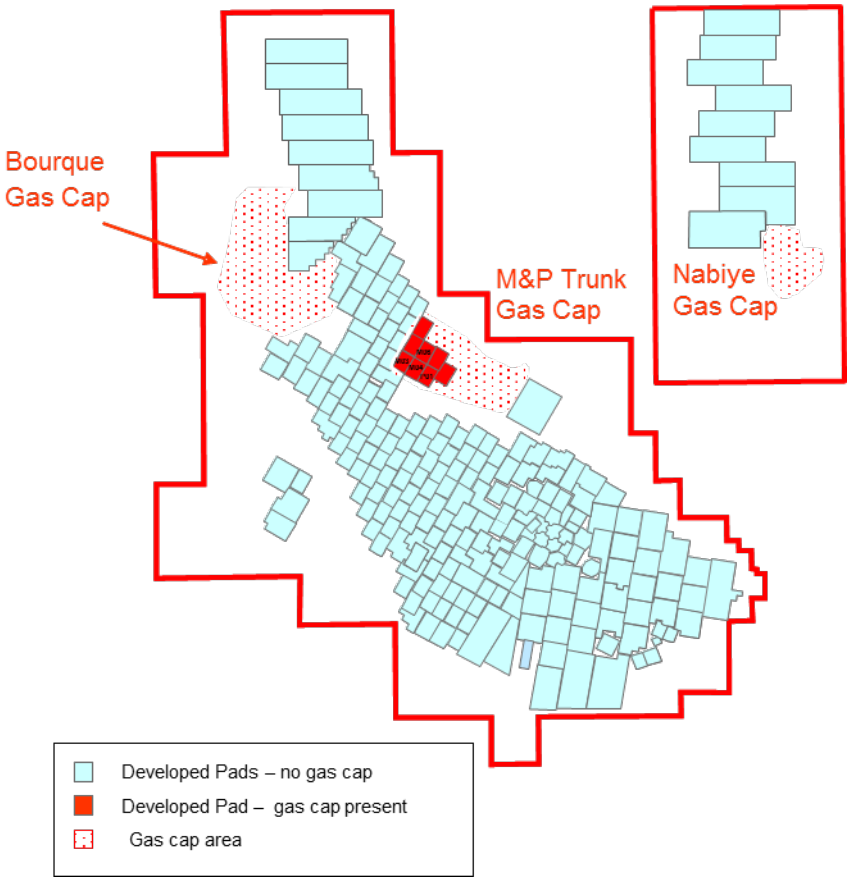
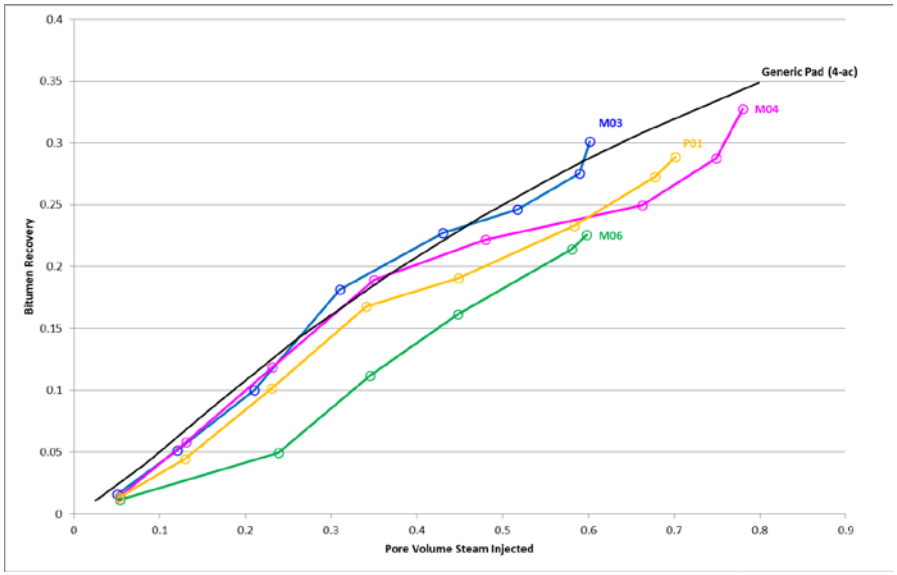
# CSS Performance - Gas Cap




**Performance of Gas Cap Pads**




- Three significant Clearwater gas cap areas
  - M&P Trunk – producing
  - Bourque Lake gas cap – undeveloped
  - South Nabiye - undeveloped
- M&P Trunk pads exhibited poorer performance due to pressure losses to the gas cap
- Steaming all pads under a gas cap together reduces steam losses and improves performance
- Recovery expectations at M&P Trunk pads are 30-40% lower due to presence of gas cap



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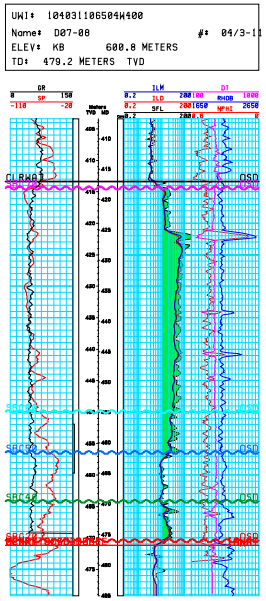
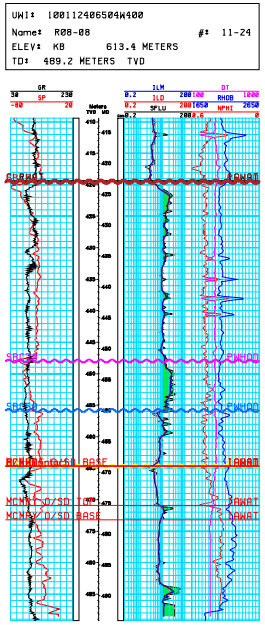
# CSS Performance - Split Pay

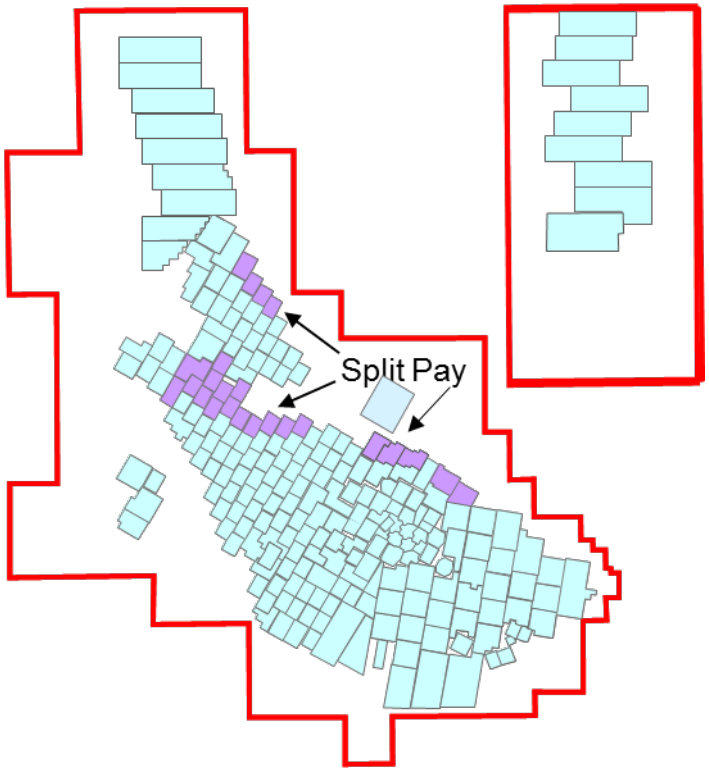
**Thick Continuous Pay**




**Thin Split Pay**




Interbedded sequence




- Split pay occurs where an interbedded sequence has cut through lower reservoir sequences
- Interbedded sands and shales act as vertical permeability barrier between lower reservoir sequences and good quality sand in upper sequence

- Upper zone can be accessed through recompletion after lower zone depletion
- Concurrent depletion trials with limited entry perforations resulted in poor inflow performance
- Thin zones have substantially lower recovery due to heat losses to surrounding non-reservoir rock
- Split pay can be used to isolate effects of top fluids



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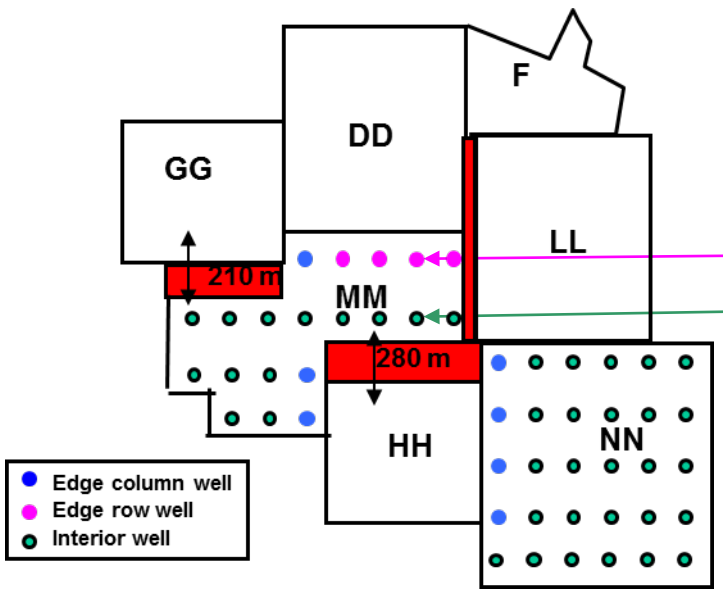
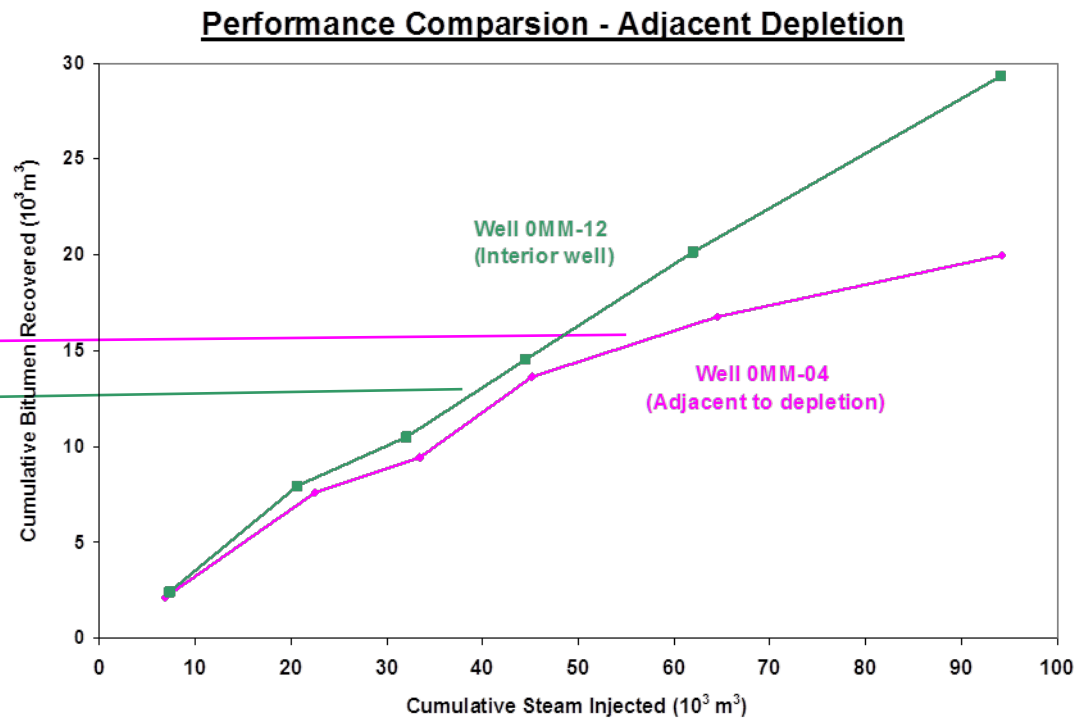
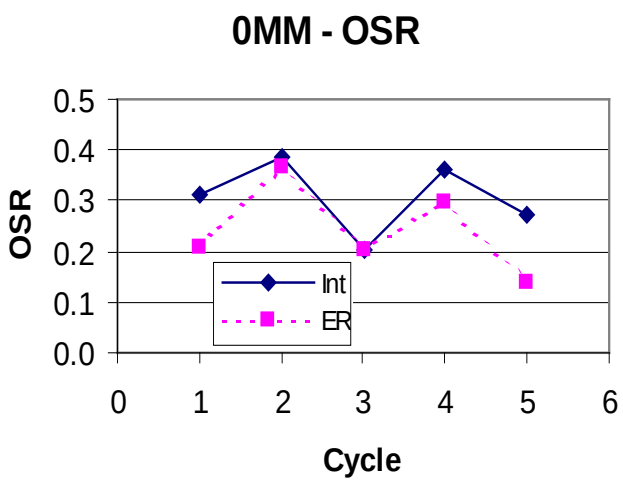
# Adjacent to Depletion Example- MM Pad

- MM pad is adjacent to depletion in DD pad which acts as thief zone for steam




- Difficult to achieve high injection pressure after cycle 2 in edge row wells
- Low fluid production in edge row wells



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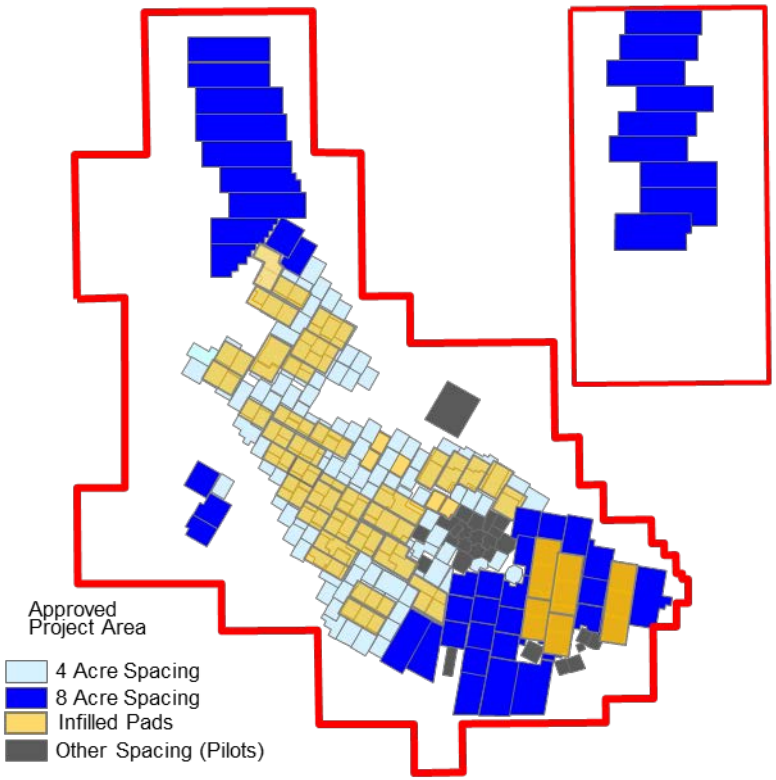
# Well Spacing




**Infill Drilling**

- Where economic, horizontal injector-only-infills are drilled between the rows of wells at mature pads
- Infill steam is directed to bypassed bitumen to increase recovery by 15 to 30% relative to CSS
- Infill steam injection volumes per pad are similar to CSS volumes

- Commercial pads are developed on 4 acre, 8 acre or 11 acre well spacing
  - 4 acre spacing in the thicker central area of the field
  - 8 or 11 acre spacing in thinner resource areas
- Cycle steam injection volumes have been derived primarily from field operating experience with the objectives of:
  - Achieving high levels of reservoir conformance to mobilize cold bitumen
  - Managing inter-well communication
  - Limiting casing damage caused by shear stress
- Current steaming practices employ the same early cycle injection volume strategy for both 4 and 8 acre well spacings:[1 2]
  - > Cycle 1 8,000 $m^3$
  - > Cycle 2 7,000 $m^3$
  - > Cycle 3 8,000 $m^3$
  - Cycle 2 volumes are reduced because injected fluids are typically not fully reproduced in cycle 1
- Subsequent cycle high pressure steam injection volumes range up to 10,000 $m^3$ (volumes injected at dilation pressure)
  - Actual injection performance from previous cycles is used to develop the steaming strategy for an individual pad
- Wells drilled on 8 acre spacing are expected to operate through more cycles than those on 4 acre spacing
- Expected recovery from 8 acre spacing is approximately 80% of 4 acre recovery based on reservoir simulation
  - Existing 8 acre pads are not sufficiently mature to demonstrate lower recovery

[1] 11 Acre Spacing steam strategy approved by the ERCB in July 2011 allowing for 12,000 $m^3$ over fill-up per cycle.
[2] At Nabiye the 1st two steam volumes are commissioning cycles (2500m3/bhl each). Cycle 1 volumes are limited to 5,000 $m^3$ per effective bottom-hole spacing. At N10 (4.7 acre) volume over fill-up is limited to 6000m3/bhl..



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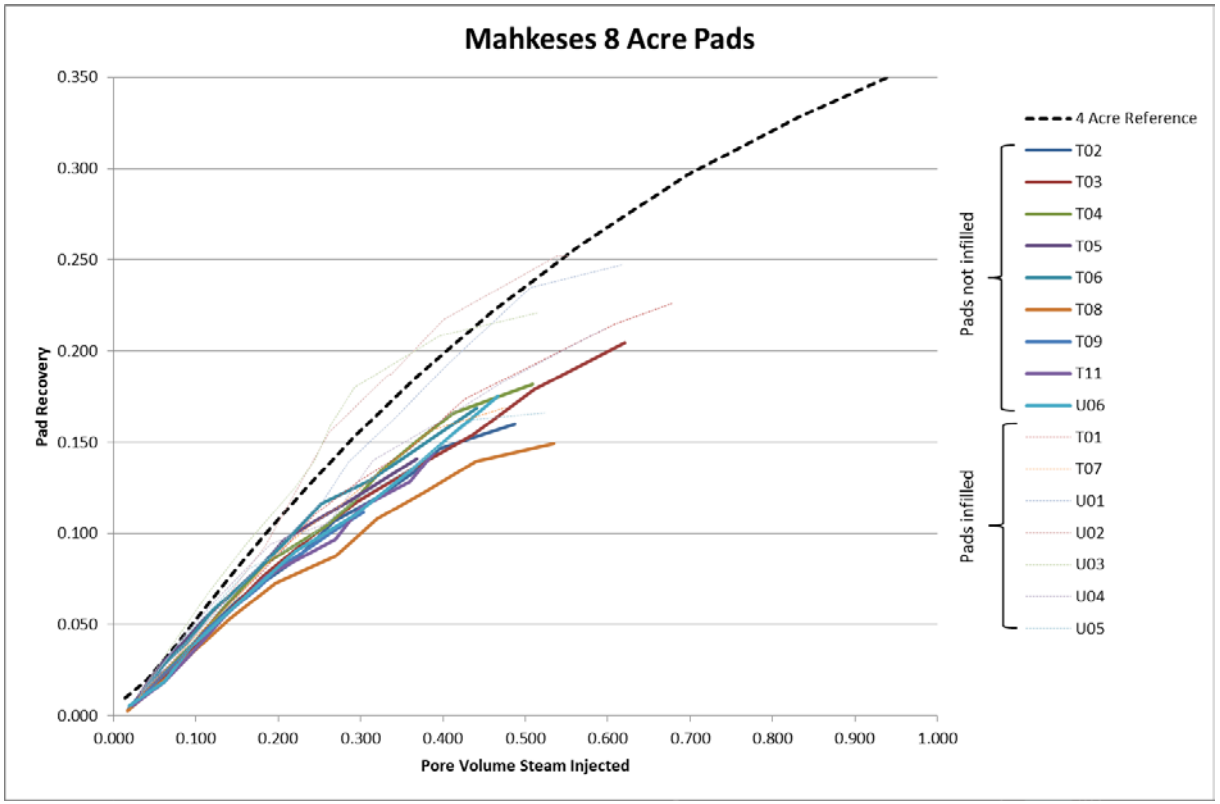
# Impact of Well Spacing on Recovery




- 4 acre performance curve shown for equivalent resource to Mahkeses 8-acre pads
- Most mature Mahkeses pads not sufficiently depleted to validate ultimate recovery expectations



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# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| 00A | 30 | 0.67 | 1184 | 193,591 | 152 | 13% | EUR = Recovery to date |
| 00B | 27 | 0.68 | 1772 | 231,800 | 126 | 7% | EUR = Recovery to date |
| 00C | 25 | 0.68 | 1559 | 211,035 | 216 | 14% | EUR = Recovery to date |
| 00D | 29 | 0.67 | 1236 | 169,839 | 212 | 17% | EUR = Recovery to date |
| 00E | 28 | 0.69 | 1257 | 207,993 | 150 | 12% | EUR = Recovery to date |
| 00F | 22 | 0.68 | 1079 | 152,336 | 233 | 22% | EUR = Recovery to date |
| 00G | 29 | 0.67 | 2097 | 262,431 | 358 | 17% | EUR = Recovery to date |
| 00H | 28 | 0.69 | 2010 | 257,344 | 291 | 14% | EUR = Recovery to date |
| 00J | 36 | 0.68 | 850 | 134,339 | 249 | 29% | EUR = Recovery to date |
| 00K | 31 | 0.70 | 1905 | 233,962 | 489 | 26% | EUR = Recovery to date |
| 00L | 35 | 0.72 | 2019 | 280,504 | 450 | 22% | EUR = Recovery to date |
| 00M | 26 | 0.66 | 982 | 129,945 | 68 | 7% | EUR = Recovery to date |
| 00N | 28 | 0.67 | 1648 | 245,719 | 490 | 30% | EUR = Recovery to date |
| 00P | 32 | 0.69 | 2341 | 331,516 | 714 | 30% | EUR = Recovery to date |
| 00Q | 35 | 0.73 | 1988 | 220,552 | 342 | 17% | EUR = Recovery to date |
| 00R | 33 | 0.71 | 1764 | 210,698 | 116 | 7% | EUR = Recovery to date |
| 00S | 26 | 0.68 | 1174 | 135,701 | 136 | 12% | EUR = Recovery to date |
| 00T | 35 | 0.70 | 2644 | 381,551 | 846 | 32% | EUR = Recovery to date |
| 00U | 28 | 0.76 | 2122 | 311,961 | 1031 | 49% | 49% - 50% |
| 00V | 29 | 0.74 | 2301 | 339,636 | 745 | 32% | 40% - 45% |
| 00W | 30 | 0.66 | 2103 | 337,998 | 1341 | 64% | 65% - 70% |
| 0AA | 30 | 0.69 | 2533 | 348,059 | 1115 | 44% | EUR = Recovery to date |
| 0BB | 32 | 0.66 | 2191 | 324,732 | 1619 | 74% | 75% - 80% |
| 0CC | 34 | 0.71 | 2546 | 302,957 | 941 | 37% | 37% - 40% |
| 0DD | 27 | 0.66 | 1883 | 356,675 | 920 | 49% | 49% - 50% |
| 0EE | 36 | 0.72 | 1854 | 273,856 | 575 | 31% | EUR = Recovery to date |
| 0FF | 34 | 0.70 | 1909 | 248,143 | 1139 | 60% | 60% - 65% |
| 0GG | 27 | 0.72 | 1403 | 229,132 | 511 | 36% | 36% - 40% |
| 0HF | 20 | 0.72 | 297 | 60,352 | 102 | 34% | EUR = Recovery to date |
| 0HH | 25 | 0.69 | 1210 | 218,243 | 628 | 52% | 52% - 55% |
| 0LL | 24 | 0.70 | 1734 | 327,247 | 732 | 42% | 42% - 45% |
| 0MA | 27 | 0.73 | 1454 | 202,030 | 126 | 9% | EUR = Recovery to date |
| 0MB | 29 | 0.70 | 1942 | 251,322 | 452 | 23% | EUR = Recovery to date |
| 0MC | 26 | 0.78 | 1087 | 206,478 | 496 | 46% | EUR = Recovery to date |
| 0MD | 30 | 0.73 | 816 | 209,255 | 496 | 61% | EUR = Recovery to date |
| 0ME | 31 | 0.71 | 2276 | 352,968 | 533 | 23% | EUR = Recovery to date |

- Pad production updated to September 2016
- Pad EBIPs changes are due to a new geological model
- E07 and D29 pad combined as they are now depleted by one set of horizontal wells
- Effective OBIP (Original Oil in Place) is volume of bitumen >8 wt% between top of Effective Pay and base of Effective Pay

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| 0MM | 23 | 0.69 | 1659 | 336,044 | 662 | 40% | 40% - 45% |
| 0NN | 24 | 0.69 | 2613 | 521,709 | 955 | 37% | 40% - 45% |
| A01 | 31 | 0.69 | 2230 | 326,575 | 954 | 43% | 43% - 45% |
| A02 | 34 | 0.69 | 2486 | 334,641 | 984 | 40% | 45% - 50% |
| A03 | 31 | 0.69 | 2235 | 335,477 | 970 | 43% | 43% - 45% |
| A04 | 35 | 0.77 | 2837 | 330,758 | 1298 | 46% | 50% - 55% |
| A05 | 28 | 0.69 | 1980 | 326,066 | 795 | 40% | 40% - 45% |
| A06 | 32 | 0.73 | 2554 | 335,476 | 993 | 39% | 39% - 40% |
| B01 | 28 | 0.69 | 2058 | 327,676 | 938 | 46% | 46% - 50% |
| B02 | 26 | 0.74 | 2045 | 327,521 | 1023 | 50% | 50% - 55% |
| B03 | 28 | 0.73 | 2104 | 325,540 | 876 | 42% | 50% - 55% |
| B04 | 27 | 0.70 | 2005 | 339,121 | 981 | 49% | 49% - 55% |
| B05 | 27 | 0.70 | 1998 | 326,038 | 1452 | 73% | 73% - 75% |
| B06 | 27 | 0.70 | 2013 | 329,908 | 1048 | 52% | 52% - 55% |
| C01 | 30 | 0.69 | 2150 | 330,162 | 876 | 41% | 41% - 45% |
| C02 | 26 | 0.71 | 1984 | 328,513 | 1104 | 56% | 56% - 60% |
| C03 | 32 | 0.73 | 2405 | 324,721 | 1367 | 57% | 65% - 70% |
| C04 | 26 | 0.73 | 1971 | 339,736 | 911 | 46% | 50% - 55% |
| C05 | 26 | 0.72 | 1946 | 326,483 | 792 | 41% | 41% - 45% |
| C08 | 34 | 0.70 | 5074 | 654,866 | 1001 | 20% | 50% - 60% |
| D01 | 30 | 0.69 | 2199 | 329,560 | 957 | 44% | 45% - 50% |
| D02 | 31 | 0.70 | 2233 | 327,006 | 760 | 34% | 45% - 55% |
| D03 | 39 | 0.70 | 2818 | 318,726 | 1154 | 41% | 41% - 50% |
| D04 | 41 | 0.76 | 3269 | 331,740 | 1521 | 47% | 50% - 60% |
| D05 | 38 | 0.75 | 2956 | 325,578 | 1579 | 53% | 55% - 65% |
| D06 | 48 | 0.81 | 3980 | 322,502 | 2677 | 67% | 75% - 80% |
| D07 | 42 | 0.78 | 3498 | 330,569 | 2010 | 57% | 60% - 70% |
| D09 | 40 | 0.79 | 3305 | 330,529 | 2238 | 68% | 75% - 80% |
| D10 | 41 | 0.78 | 3307 | 325,822 | 1871 | 57% | 57% - 65% |
| D11 | 24 | 0.71 | 2431 | 319,000 | 80 | 3% | EUR = Recovery to date |
| D12 | 28 | 0.71 | 2135 | 337,254 | 559 | 26% | 26% - 35% |
| D21 | 28 | 0.68 | 2014 | 328,433 | 718 | 36% | 45% - 50% |
| D22 | 34 | 0.75 | 2659 | 331,754 | 1263 | 48% | 50% - 55% |
| D23 | 40 | 0.72 | 2934 | 321,196 | 1311 | 45% | 50% - 60% |
| D24 | 29 | 0.67 | 2007 | 325,503 | 859 | 43% | 50% - 55% |
| D25 | 35 | 0.72 | 2597 | 326,409 | 1175 | 45% | 45% - 50% |

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| D26 | 37 | 0.79 | 3021 | 325,318 | 1538 | 51% | 51% - 55% |
| D27 | 34 | 0.72 | 2562 | 324,687 | 964 | 38% | 38% - 40% |
| D28 | 30 | 0.68 | 2430 | 356,683 | 681 | 28% | 40% - 50% |
| D31 | 42 | 0.76 | 5743 | 561,922 | 1991 | 35% | 50% - 65% |
| D33 | 36 | 0.75 | 4385 | 499,814 | 1723 | 39% | 55% - 70% |
| D35 | 38 | 0.73 | 3427 | 368,988 | 904 | 26% | 50% - 60% |
| D36 | 34 | 0.76 | 3447 | 431,876 | 1038 | 30% | 50% - 60% |
| D39 | 32 | 0.69 | 3867 | 555,722 | 945 | 24% | 40% - 50% |
| D51 | 36 | 0.80 | 3019 | 332,199 | 1117 | 37% | 50% - 70% |
| D52 | 36 | 0.76 | 2904 | 333,491 | 789 | 27% | 27% - 30% |
| D53 | 33 | 0.74 | 2610 | 345,284 | 1367 | 52% | 55% - 65% |
| D54 | 23 | 0.69 | 1705 | 334,858 | 644 | 38% | 38% - 40% |
| D55 | 19 | 0.68 | 1363 | 327,587 | 649 | 48% | 48% - 50% |
| D57 | 9 | 0.68 | 769 | 380,454 | 97 | 13% | 13% - 15% |
| D62 | 33 | 0.76 | 2563 | 315,544 | 1251 | 49% | 55% - 65% |
| D63 | 30 | 0.70 | 2213 | 333,936 | 1019 | 46% | 55% - 65% |
| D64 | 32 | 0.76 | 2499 | 316,147 | 1356 | 54% | 55% - 65% |
| D65 | 30 | 0.75 | 2427 | 331,446 | 1018 | 42% | 50% - 60% |
| D66 | 13 | 0.73 | 1498 | 494,818 | 187 | 12% | EUR = Recovery to date |
| D67 | 27 | 0.74 | 3180 | 496,595 | 668 | 21% | 25% - 35% |
| E01 | 30 | 0.67 | 3179 | 514,745 | 1044 | 33% | 50% - 60% |
| E02 | 27 | 0.68 | 2321 | 409,248 | 857 | 37% | 40% - 50% |
| E03 | 29 | 0.67 | 2025 | 320,130 | 798 | 39% | 40% - 50% |
| E04 | 31 | 0.68 | 2293 | 343,432 | 768 | 33% | 50% - 65% |
| E05 | 31 | 0.67 | 3843 | 583,592 | 1002 | 26% | 50% - 60% |
| E07 | 34 | 0.68 | 2438 | 330,043 | 263 | 11% | 20% - 25% |
| E08 | 24 | 0.67 | 1734 | 328,747 | 591 | 34% | 40% - 45% |
| E09 | 26 | 0.73 | 1971 | 330,440 | 684 | 35% | 35% - 40% |
| E10 | 25 | 0.74 | 1946 | 330,934 | 619 | 32% | 35% - 40% |
| E11 | 20 | 0.71 | 8736 | 1,846,967 | 1104 | 13% | 35% - 50% |
| F01 | 27 | 0.70 | 2770 | 454,370 | 953 | 34% | 35% - 40% |
| F02 | 20 | 0.70 | 2174 | 484,521 | 749 | 34% | 35% - 40% |
| F03 | 28 | 0.71 | 3166 | 490,118 | 1310 | 41% | 45% - 55% |
| F04 | 20 | 0.69 | 2242 | 494,641 | 992 | 44% | 45% - 55% |
| F05 | 27 | 0.74 | 2995 | 468,232 | 1506 | 50% | 55% - 65% |

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| F06 | 19 | 0.72 | 2141 | 482,036 | 911 | 43% | 45% - 50% |
| F07 | 27 | 0.70 | 3282 | 541,922 | 1325 | 40% | 50% - 60% |
| F08 | 9 | 0.70 | 2687 | 1,156,520 | 395 | 15% | 15% - 25% |
| G01 | 30 | 0.73 | 3852 | 559,883 | 1573 | 41% | 50% - 60% |
| G02 | 21 | 0.69 | 2585 | 573,215 | 1003 | 39% | 50% - 55% |
| G03 | 15 | 0.67 | 1734 | 561,124 | 1055 | 61% | 61% - 65% |
| H01 | 35 | 0.75 | 2763 | 329,061 | 1863 | 67% | 70% - 75% |
| H02 | 25 | 0.75 | 1949 | 328,573 | 1149 | 59% | 59% - 65% |
| H03 | 15 | 0.67 | 1048 | 328,976 | 447 | 43% | 45% - 50% |
| H04 | 17 | 0.71 | 1249 | 326,043 | 511 | 41% | 50% - 55% |
| H05 | 21 | 0.70 | 1547 | 330,248 | 339 | 22% | 25% - 30% |
| H06 | 31 | 0.67 | 2213 | 327,229 | 147 | 7% | 07% - 10% |
| H10 | 17 | 0.67 | 2101 | 562,300 | 585 | 28% | 30% - 35% |
| H11 | 20 | 0.71 | 2234 | 488,848 | 1242 | 56% | 60% - 70% |
| H14 | 28 | 0.68 | 2043 | 330,480 | 366 | 18% | 20% - 25% |
| H15 | 28 | 0.72 | 3079 | 483,319 | 1161 | 38% | 38% - 45% |
| H16 | 30 | 0.74 | 2366 | 331,325 | 930 | 39% | 45% - 50% |
| H18 | 34 | 0.77 | 2718 | 329,107 | 819 | 30% | 35% - 45% |
| H19 | 26 | 0.77 | 2074 | 331,169 | 1064 | 51% | 65% - 70% |
| H21 | 30 | 0.76 | 2421 | 329,180 | 1137 | 47% | 60% - 65% |
| H22 | 34 | 0.77 | 2720 | 327,643 | 1287 | 47% | 50% - 60% |
| H23 | 34 | 0.77 | 4105 | 491,422 | 1968 | 48% | 65% - 70% |
| H24 | 29 | 0.77 | 2332 | 327,075 | 723 | 31% | 31% - 35% |
| H25 | 32 | 0.76 | 3786 | 489,048 | 1752 | 46% | 60% - 65% |
| H26 | 29 | 0.78 | 3574 | 493,206 | 1009 | 28% | 30% - 35% |
| H27 | 33 | 0.79 | 4048 | 489,320 | 1369 | 34% | 45% - 50% |
| H31 | 28 | 0.75 | 2161 | 327,260 | 834 | 39% | 45% - 50% |
| H32 | 29 | 0.74 | 2208 | 326,110 | 657 | 30% | 30% - 40% |
| H33 | 26 | 0.71 | 1923 | 329,580 | 556 | 29% | 35% - 40% |
| H34 | 20 | 0.72 | 1460 | 322,027 | 323 | 22% | 22% - 25% |
| H35 | 19 | 0.71 | 1447 | 329,729 | 326 | 23% | 25% - 35% |
| H36 | 22 | 0.72 | 1664 | 330,145 | 353 | 21% | 21% - 25% |
| H37 | 16 | 0.72 | 1838 | 491,579 | 511 | 28% | 28% - 30% |
| H39 | 22 | 0.74 | 3892 | 822,158 | 519 | 13% | 40% - 50% |
| H40 | 33 | 0.69 | 2949 | 411,352 | 787 | 27% | 45% - 55% |
| H41 | 27 | 0.73 | 4939 | 820,397 | 1679 | 34% | 60% - 65% |

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| H42 | 28 | 0.73 | 3181 | 481,582 | 1302 | 41% | 55% - 65% |
| H45 | 32 | 0.75 | 4343 | 606,922 | 842 | 19% | 30% - 40% |
| H46 | 26 | 0.72 | 3557 | 598,473 | 1350 | 38% | 50% - 65% |
| H47 | 22 | 0.73 | 4901 | 984,121 | 1033 | 21% | 50% - 65% |
| H51 | 25 | 0.72 | 6700 | 1,178,021 | 845 | 13% | 35% - 50% |
| H57 | 21 | 0.72 | 8733 | 1,768,000 | 1028 | 12% | 35% - 55% |
| H58 | 18 | 0.68 | 8726 | #N/A | 1944 | 22% | 40% - 50% |
| H59 | 18 | 0.70 | 9191 | #N/A | 1868 | 20% | 30% - 45% |
| H62 | 15 | 0.69 | 9144 | 2,734,667 | 1245 | 14% | 20% - 35% |
| H63 | 11 | 0.67 | 6798 | 2,742,767 | 1046 | 15% | 15% - 35% |
| H65 | 12 | 0.67 | 7266 | 2,641,134 | 1274 | 18% | 18% - 30% |
| H68 | 13 | 0.68 | 7016 | 2,490,035 | 986 | 14% | 20% - 35% |
| H69 | 13 | 0.68 | 7816 | 2,630,744 | 673 | 9% | 20% - 35% |
| J01 | 38 | 0.77 | 3002 | 322,674 | 2112 | 70% | 72% - 75% |
| J02 | 25 | 0.76 | 1926 | 319,882 | 1280 | 66% | 70% - 80% |
| J03 | 31 | 0.78 | 2576 | 334,676 | 1682 | 65% | 70% - 75% |
| J04 | 35 | 0.78 | 2804 | 323,742 | 1753 | 63% | 63% - 65% |
| J05 | 20 | 0.74 | 1515 | 326,851 | 796 | 53% | 53% - 55% |
| J06 | 31 | 0.74 | 2451 | 338,008 | 958 | 39% | 40% - 45% |
| J07 | 28 | 0.75 | 2147 | 325,143 | 1734 | 81% | 81% - 83% |
| J08 | 34 | 0.83 | 3027 | 331,895 | 2566 | 85% | 85% - 87% |
| J10 | 36 | 0.83 | 3068 | 318,930 | 2059 | 67% | 70% - 73% |
| J11 | 37 | 0.80 | 3136 | 316,976 | 1284 | 41% | 41% - 45% |
| J12 | 34 | 0.80 | 2773 | 309,991 | 1848 | 67% | 67% - 70% |
| J13 | 40 | 0.86 | 3480 | 310,583 | 2413 | 69% | 70% - 75% |
| J14 | 43 | 0.82 | 3692 | 335,978 | 1635 | 44% | 65% - 70% |
| J15 | 39 | 0.84 | 3356 | 321,799 | 2366 | 71% | 71% - 75% |
| J16 | 41 | 0.82 | 3424 | 315,616 | 1974 | 58% | 65% - 70% |
| J21 | 32 | 0.78 | 2584 | 342,840 | 1361 | 53% | 53% - 60% |
| J25 | 30 | 0.75 | 2358 | 324,313 | 796 | 34% | 34% - 40% |
| J27 | 25 | 0.80 | 2080 | 328,353 | 395 | 19% | 20% - 25% |
| K22 | 22 | 0.65 | 1526 | 329,325 | 516 | 34% | 34% - 35% |
| K23 | 15 | 0.65 | 2648 | 848,469 | 677 | 26% | 26% - 30% |
| K24 | 11 | 0.65 | 1897 | 809,848 | 507 | 27% | 27% - 30% |
| K26 | 14 | 0.66 | 1954 | 645,847 | 288 | 15% | 15% - 20% |
| L05 | 27 | 0.67 | 2831 | 495,108 | 1244 | 44% | 50% - 60% |

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| L06 | 20 | 0.72 | 2234 | 490,761 | 1533 | 69% | 70% - 75% |
| L07 | 20 | 0.74 | 2382 | 501,860 | 1453 | 61% | 61% - 65% |
| L08 | 8 | 0.65 | 812 | 473,030 | 475 | 58% | 60% - 65% |
| L09 | 24 | 0.66 | 2332 | 540,745 | 300 | 13% | 25% - 30% |
| L11 | 25 | 0.69 | 2755 | 489,823 | 1387 | 50% | 55% - 65% |
| M03 | 36 | 0.75 | 2807 | 327,035 | 843 | 30% | 30% - 35% |
| M04 | 32 | 0.76 | 2599 | 330,753 | 842 | 32% | 35% - 45% |
| M05 | 26 | 0.73 | 1998 | 327,665 | 482 | 24% | 25% - 35% |
| M06 | 25 | 0.73 | 1977 | 333,545 | 456 | 23% | 25% - 30% |
| M07 | 20 | 0.68 | 1454 | 328,371 | 285 | 20% | 20% - 25% |
| N01 | 20 | 0.73 | 11101 | 2,407,368 | 538 | 5% | 20% - 35% |
| N02 | 16 | 0.71 | 8621 | 2,409,732 | 297 | 3% | 15% - 30% |
| N03 | 15 | 0.71 | 7777 | 2,401,245 | 211 | 3% | 15% - 30% |
| N04 | 13 | 0.74 | 7589 | 2,399,090 | 313 | 4% | 20% - 35% |
| N05 | 14 | 0.76 | 7828 | 2,396,682 | 277 | 4% | 20% - 35% |
| N06 | 13 | 0.74 | 6383 | 2,119,119 | 227 | 4% | 20% - 35% |
| N07 | 14 | 0.71 | 6878 | 2,200,195 | 215 | 3% | 20% - 35% |
| N08 | 13 | 0.69 | 9307 | 2,736,576 | 201 | 2% | 20% - 35% |
| N09 | 12 | 0.66 | 9179 | 3,464,504 | 0 | 0% | 15% - 30% |
| P01 | 35 | 0.77 | 2730 | 317,709 | 789 | 29% | 30% - 35% |
| P02 | 25 | 0.73 | 1894 | 317,130 | 347 | 18% | 20% - 25% |
| P03 | 28 | 0.76 | 2255 | 329,951 | 487 | 22% | 22% - 25% |
| R01 | 32 | 0.74 | 2410 | 313,829 | 1093 | 45% | 50% - 55% |
| R02 | 32 | 0.71 | 2341 | 317,549 | 793 | 34% | 45% - 55% |
| R03 | 35 | 0.68 | 2580 | 336,378 | 755 | 29% | 35% - 40% |
| R04 | 28 | 0.70 | 2089 | 332,424 | 489 | 23% | 25% - 30% |
| R05 | 24 | 0.68 | 1734 | 325,946 | 613 | 35% | 45% - 50% |
| R06 | 17 | 0.71 | 1293 | 324,779 | 466 | 36% | 36% - 40% |
| R07 | 22 | 0.71 | 1631 | 337,454 | 651 | 40% | 40% - 40% |
| T01 | 28 | 0.72 | 4759 | 743,062 | 983 | 21% | 40% - 50% |
| T02 | 29 | 0.71 | 5216 | 806,525 | 768 | 15% | 35% - 45% |
| T03 | 23 | 0.70 | 3997 | 775,850 | 726 | 18% | 25% - 35% |
| T04 | 23 | 0.68 | 3908 | 775,056 | 657 | 17% | 25% - 35% |
| T05 | 31 | 0.69 | 5528 | 774,841 | 705 | 13% | 25% - 35% |
| T06 | 29 | 0.70 | 4696 | 710,449 | 712 | 15% | 40% - 50% |
| T07 | 33 | 0.72 | 5676 | 745,035 | 888 | 16% | 35% - 45% |

# Pad Recovery

| Pad | Net Pay (m) | Average Effective So | Effective OBIP (e3m3) | Drainage Area (m2) | Recovery to Sept 2016 | | Ultimate Recovery (% EBIP) |
|---|---|---|---|---|---|---|---|
| | | | | | e3m3 | % EBIP | |
| T08 | 30 | 0.72 | 5401 | 774,990 | 755 | 14% | 35% - 45% |
| T09 | 29 | 0.70 | 5005 | 775,378 | 530 | 11% | 35% - 45% |
| T10 | 35 | 0.70 | 5996 | 774,721 | 583 | 10% | 30% - 40% |
| T11 | 26 | 0.70 | 4499 | 774,660 | 637 | 14% | 20% - 30% |
| T12 | 26 | 0.70 | 4553 | 775,105 | 653 | 14% | 20% - 30% |
| T13 | 27 | 0.67 | 1489 | 777,953 | 191 | 13% | 25% - 35% |
| T14 | 19 | 0.72 | 6287 | 1,404,366 | 719 | 11% | 25% - 40% |
| T15 | 19 | 0.72 | 9624 | 2,275,165 | 834 | 9% | 25% - 40% |
| T18 | 18 | 0.69 | 5366 | 1,129,443 | 369 | 7% | 25% - 40% |
| U01 | 26 | 0.70 | 4668 | 809,886 | 1083 | 23% | 40% - 50% |
| U02 | 23 | 0.67 | 3772 | 777,104 | 937 | 25% | 45% - 60% |
| U03 | 29 | 0.69 | 4931 | 775,924 | 1005 | 20% | 50% - 65% |
| U04 | 30 | 0.72 | 5162 | 742,187 | 943 | 18% | 35% - 50% |
| U05 | 33 | 0.71 | 5912 | 805,485 | 912 | 15% | 35% - 45% |
| U06 | 23 | 0.68 | 3840 | 776,382 | 660 | 17% | 25% - 30% |
| U07 | 22 | 0.68 | 5617 | 1,177,350 | 679 | 12% | 20% - 30% |
| U08 | 20 | 0.68 | 4523 | 1,052,598 | 782 | 17% | 25% - 40% |
| U09 | 21 | 0.69 | 3822 | 824,646 | 641 | 17% | 30% - 45% |
| V01 | 29 | 0.69 | 4915 | 775,459 | 1003 | 20% | 40% - 50% |
| V02 | 29 | 0.72 | 5226 | 775,578 | 868 | 17% | 25% - 35% |
| V03 | 24 | 0.71 | 4454 | 807,966 | 697 | 16% | 20% - 30% |
| V04 | 29 | 0.71 | 4934 | 740,131 | 1018 | 21% | 40% - 55% |
| V05 | 27 | 0.67 | 4666 | 790,676 | 974 | 21% | 40% - 55% |
| V08 | 30 | 0.72 | 5380 | 775,455 | 946 | 18% | 40% - 55% |
| V09 | 27 | 0.77 | 4978 | 740,326 | 880 | 18% | 40% - 50% |
| V10 | 20 | 0.71 | 8774 | 2,046,491 | 1249 | 14% | 25% - 40% |
| V13 | 18 | 0.71 | 8516 | 2,003,100 | 700 | 8% | 20% - 30% |
| Y16 | 29 | 0.67 | 2444 | 439,317 | 802 | 33% | 40% - 50% |
| Y31 | 30 | 0.67 | 2146 | 326,381 | 663 | 31% | 40% - 50% |
| Y32 | 35 | 0.67 | 2539 | 328,955 | 268 | 11% | 45% - 50% |
| Y34 | 29 | 0.68 | 2123 | 376,127 | 670 | 32% | 40% - 45% |
| Y36 | 33 | 0.68 | 2917 | 437,859 | 774 | 27% | 40% - 50% |

# Future Plans

# Pad Steaming Priorities

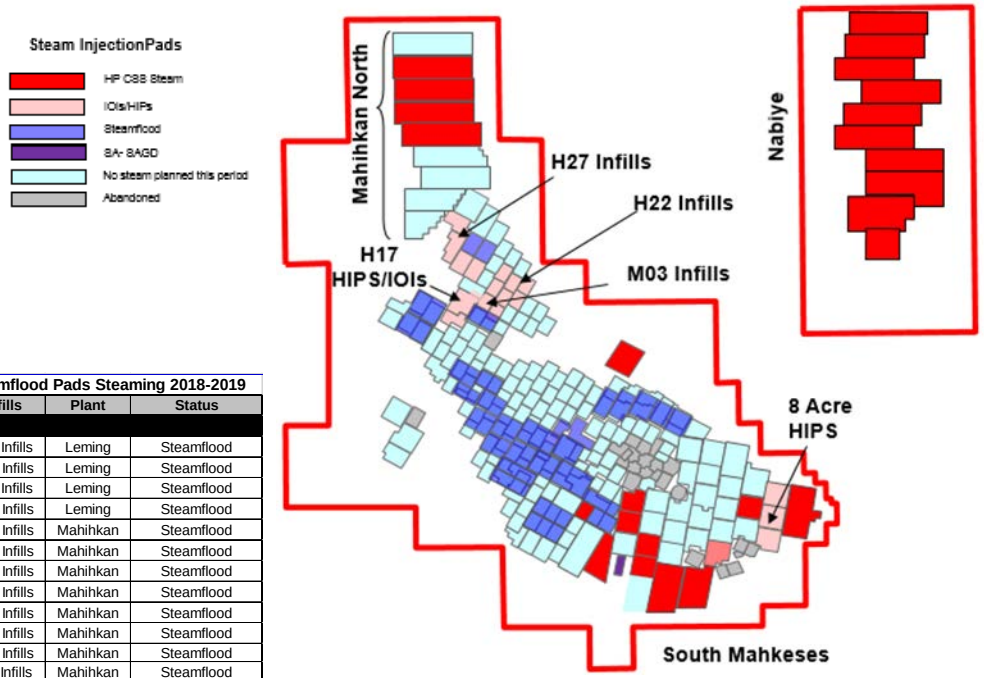
- Long-term steam plans developed annually
  - Targeted cycle timing based on historical performance and optimal cycle length
  - Development plans tied to projected steam demand at each site to fully utilize installed steam capacity

- Earlier cycle pads receive priority during periods of steam demand higher than plant capacity and for scheduling considerations
  - Pads are steamed less frequently as they mature (steam timing is less critical to performance)
  - Individual pad steaming suspended at an economic limit
  - Infill steamflood pads can operate effectively at a range of steaming rates, providing flexibility to steam scheduling

- Steam patterns are developed to balance cycle timing optimization, shear stress management and interwell communication

- Additional factors
  - Setback requirements between drilling and steaming operations

# Steam Plans to End 2019




**Steamflood Pads Steaming 2018-2019**

| | Infills | Plant | Status |
|---|---|---|---|
| Steamflood | T05 Infills | Leming | Steamflood |
| | 00U Infills | Leming | Steamflood |
| | 0FF Infills | Leming | Steamflood |
| | G02 Infills | Leming | Steamflood |
| | H01 Infills | Mahihkan | Steamflood |
| | H04 Infills | Mahihkan | Steamflood |
| | H11 Infills | Mahihkan | Steamflood |
| | H15 Infills | Mahihkan | Steamflood |
| | H17 Infills | Mahihkan | Steamflood |
| | H22 Infills | Mahihkan | Steamflood |
| | H24 Infills | Mahihkan | Steamflood |
| | J06 Infills | Mahihkan | Steamflood |
| | J07 Infills | Mahihkan | Steamflood |
| | J08 Infills | Mahihkan | Steamflood |
| | J10 Infills | Mahihkan | Steamflood |
| | J16 Infills | Mahihkan | Steamflood |
| | L09 Infills | Mahihkan | Steamflood |
| | A06 Infills | Maskwa | Steamflood |
| | D01 Infills | Maskwa | Steamflood |
| | D02 Infills | Maskwa | Steamflood |
| | D03 Infills | Maskwa | Steamflood |
| | D04 Infills | Maskwa | Steamflood |
| | D05 Infills | Maskwa | Steamflood |
| | D06 Infills | Maskwa | Steamflood |
| | D07 Infills | Maskwa | Steamflood |
| | D10 Infills | Maskwa | Steamflood |
| | D12 Infills | Maskwa | Steamflood |
| | D22 Infills | Maskwa | Steamflood |
| | D24 Infills | Maskwa | Steamflood |
| | E08 Infills | Maskwa | Steamflood |
| | E09 Infills | Maskwa | Steamflood |
| | F02 Infills | Maskwa | Steamflood |
| | F03 Infills | Maskwa | Steamflood |

**Nabiye 18 Corporate Plan Steam Schedule**

Date Prepared: April 2018

| | Pad | Date | Cycle | Status | Forecasted Vol/EBHS |
|---|---|---|---|---|---|
| 2018 | N06 | 15-Oct-18 | 6 | HPCSS | 10,000 |
| | N07 | 1-Dec-18 | 6 | HPCSS | 10,000 |
| 2019 | N10 | 15-Jan-19 | 1 | HPCSS | 2,500 |
| | N08 | 1-Feb-19 | 5 | HPCSS | 9,000 |
| | N09 | 1-Mar-19 | 5 | HPCSS | 8,000 |
| | N10 | 15-Apr-19 | 1* | HPCSS | 2,500 |
| | N01 | 1-May-19 | 7 | HPCSS | 11,500 |
| | N10 | 15-Jun-19 | 2 | HPCSS | 5,000 |
| | N02 | 15-Jul-19 | 6 | HPCSS | 9,500 |
| | N03 | 1-Aug-19 | 6 | HPCSS | 9,000 |
| | N04 | 15-Oct-19 | 7 | HPCSS | 12,000 |
| | N10 | 1-Dec-19 | 3 | HPCSS | 6,000 |

**Mahihkan 18 Corporate Plan Steam Schedule**

Date Prepared: April 2018

| | Pad | Date | Cycle | Status | Forecasted Vol/EBHS |
|---|---|---|---|---|---|
| 2018 | H62 | Oct | 7 | HPCSS LASER | 17,000 |
| | H22 IOI | Nov | 2 | LPIOI | 10,000 |
| 2019 | H63 | Feb | 6 | HPCSS LASER | 14,000 |
| | M03 IOI | Feb | 1 | LPIOI | 20,000 |
| | H17 HIP | Mar | 1 | HPCSS | 10,000 |
| | H65 | Aug | 8 | HPCSS LASER | 20,000 |
| | H27 IOI | Sep | 1 | LPIOI | 20,000 |
| | H68 | Nov | 7 | HPCSS LASER | 17,000 |

**Maskwa 18 Corporate Plan Steam Schedule**

Date Prepared: April 2018

| | Pad | Date | Cycle | Status | Forecasted Vol/EBHS |
|---|---|---|---|---|---|
| 2019 | F08 | December | 7 | HPCSS | 17,000 |

**Leming 18 Corporate Plan Steam Schedule**

Date Prepared: April 2018

| | Pad | Date | Cycle | Status | Forecasted Vol/EBHS |
|---|---|---|---|---|---|
| 2019 | Y32 | August | 7 | HPCSS | 17,000 |

**Mahkeses 18 Corporate Plan Steam Schedule**

Date Prepared: April 2018

| | Pad | Date | Cycle | Status | Forecasted Vol/EBHS |
|---|---|---|---|---|---|
| 2018 | V28 HIPs (6-9) | 3-Sep-18 | 3 | HPCSS HIPs | 12,000 |
| | V02 IOIs (29-32) | 15-Sep-18 | 2 | HP IOI | 15,000 |
| | V03 Pad | 15-Sep-18 | 10 | HPCSS | 15,000 |
| | T15 Dev Wells | 13-Nov-18 | 7 | HPCSS | 27,000 |
| | V13 Pad | 13-Nov-18 | 6 | HPCSS | 18,000 |
| | T05 Pad | 10-Dec-18 | 12 | HPCSS | 36,000 |
| 2019 | T15 Hz Wells | 1-May-19 | 7 | HPCSS | 27,000 |
| | T06 Pad | 1-May-19 | 12 | HPCSS | 40,000 |
| | T12 Pad | 1-May-19 | 12 | HPCSS | 31,000 |
| | T18 Pad | 1-Aug-19 | 6 | HPCSS | 23,000 |
| | T09 Pad | 1-Aug-19 | 11 | HPCSS | 29,000 |
| | V09 HIPs (25-28) | 15-Sep-19 | 4 | HPCSS HIPs | 15,000 |
| | V28 HIPs (1-5) | 1-Nov-19 | 4 | HPCSS HIPs | 15,000 |
| | V10 Pad | 1-Nov-19 | 8 | HPCSS | 28,000 |
| | V05 Pad | 15-Nov-19 | 10 | HPCSS | 33,000 |
| | V28 HIPs (6-9) | 15-Dec-19 | 4 | HPCSS HIPs | 15,000 |

Corporate Plan steam schedule. This schedule is subject to change



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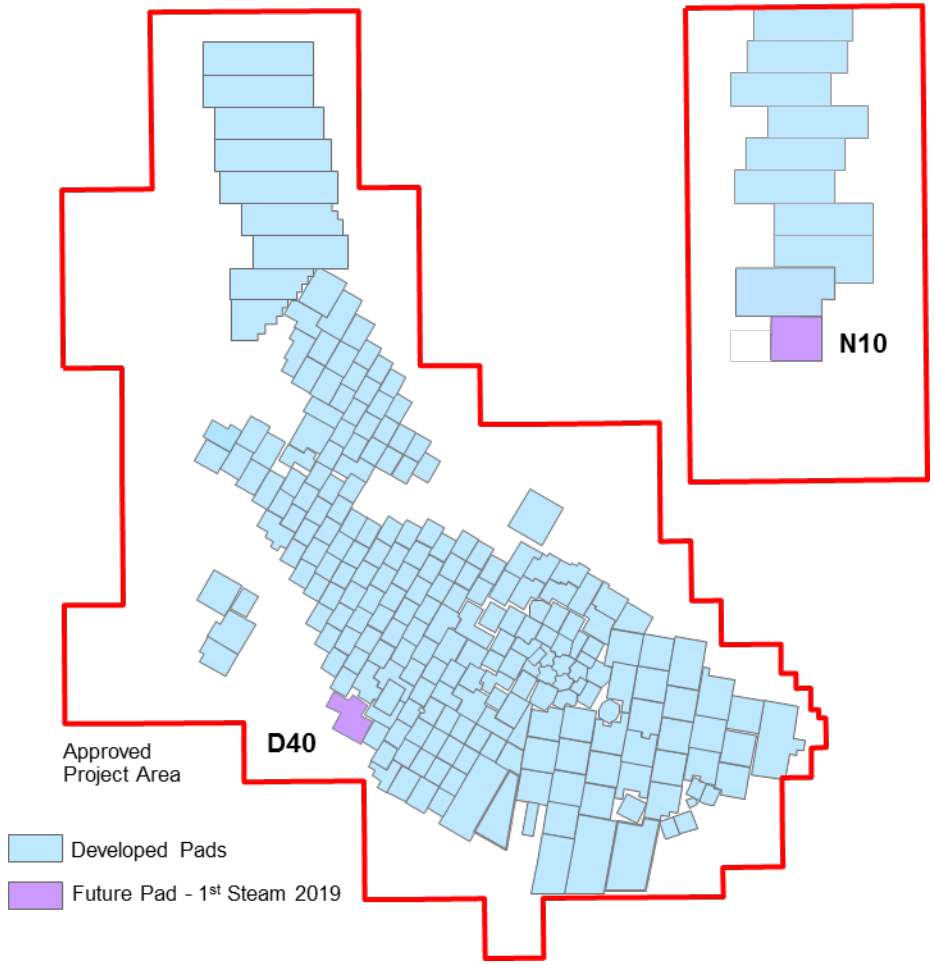
# Pad Development Program




**Drilling and Steaming Schedule**

| | | |
|---|---|---|
| N10 | 2018 | 2019 |
| D40 | 2019 | 2019 |



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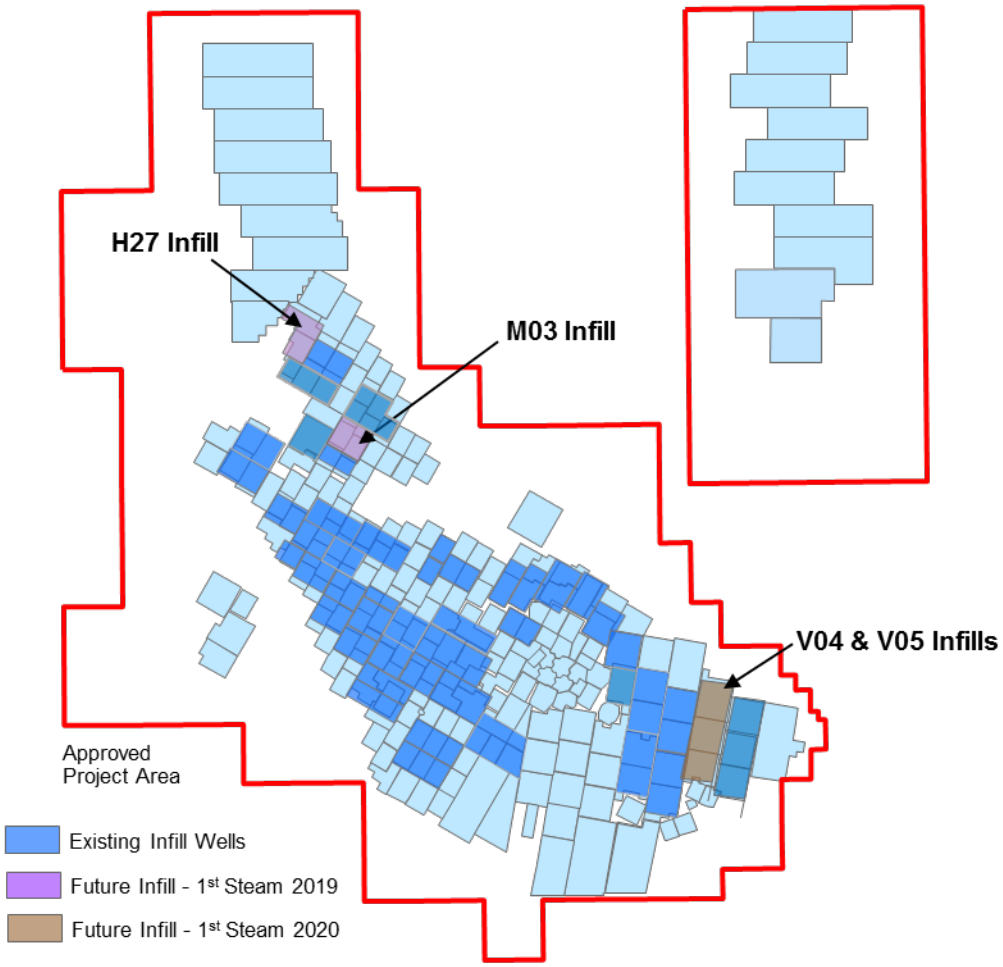
# Infill Drilling Program




**Drilling and Steaming Schedule**

| Infill Pad | Year Drilled | 1st Steam |
|---|---|---|
| M03 | 2018 | 2019 |
| H27 | 2018 | 2019 |
| V04 | 2019 | 2020 |
| V05 | 2019 | 2020 |



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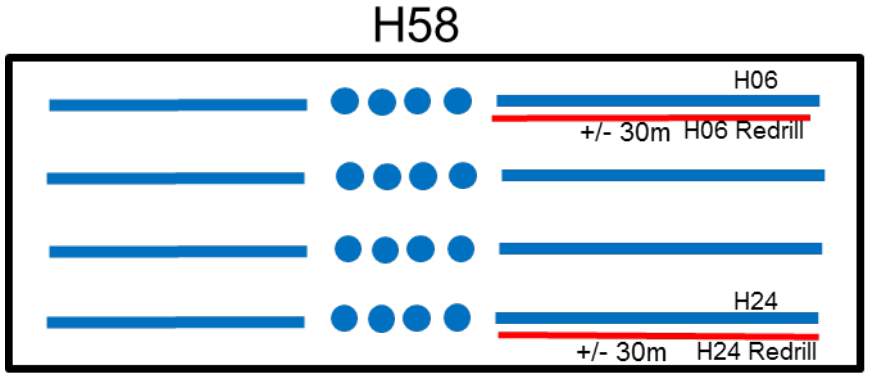
# H58 Redrill Program

- Pad Status
  - H58-H06 and H24 were Clearwater Abandoned in 2015 after suspected Clearwater Top Failure
  - H58-H06 was converted to Lower Grand Rapids Monitoring Well in December 2017
  - H58 Pad is in CSS Cycle 8 production

- Project Scope
  - To redrill two horizontal wells with +/- 30m offset to the existing wellbores without adding any additional surface facilities

- Backup Project Scope
  - If issues encountered during redrilling, then drill maximum two Horizontal Injector Producers (HIPs) on the west side of the pad to infill western CSS horizontal wells



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# T-13
# SA-SAGD Pilot

# Summary

Solvent Assisted - Steam Assisted Gravity Drainage pilot in Cold Lake

Pilot Design:

- Two horizontal well pairs (four wells)
- Six observation wells (OB wells)
- Injection and testing facilities
- Located in Mahkeses Field

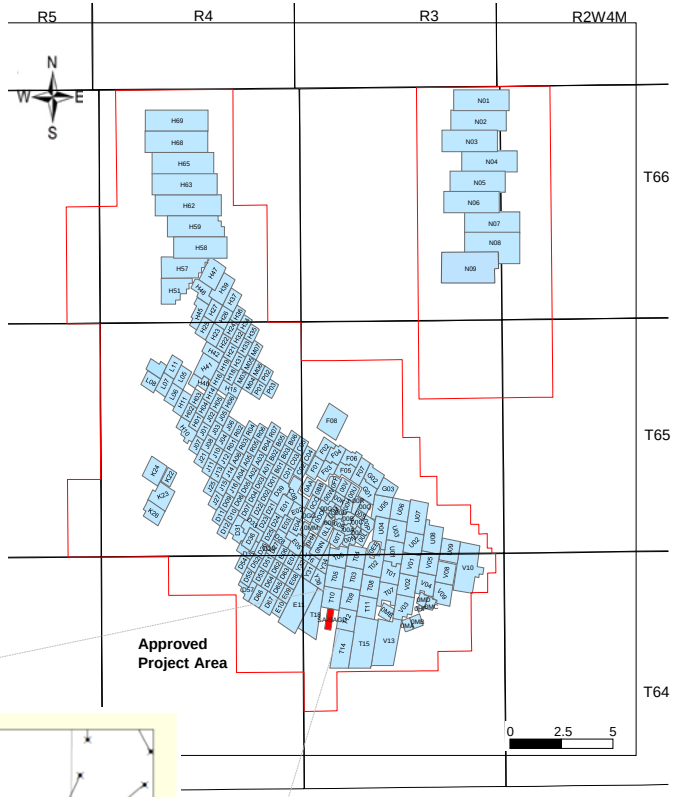
Pilot Approval 10689D rescinded and transitioned to Approval 8558 on July 14, 2016

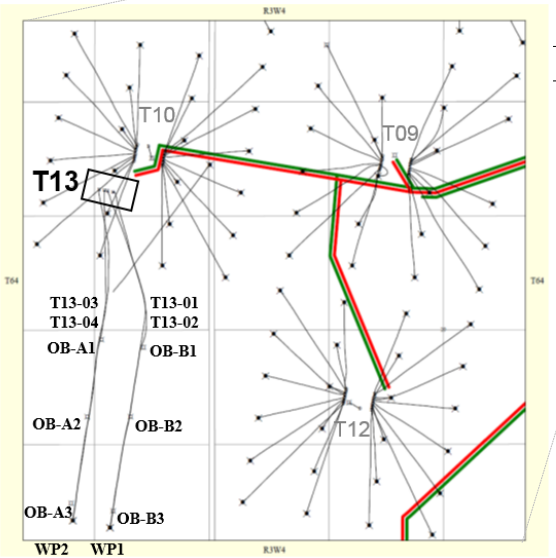
Key Milestones

- Q4 2009: Pilot start-up
- 2010 - 2012: WP2 SA-SAGD, WP1 SAGD
- 2012 - 2016: WP2 SAGD, WP1 SA-SAGD
- 2016: WP2 Shut-in, WP1 SAGD
- 2018: WP2 restarted SAGD

Recovery to date:

| | Cumulative Hydrocarbon Production (km3) | OBIP (km3) |
|---|---|---|
| **T13** | **222** | **1062** |




Legend

- Heavy Oil Well
- Observation Well
- Directional Well Path
- Steam Pipeline
- Production Pipeline

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# Well Schematics (SAGD / SA-SAGD Mode)

Injection wells configured with:

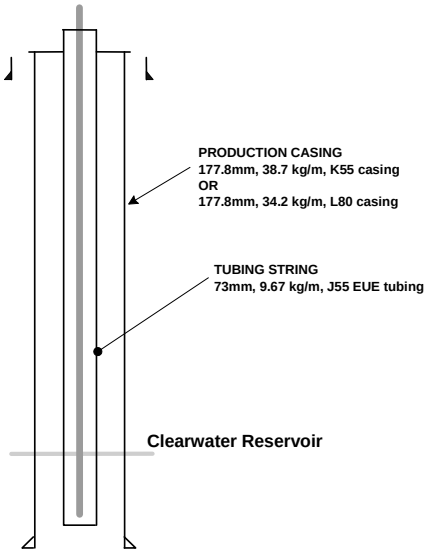
- Horizontal slotted liner
- Toe / heel tubing string (steam injection)
- Intermediate casing (filled with N2)

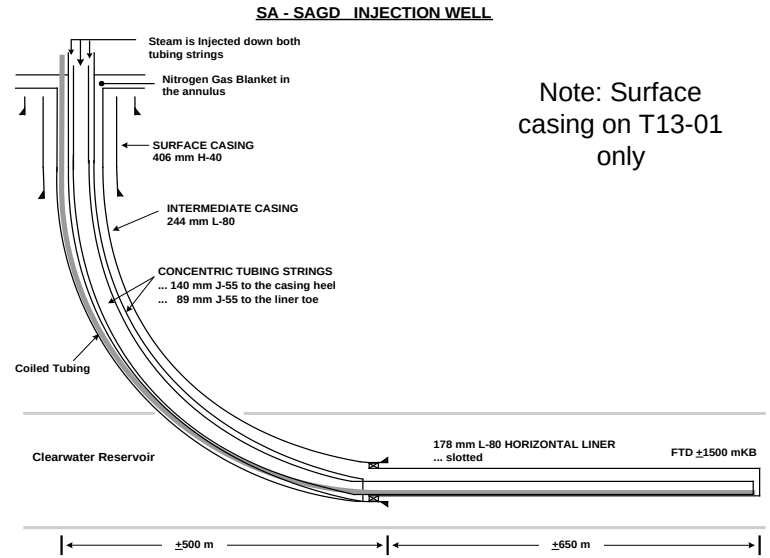
Production wells configured with:

- Horizontal slotted liner
- Downhole pump at heel of well
- Production tubing for fluids
- Intermediate casing for gas production

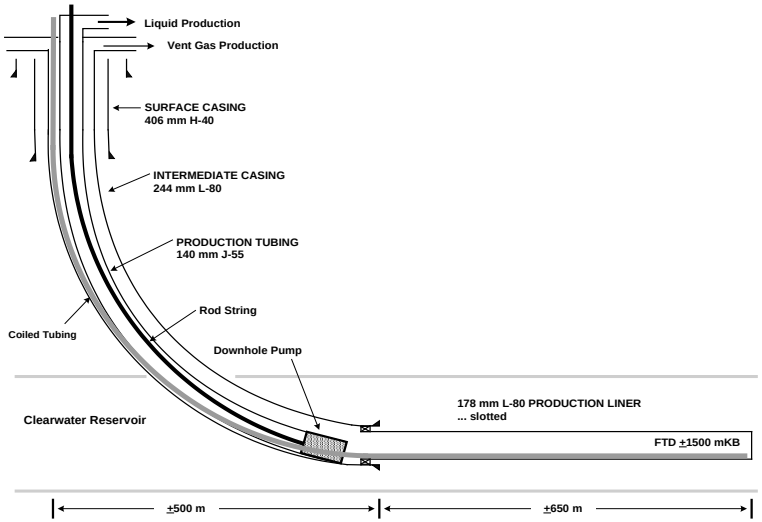
Instrumentation in wells include:

- 3 bubble tubes & 20 thermocouples in producers
- 12 thermocouples in injectors
- Between 27 and 34 thermocouples in OB wells




Note: Surface casing on T13-01 only



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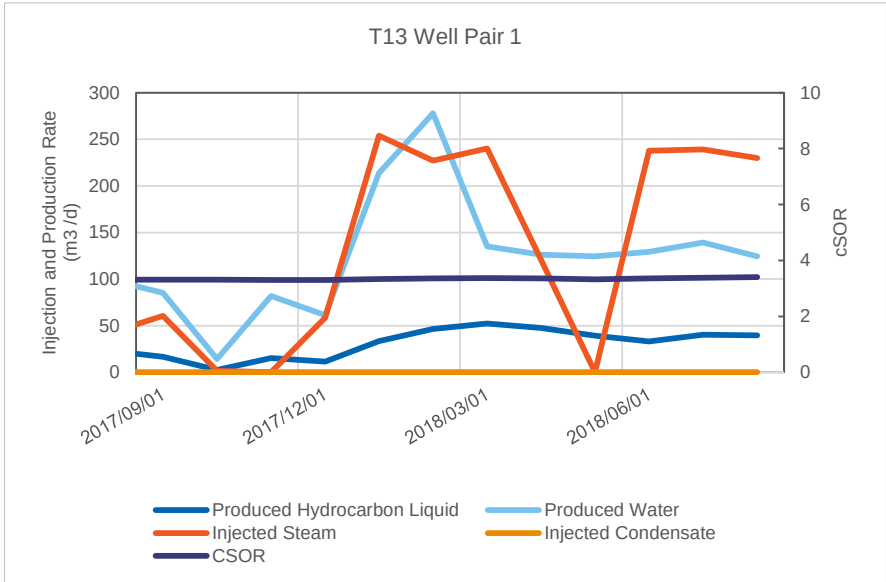
# 2018 Overview

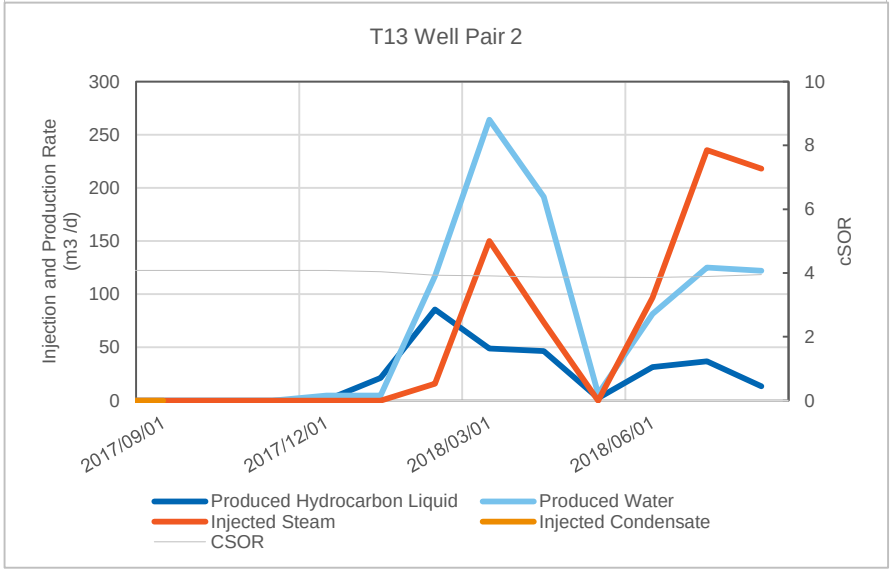
Key Events:

- Steam Outage: Mahkeses PM (May-June), T13 annual PM (September)
- Steam Separator: Performance impacted during extreme cold weather (Dec / Jan)
- Well Pair 1 (WP1): Acid stimulation job (Dec). SAGD operation mode stable in 2018
- Well Pair 2 (WP2): Production restarted after acid stimulation workover (Dec). Steam injection restarted late Feb

Future Plans:

- WP1: Optimize operating parameters
- WP2: Study post restart performance



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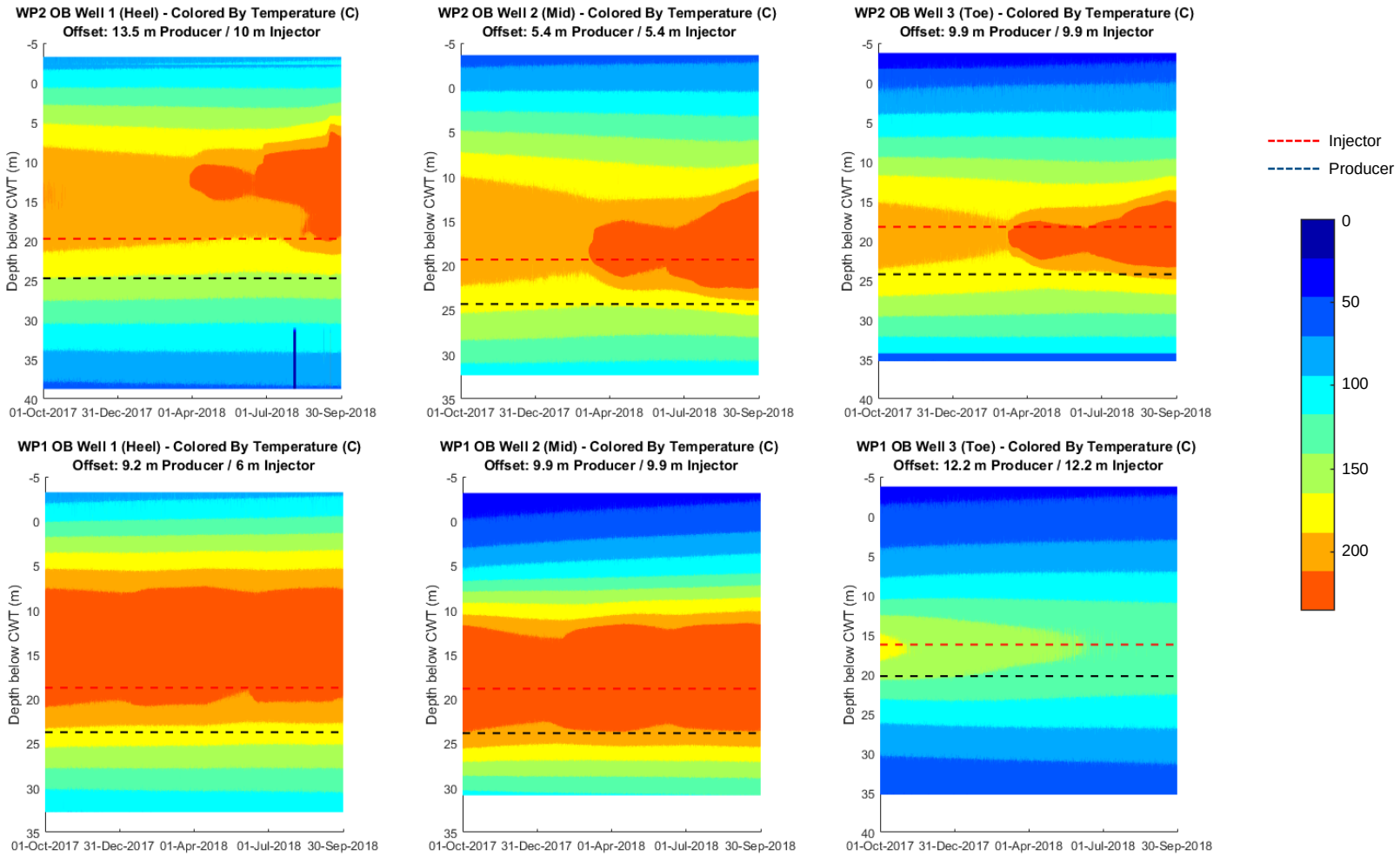
# Observation Well Temperatures

- Temperature at observation (OB) wells provides a measure of amount of heat transferred to reservoir
- WP2 OB well temperatures increasing post restart
- WP1 OB well temperatures stable, with few variances due to steam interruptions

WP2

WP1



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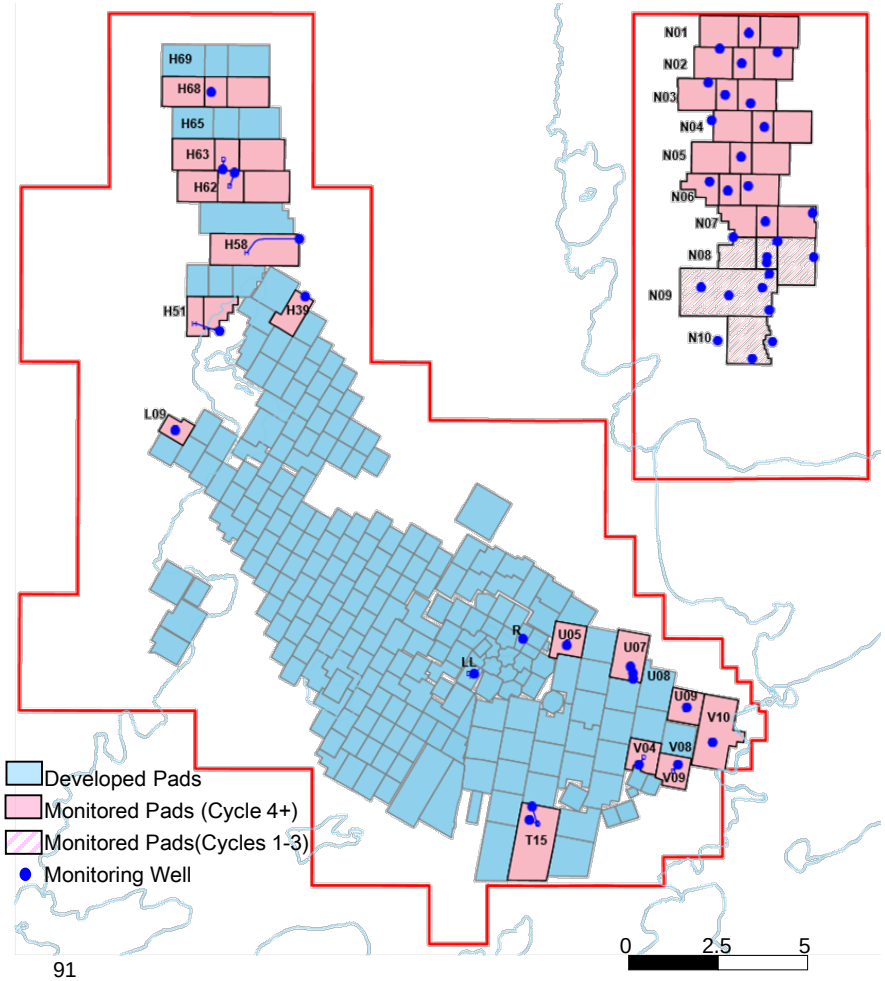
# Other Discussion Items

# Grand Rapids Monitoring Program

**Objective**

- Apply risk-based approach and monitor specific pads at Cold Lake for potential fluid excursions into the Grand Rapids formation.
- If excursion occurs, identify sources, determine volumes, notify AER, mitigate, and take steps to limit future fluid excursions.
- Cold Lake Commercial Scheme (8558II) amended Aug 2017 for Nabiye Operating Practices




| Pad | Basis |
|---|---|
| U05 | Elevated Upper Grand Rapids (UGR) pressure |
| U07 | Elevated Upper Grand Rapids (UGR) pressure |
| U09 | Elevated Lower Grand Rapids (LGR) pressure |
| V04 | Increase monitoring network |
| V09 | Increase monitoring network |
| V10 | Poor primary cement bond log |
| T15 | Potential cement channels |
| LL | Unsuccessful abandonment of adjacent OV well |
| L09 | Control pad |
| H39 | Increase monitoring network |
| H51 | Possible ghost hole in the Grand Rapids |
| H58 | Increase monitoring network |
| H62 | Poor primary cement bond log |
| H63 | Poor primary cement bond log |
| H68 | Control pad |
| Nabiye | Geologic factors and proximity to FTS |



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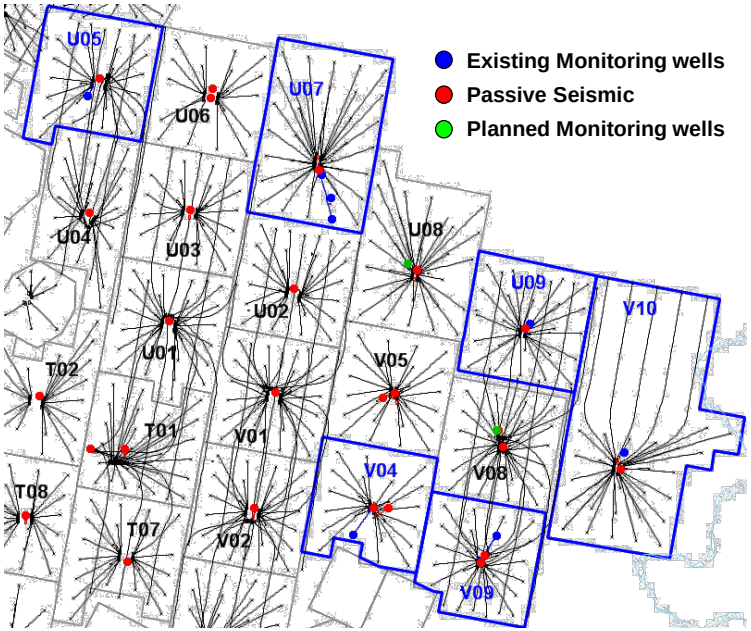
# U/V Trunk Grand Rapids Monitoring

**Grand Rapids Monitoring Program**

- All Pads: Standard passive seismic; Steam injection rates and pressures
- U05: One pressure monitoring well in UGR
- U07: One pressure monitoring well in LGR and two wells in UGR, and one additional passive seismic well to monitor the Grand Rapids
- U09: Monitoring discontinued at U09-08 in 2016 and U09-13 recompleted as UGR/LGR pressure monitoring well
- V04: One pressure monitoring well in LGR
- V09: One pressure monitoring well in LGR
- V10: One pressure monitoring well in LGR and UGR




**Observations**

- U07 - Pressure responses in the LGR and UGR observed at U07 in Cycle 2 and 3 were not observed in Cycle 4 when most likely source wells were selectively steamed. Poro-elastic response observed in Cycle 5 and minor fluid excursion observed at well U07-20 in Cycle 6 (2015) under Cold Lake steaming best practices. Fluid excursion was detected in Cycle 7 (2018).
- V10 - GR pressure responses at V10 diminished between cycles 2 – 6. Increased LGR pressure responses observed in Cycle 7 (2017) from a faulty downhole well packer. New monitoring well drilled and 3 legacy monitoring wells converted into HP CSS wells.
- U09 - Pressure responses in the LGR and UGR observed at U09-13 during Cycle 8 steam. Poro-elastic response observed in UGR and a fluid excursion detected in the LGR.

**Conclusions**

- Previous conclusion that excursions are an early cycle phenomenon is challenged by recent observations of excursions on pads that had a number of cycles without excursions
- High pressures in UGR bitumen zones can be highly localized

**Plans**

- Steam all pads with high overlap strategy per Cold Lake best practices –including infill wells on U09, V08 and V09
- Progress additional GR monitoring at U08 & V08



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# Mahihkan North Grand Rapids Monitoring

## Grand Rapids Monitoring Program

- H39: 1 LGR & UGR pressure monitoring well
- H51: 1 LGR pressure monitoring well
- H58: 1 LGR pressure monitoring well
- H62: 1 LGR pressure monitoring well
- H63: 1 LGR pressure monitoring well
- H68: 1 Hybrid Passive Seismic Well with LGR pressure monitoring

## Observations

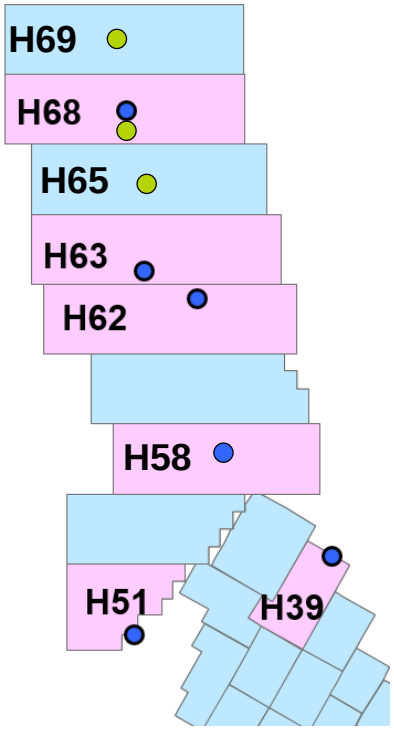
- H51 – Fluid excursion was detected in Cycle 7 (2015). Monitoring well re-perforated into higher quality Lower Grand Rapids water sand 13 metres above original perforations. Fluid excursion was detected in Cycle 8 (2017)
- H58 – Fluid excursion was detected in Cycle 8 (2018)
- H62 – Fluid excursion was detected in Cycle 6 (2016)
- H63 – Only poro-elastic responses observed during steaming
- H68 – Possible excursion identified in Cycle 3 (2013). Poro-elastic responses observed during steaming Cycle 5 (2015). Fluid excursion was detected in Cycle 6 (2017)

## Conclusions

- Cement channels on H62-H63 are not significant pathways for fluid excursions to the Grand Rapids

## Plans

- Progress additional GR monitoring at H65, H68, H69




Existing Monitoring Wells

Planned Monitoring Wells



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# Nabiye Grand Rapids Practices

## Factors that may impact fluid containment in the Clearwater formation at Nabiye

- Salt dissolution can create fractures in the overlying Clearwater shale
- Thicker overburden increases likelihood of vertical fracturing
- Presence of Mannville faults that intersect the Clearwater shale
- Proximity to CNRL Primrose East flow-to-surface events

## Prevention Practices – Designed to prevent out-of-zone fluid excursions

- Reduced steam volume targets for all Nabiye pads compared to Cold Lake Best Practices when necessary
- Increased well spacing at Nabiye reduces uplift-induced stress changes in the Colorado shale
- Increased well spacing at Nabiye reduces risk of multi-well excursion event
- Proven drilling and cementing practices
- Nearby abandoned wells thoroughly reviewed and confirmed as being competent
- Extensive casing integrity program

## Detection Practices – Designed to identify and locate excursions

- Pressure monitoring network of 28 wells covering 44 zones within the Grand Rapids
- Automated alarm system to detect rapidly changing pressure
- 4-D seismic surveys; first survey acquired across pads N01-N04, additional surveys acquired for N01,N02,N07,N08 in 2018
- Passive seismic monitoring, well injectivity monitoring and casing integrity verification

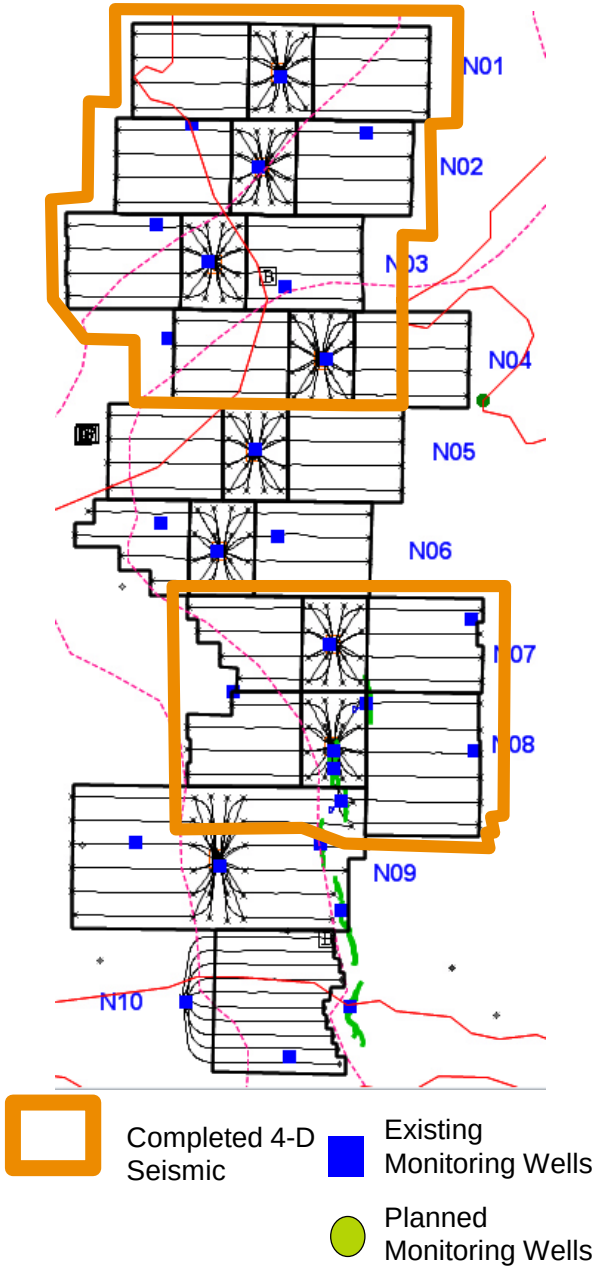
## Response Practices – Designed to minimize the volume of excursions

- Identify suspect steaming wells which are then shut-in and may be re-started with lower target volumes
- Reduce steam to field when necessary to manage reduced target well volumes
- Reduce steam rates
- Re-steam suspect wells in the same or subsequent cycles to build horizontal stress to favour horizontal fractures

# Nabiye Grand Rapids Monitoring

| Pad | Wells (year installed) | Monitored Zones | Fluid Excursion Confirmed |
|---|---|---|---|
| N01 | N01 (2013) | LGR,UGR | All cycles |
| N02 | N02-C (2014), N02-E (2016), N02-W (2016) | LGR,UGR | All cycles |
| N03 | N03-C (2014), N03-E (2016), N03-W (2016) | LGR,UGR | All cycles |
| N04 | N04-C (2014), N04-W (2016) | LGR,UGR | Cycles 1, 3 and 5 |
| N05 | N05 (2013) | LGR,UGR | Cycles 2, 3 and 5 |
| N06 | N06-C (2014), N06-E (2017), N06-W (2017) | LGR | Cycle 3,4,5 |
| N07 | N07-FMW* (2013), N07-C (2014), N07-E (2017) | LGR, UGR, PS | All cycles |
| N08 | N08-C (2013), N08-FMW* (2014), N08-E (2017), N08-W (2017) | LGR, UGR, PS | All Cycles |
| N09 | N09 (2014), N09-FMW1 (2015), N09-FMW2 (2015), N09-FMW3 (2015), N09-W (2018) | LGR, UGR, PS | All Cycles |
| N10 | N10-S (2017), N10-C (2018), N10-FMW (2018) | LGR, UGR, PS | Not yet steamed |

*Note: All FMW wells include passive seismic monitoring




## Observations

- Fluid excursions to the Grand Rapids have been observed consistently during early cycles
- Post-steam seismic anomalies identified via 4-D seismic on pads N01 and N02

## Conclusions

- Combination of geologic factors likely contributing to increased fluid excursions relative to the rest of Cold Lake
- Monitoring and response practices effective at identifying and mitigating fluid excursions

## Plans

- Continue to apply the Prevention, Detection and Response Practices developed for Nabiye (see previous page)
- 1 additional Grand Rapids monitoring wells planned over N04 east horizontal wells



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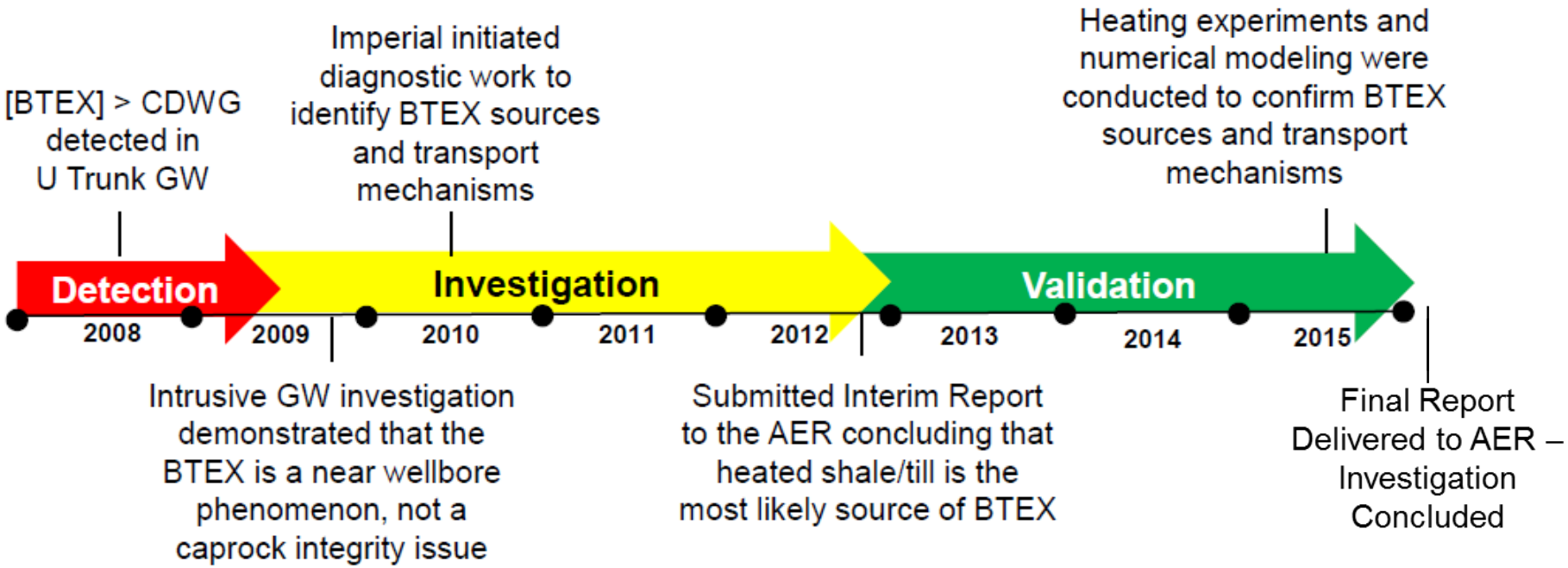
# Investigation of BTEX in Deep Groundwater Monitoring Wells

**Purpose**

- Confirm the sources and transport mechanism of BTEX in groundwater

**Background**




**Conclusions**

- Heated Colorado Shales and Glacial Tills are the primary sources of BTEX
- No pathway from the Grand Rapids or Clearwater formations to aquifers
- Flow outside casing in Colorado Shales and Quaternary and direct fluid exchange from the shales or tills are the most likely transport mechanisms for BTEX introduction to the aquifers
- BTEX generation ceases when heating stops and attenuation in the aquifers will reduce BTEX concentration over time

# Facilities

# Facility Modifications

Mahkeses Plant Debottleneck

- Cleaned SRU inlet gas piping and upgraded HRSG duct burner controls
- Installed clean out hot taps for online line cleaning
- Installed additional hot lime softener outlet lines to reduce pressure loss
- Restored >4000m3/day treated water capacity lost due to line fouling

# Facility Performance

## Bitumen Treatment and Vapour Recovery

- Bitumen production remained within AER inlet license limits over reporting period

| AER Inlet License | Maskwa | Mahihkan | Leming | Mahkeses | Nabiye |
|---|---|---|---|---|---|
| Bitumen License ($m^3$/d) | 11,000 | 15,000 | 5,000 | 8,000 | 8,000 |
| Actual Oct/17 – Sep/18 ($m^3$/d monthly avg) | 5,831 | 8,024 | 1,205 | 5,471 | 3,405 |

- Issues & Limitations
  - None

- Major Downtime
  - Maskwa Plant Shut Down – 24 days partial, 12 days total May/Jun 2018
  - Mahkeses GTG/HRSG's inspection – 20 days Apr 2018
  - Nabiye GTG/HRSG inspection – 23 days Sep/Oct 2018

- Major Equipment Failures
  - None

- Vapour Recovery Performance - >99% produced gas recovery Oct/17 to Sep/18
  - Recent activities to improve venting performance:
    - P4 tank farm STVR header replacement with larger stainless steel piping
    - Continued use of Forward Looking Infra-red (FLIR) camera
    - Optimizing tank PVRV settings and increased surveillance

# Facility Performance

## Water Treatment

- Water production remained within AER inlet licence limits over reporting period

| AER Inlet License | Maskwa | Mahihkan | Leming | Mahkeses | Nabiye |
|---|---|---|---|---|---|
| Water License ($m^3$/d) | 38,000 | 50,000 | 13,500 | 28,000 | 22,665 |
| Actual Oct/17 – Sep/18 ($m^3$/d monthly avg) | 24,430 | 32,020 | 6,112 | 20,574 | 12,628 |

- Issues & Limitations
  - Continued focus on improving treated water transfer from Maskwa & Mahkeses to Leming

- Major Downtime
  - Mahkeses GTG/HRSG inspection Apr 2018
  - Nabiye GTG/HRSG inspection Sep/Oct 2018

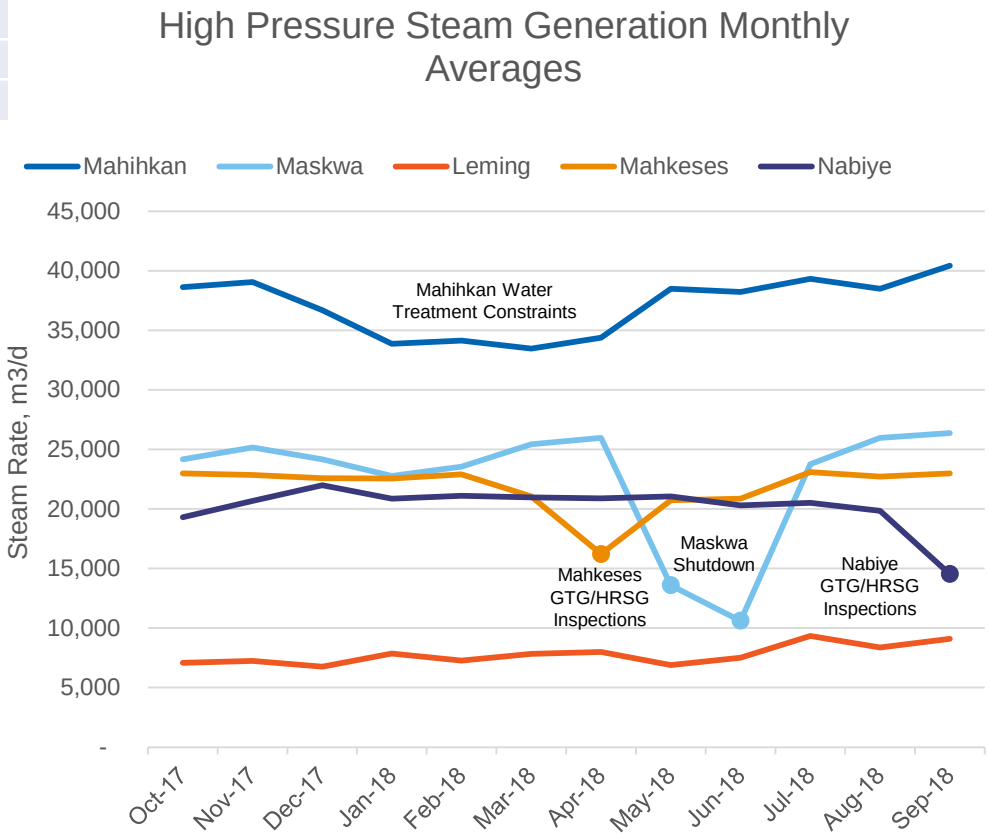
- Major Equipment Failures
  - None

# Facility Performance

## Steam Generation

| Cold Lake District HP Steam Generation (m³/d) | | | | | | |
|---|---|---|---|---|---|---|
| 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 YTD |
| 90,386 | 93,445 | 90,361 | 118,144 | 108,158 | 111,782 | 108,233 |

- Nabiye steam reduction -1500 m³/d
  - Field steam strategy
- Leming steam increase +1000 m³/d
  - Field steam economics/strategy
- Major Downtime
  - Maskwa Plant Shut Down – 24 days partial, 12 days total May/Jun 2018
  - Mahkeses GTG/HRSG's inspection – 20 days Apr 2018
  - Nabiye GTG/HRSG inspection – 23 days Sep/Oct 2018
- Mahihkan water treatment constraints due to pipeline and HLS flow restrictions Q1 2018
- Major Equipment Failures
  - None



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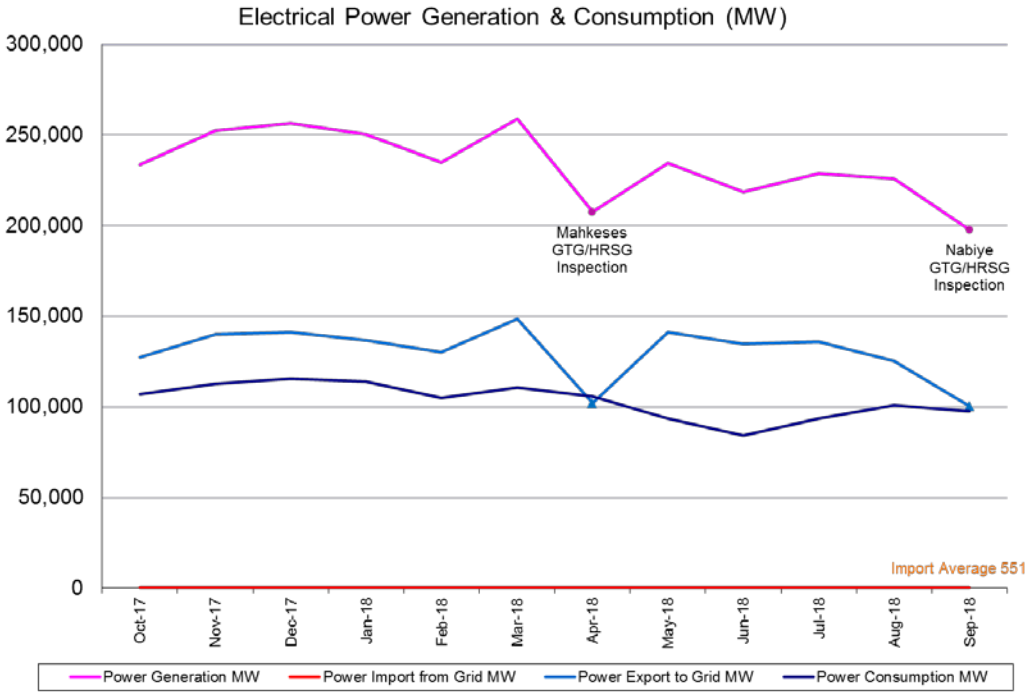
# Facility Performance

## Electrical Power Generation and Consumption

- Mahkeses & Nabiye Plants each have two gas turbine electrical power generators within a co-generation steam plant that generates power for the district and exports power to the Alberta power grid
- Power in 2018 was imported only to Imperial facilities that are outside the district power grid, from the Alberta power grid
- Issues & Limitations
  - None
- Major Downtime
  - Mahkeses gas turbine generator planned inspections – 20 days planned inspections Apr 2018
  - Nabiye gas turbine generator planned inspections – 23 days planned inspections Sep/Oct 2018
- Major Equipment Failures
  - None



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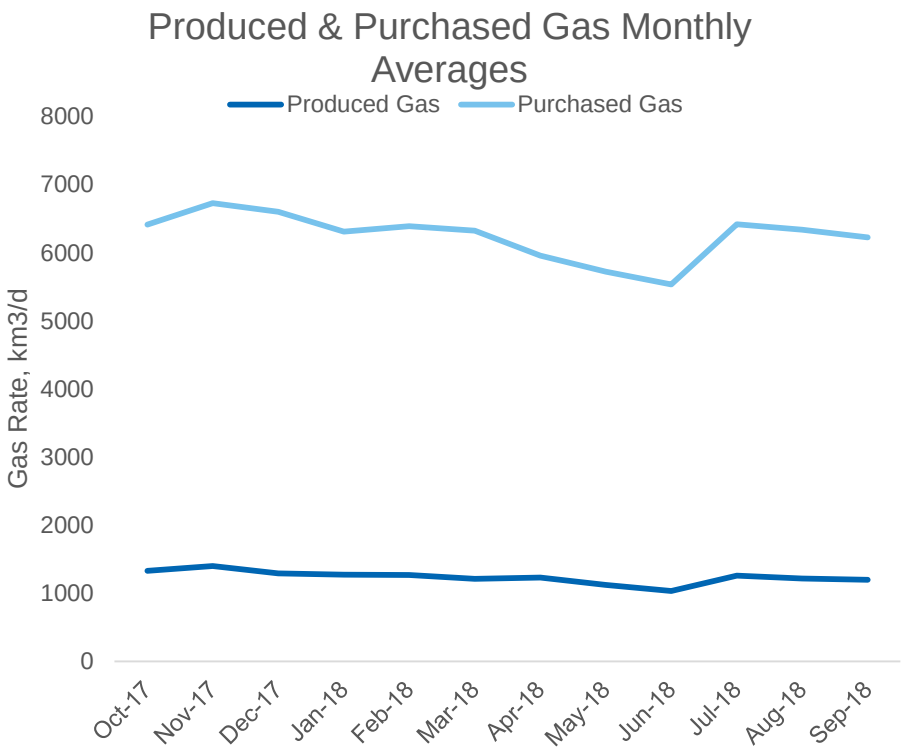
# Facility Performance

## Produced Gas Management

- All recovered produced gas used as fuel for high pressure steam generation
- Purchased sweet gas is used for steam generation (high and low pressure) and heater operation
- Issues and Limitations
  - None
- Major Downtime
  - As per bitumen and water summaries
- Major Equipment Failures
  - None



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# Measurement & Reporting

- There were zero compliance issues with volume reporting for CLO for the reporting period Q4 2017-Q3 2018

# Proration Factors

## Cold Lake Oct 2017 - Sep 2018 Profac Report

Profacs which are outside tolerated limits

| Battery Code (1330520) | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LEMING | OIL | 0.85-1.15% | 1.07 | 1.09 | 1.13 | 1.14 | 1.17 | 1.17 | 1.17 | 1.21 | 1.17 | 1.12 | 1.17 | 1.23 | 1.15 |
| | WATER | 0.85-1.15% | 1.11 | 1.12 | 1.09 | 1.11 | 1.07 | 1.07 | 1.09 | 1.11 | 1.16 | 1.17 | 1.17 | 1.19 | 1.12 |
| | GAS | | 1.10 | 1.14 | 1.15 | 1.25 | 1.25 | 1.16 | 0.96 | 0.93 | 0.97 | 1.03 | 1.13 | 1.23 | 1.11 |
| Leming Steam Inj | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
| IF:0007678 | STEAM | | 0.86 | 0.73 | 0.77 | 0.86 | 0.88 | 0.85 | 0.83 | 0.76 | 0.80 | 0.82 | 0.92 | 1.00 | 0.84 |

| Battery Code (0111783) | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAHKESES | OIL | 0.85-1.15% | 0.90 | 0.89 | 0.87 | 0.87 | 0.93 | 0.87 | 0.88 | 0.88 | 0.92 | 0.86 | 0.83 | 0.89 | 0.88 |
| | WATER | 0.85-1.15% | 1.12 | 1.08 | 1.06 | 1.15 | 1.13 | 1.00 | 1.04 | 1.07 | 1.07 | 1.13 | 1.12 | 1.12 | 1.09 |
| | GAS | | 0.84 | 0.89 | 0.78 | 0.81 | 0.92 | 0.90 | 0.86 | 0.87 | 0.94 | 0.91 | 0.87 | 0.92 | 0.88 |
| Mahkeses Steam Inj | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
| IF:0111784 | STEAM | | 1.01 | 1.01 | 1.02 | 1.02 | 1.05 | 1.04 | 1.02 | 0.99 | 1.01 | 0.99 | 1.00 | 0.98 | 1.01 |

| Battery Code (0051211) | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MASKWA | OIL | 0.85-1.15% | 1.08 | 1.04 | 1.13 | 1.06 | 1.10 | 1.01 | 1.11 | 1.04 | 0.97 | 1.14 | 1.14 | 1.17 | 1.08 |
| | WATER | 0.85-1.15% | 1.13 | 1.07 | 1.08 | 1.13 | 1.13 | 1.05 | 1.07 | 1.07 | 0.96 | 1.12 | 1.15 | 1.12 | 1.09 |
| | GAS | | 0.94 | 1.00 | 0.88 | 0.93 | 0.95 | 0.76 | 1.02 | 1.00 | 0.65 | 1.11 | 1.00 | 0.95 | 0.93 |
| Maskwa Steam Inj | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
| IF:0000797 | STEAM | | 0.98 | 1.02 | 1.07 | 1.07 | 0.96 | 0.94 | 0.94 | 0.96 | 0.85 | 0.91 | 0.96 | 1.01 | 0.97 |

| Battery Code (00051212) | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAHIHKAN | OIL | 0.85-1.15% | 0.87 | 0.89 | 0.91 | 0.90 | 0.90 | 0.87 | 0.85 | 0.95 | 0.94 | 0.91 | 0.89 | 0.91 | 0.90 |
| | WATER | 0.85-1.15% | 1.01 | 1.00 | 0.97 | 1.00 | 1.07 | 1.06 | 0.95 | 0.98 | 0.93 | 0.90 | 0.95 | 0.97 | 0.98 |
| | GAS | | 0.80 | 0.83 | 0.93 | 0.91 | 0.96 | 0.97 | 0.96 | 1.08 | 1.02 | 0.94 | 0.87 | 0.93 | 0.93 |
| Mahihkan Steam Inj | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
| IF:0008798 | STEAM | | 0.99 | 1.00 | 0.99 | 1.02 | 1.10 | 1.06 | 1.02 | 1.01 | 1.01 | 0.98 | 0.98 | 0.97 | 1.01 |

| Battery Code (0119087) | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NABIYE | OIL | 0.85-1.15% | 0.88 | 1.06 | 1.05 | 0.86 | 0.82 | 0.79 | 0.94 | 0.89 | 0.89 | 0.88 | 0.89 | 0.86 | 0.90 |
| | WATER | 0.85-1.15% | 0.84 | 0.99 | 0.99 | 0.90 | 0.94 | 0.89 | 0.90 | 0.86 | 0.86 | 0.87 | 0.96 | 0.96 | 0.91 |
| | GAS | | 1.01 | 1.00 | 0.71 | 0.72 | 0.79 | 0.97 | 1.07 | 0.98 | 0.96 | 0.91 | 0.81 | 0.86 | 0.90 |
| Nabiye Steam Inj | | | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | AVG |
| IF:0119086 | STEAM | | 1.00 | 0.98 | 0.96 | 1.02 | 1.03 | 1.01 | 1.02 | 0.99 | 1.03 | 1.03 | 1.03 | 1.06 | 1.01 |

Facility proration factors reviewed daily at production review meetings with Field, Plant, Well Servicing, Maintenance, Management Representatives. Monthly proration factors documented, reviewed & approved with action plans assigned & stewarded for deviations (Gas & Steam Injection proration factors are used for monitoring & stewardship vs compliance).



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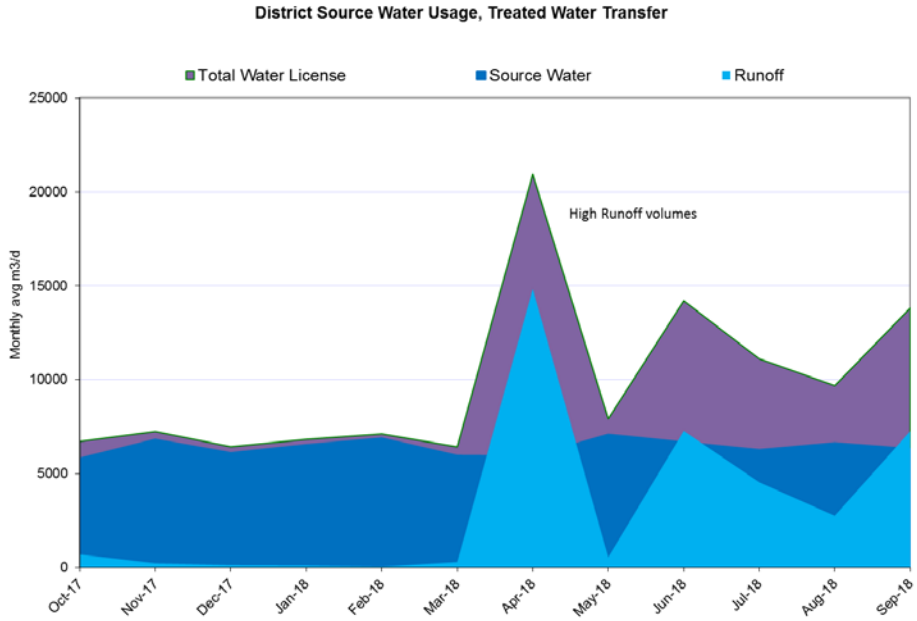
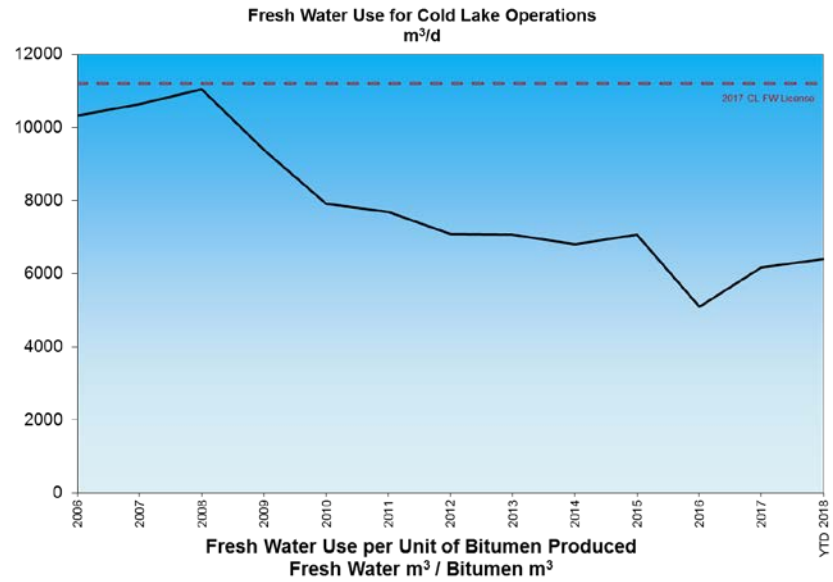
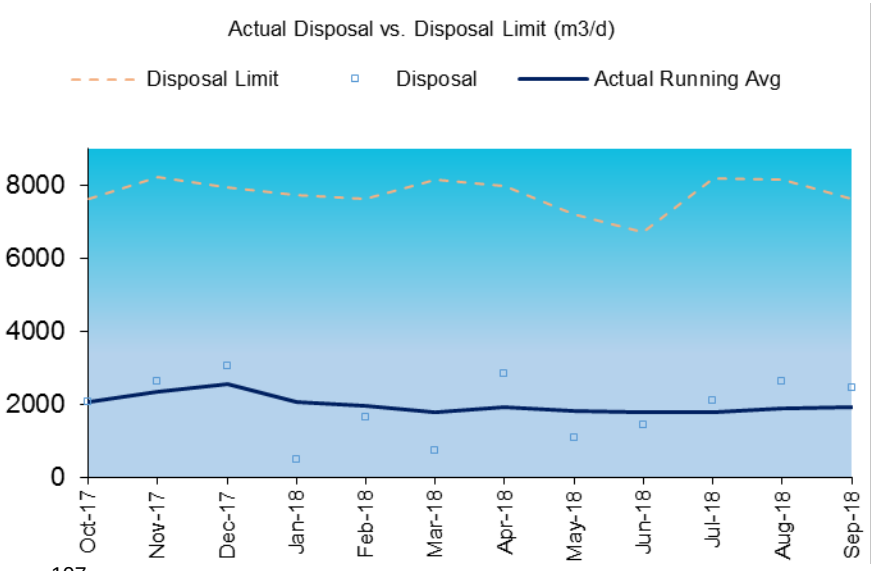
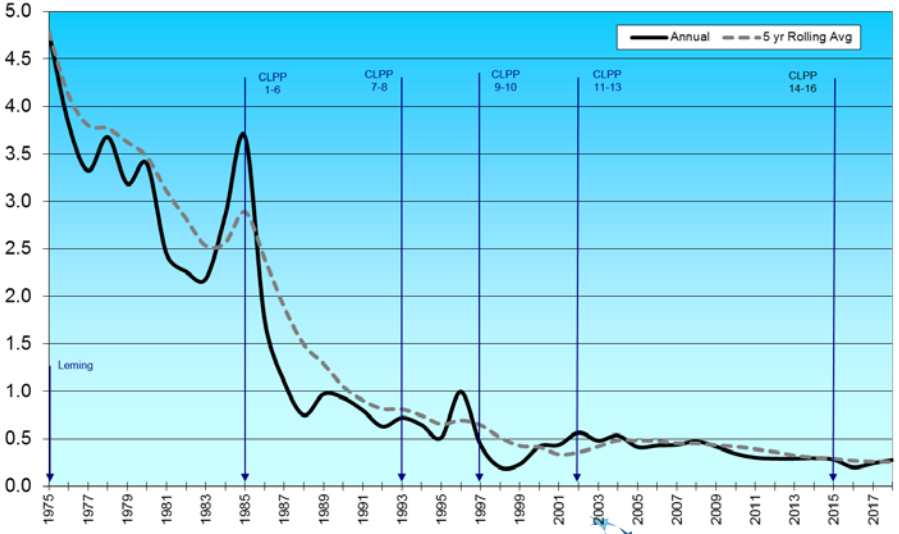
# Water Sources and Use

# Cold Lake Water Use

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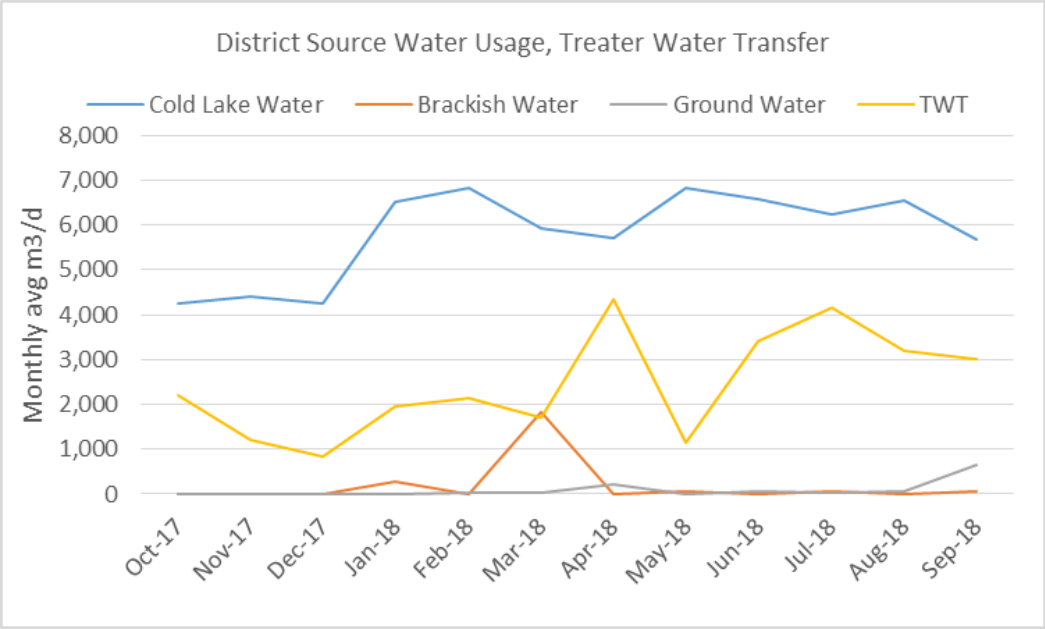
# Cold Lake Water Use (cont'd)

**Fresh Water Use & Actual Disposal vs. Disposal Limit**

- 2017-2018 ground water use only required during water system maintenance periods
- Transitioned to disposal limit formula November 2015
  - 2017 actual disposal volumes 3,372 $m^3$/d vs. disposal limit of 7,973 $m^3$/d
  - 2018 YTD Actual Disposal volumes 1,705 $m^3$/d vs. disposal limit of 7,707 $m^3$/d
- Disposal volumes forecasted to increase as produced water import to Nabiye decreases




| | Disposal Limit, m3/d | Actual Disposal m3/d |
|---|---|---|
| Jan-17 | 7,730 | 3,046 |
| Feb-17 | 7,947 | 2,727 |
| Mar-17 | 7,565 | 4,274 |
| Apr-17 | 7,489 | 3,624 |
| May-17 | 7,506 | 2,581 |
| Jun-17 | 7,623 | 1,341 |
| Jul-17 | 7,895 | 232 |
| Aug-17 | 7,769 | 2,819 |
| Sep-17 | 7,325 | 2,973 |
| Oct-17 | 8,227 | 1,822 |
| Nov-17 | 8,475 | 1,407 |
| Dec-17 | 8,202 | 614 |
| YE* | 7,973 | 3,372 |



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# Freshwater Reduction

- Freshwater reduction continues to be key focus area
- 2018 YTD (Sept 30) non-saline water consumption ~6,434 $m^3$/d, continuing strong performance since 2011
- 1M $m^3$ of allocation from Cold Lake released during water license renewal driven by performance and focus on continued reductions
- Technical assessments of alternatives ongoing in freshwater utility boilers, inlet cooling, and improved treated water transfer

# Water Disposal and Waste Management

# Produced Water Disposal to Cambrian – Approval 4510

## Monthly Injection Volumes and Average Wellhead Injection Pressures

**Monthly Injection Volumes and Average Wellhead Injection Pressures**

| | | 2017 | | | | | | 2018 | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WELL | Disposal | OCTOBER | | NOVEMBER | | DECEMBER | | JANUARY | | FEBRUARY | | MARCH | | APRIL | | MAY | | JUNE | | JULY | | AUGUST | | SEPTEMBER | |
| IDENTIFIER | Zone | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) | (MPA) | ($m^3$) |
| 00 01 19 064 03 4 00 (SWDFT701) | Cambrian | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 | 0.0000 | 0.0 |
| 00 01 32 064 03 4 00 (SWDFT702) | Cambrian | 12.0300 | 40,438.5 | 12.2720 | 41,502.7 | 12.5670 | 18,191.2 | 12.7970 | 14,467.7 | 12.330 | 33,862.5 | 11.4800 | 17,295.2 | 11.9590 | 56,362.4 | 12.5000 | 24,314.0 | 12.5000 | 31,842.0 | 11.5070 | 49,041.4 | 11.5400 | 53,186.7 | 11.7520 | 51,907.6 |
| 02 02 03 064 03 4 00 (SWDFT703) | Cambrian | 12.1030 | 14,482.3 | 11.7690 | 456.8 | 12.7670 | 128.5 | 13.1630 | 75.1 | 13.307 | 11,452.9 | 11.3470 | 5,698.2 | 11.8310 | 29,900.7 | 12.0000 | 8,571.8 | 12.0000 | 9,911.1 | 11.7170 | 15,026.7 | 11.7200 | 26,901.9 | 12.1340 | 20,033.9 |
| 00 03 04 065 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 04 17 065 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 08 33 064 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 11 07 065 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 12 08 065 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| 00 07 18 064 03 4 00 (SWDFT705) | Cambrian | 0.0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 00 11 22 064 03 4 00 Abandoned | Cambrian | | | | | | | | | | | | | | | | | | | | | | | | |
| **TOTAL DISPOSAL ($m^3$)** | | | **54921** | | **41960** | | **18320** | | **14543** | | **45315** | | **22993** | | **86263** | | **32886** | | **41753** | | **64068** | | **80089** | | **71942** |
| **DAILY AVERAGE($m^3$)** | | | **1772** | | **1399** | | **591** | | **469** | | **1618** | | **742** | | **2875** | | **1061** | | **1392** | | **2067** | | **2584** | | **2398** |

- Water disposal required due to high field produced water levels (high water to steam ratios)
- Efforts to improve water recycle include reduced fresh water usage, improved steam generation and water reuse service factors, and improved water inter-plant transfer capability



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# Cold Lake Waste Management

## 2017 Annual Waste Volumes

| | Volume (m3 unless otherwise specified) |
|---|---|
| **Class II Landfill** | |
| Lime Sludge | 67,401 |
| All Other Waste Streams | 8,940 |
| **Maskwa Ecopit (OWBSF)** | |
| Oily Waste | 12,026 |
| **Off Site Disposal / Recycled** | |
| Empty Containers (EMTCON) | 198 |
| Steel | 467 |
| Wood (burned on site) | 2,149 |
| Landfill Leachate Collection and Recycle at Mahkeses Plant | 31,495 |
| Solid Waste (Rags, soils, etc.) | 1,335 |
| Liquid Waste (Glycol, etc.) | 3,485 |
| Sludge (sludge cont. hydrocarbons) | 4,538 |

# Environmental Summary

# Approval Renewals and Amendments

## AER Approvals

- Received approval for the Cold Lake Expansion Project (Grand Rapids SA-SAGD) (commercial Scheme Approval 8558MM).

## Approvals under the Environmental Protection and Enhancement Act (EPEA)

- EPEA amended to address newly approved Cold Lake Expansion Project (Grand Rapids SA-SAGD).

## Approvals under the Water Act

- No change

# Monitoring Programs – Wildlife

Cold Lake Operations continues to enhance and restore wildlife habitat.

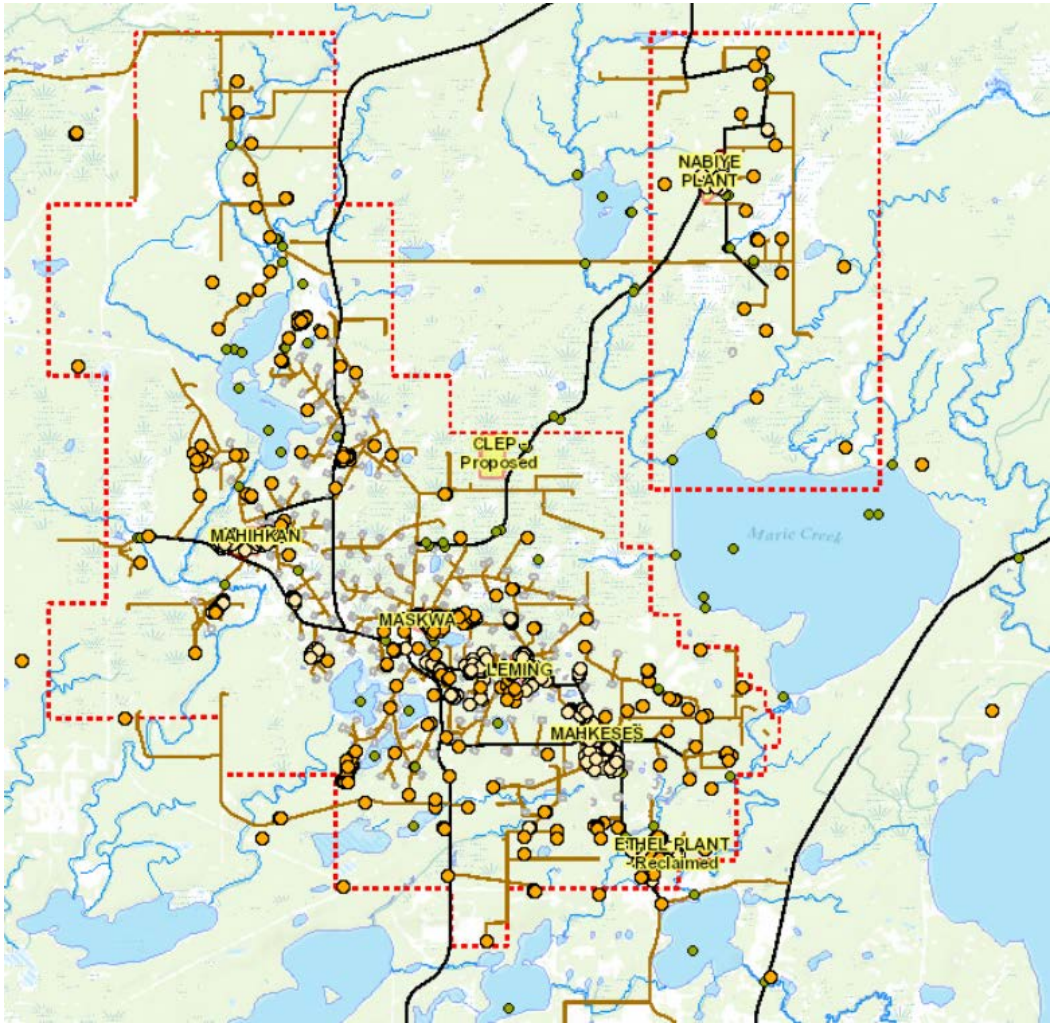
- In 2010, Imperial Cold Lake Operations received the Wildlife at Work Certification from the Wildlife Habitat Council for the successful implementation of a comprehensive wildlife habitat management program. Imperial achieved recertification in 2018.
  - > The Wildlife Habitat Council (WHC) created in 1988, is a nonprofit group of corporations, conservation organizations and individuals dedicated to enhancing and restoring wildlife habitat. WHC helps large landowners, like Imperial, manage their unused lands in an ecologically sensitive manner for the benefit of wildlife.

- Continue implementation of AEP-approved *Wildlife Monitoring and Mitigation Plan* and *Caribou Mitigation and Monitoring Plan*, which address wildlife habitat preservation measures.

- Annual issuance of AEP *Research and Collection License*.

# Monitoring Programs – Groundwater

Cold Lake Operations maintains an extensive groundwater monitoring program.




- Monitoring
  > 400 deep groundwater wells (including 17 domestic), and
  > 220 shallow wells
- Monitoring includes chemistry & water levels
- Drilling activity in 2017/2018
  - > Deep:
    - V10 GEW 17-2 (SR)
    - M3 GEW 18-14 (E1)
    - N10 Pad: 5 GEWs
    - E Pad: 8 GEWs installed for investigation
  - > Shallow:
    - Landfill: 6 wells installed
- 2017/2018 Abandonment:
  - > No wells were abandoned



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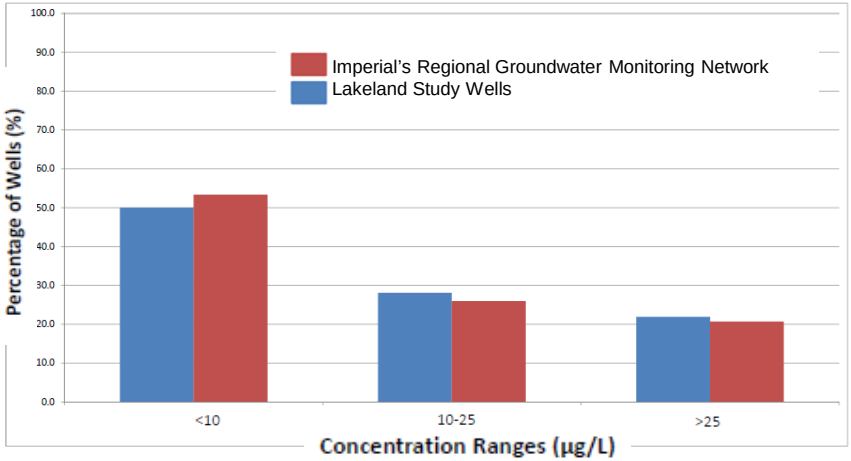
# Monitoring Programs – Thermal Mobilization

Based on groundwater monitoring to date, there is no evidence that mobilized arsenic has impacted domestic or livestock groundwater wells. Cold Lake Operations continues its extensive groundwater monitoring program.

**Technical Update**

- In 2006, Health Canada lowered the maximum acceptable concentration for
  arsenic in drinking water from 25 µg/L to 10 µg/L.
- Using this standard, 50% of domestic wells in the Lakeland area have naturally high arsenic concentrations above guidelines. (Alberta Health and Wellness Data: Arsenic in Groundwater from Domestic Wells in Three Areas of Northern Alberta, Oct 2000).
- In 2017, Imperial conducted a review of arsenic in its regional groundwater wells and reconfirmed that arsenic concentrations are similar to the AHW (2000) study and do not display increasing trends over time.
- Imperial monitors thermally mobilized arsenic at D55, D57, L08, V10.
- Field observations confirm that heat convection cells play a significant role in the release and transport of arsenic when the GW velocity is low.
- Laboratory experiments indicate that arsenic released by conductive heating is re-adsorbed when the GW is exposed to unheated sediments.




**A comparison of arsenic concentrations in wells tested by Alberta Health and Wellness (Lakeland Study Wells - 2000) and wells in Imperial's Regional Groundwater Monitoring Network (IOR Regional Wells - 2017)**

- Field study results indicate that peak arsenic concentrations and arsenic mass at D55 and D57 pads have declined as the arsenic plumes migrate down gradient. The average velocity of the dissolved arsenic is retarded relative to GW flow velocity. These observations indicate that arsenic attenuates as it moves down gradient.
- Additional downgradient monitoring wells are positioned to measure the rate and extent of attenuation.
- Imperial will submit a Groundwater Monitoring Thermal Proposal by March 31, 2020, as per the Assessment of Thermally-Mobilized Constituents in Groundwater for Thermal In Situ Operations Directive



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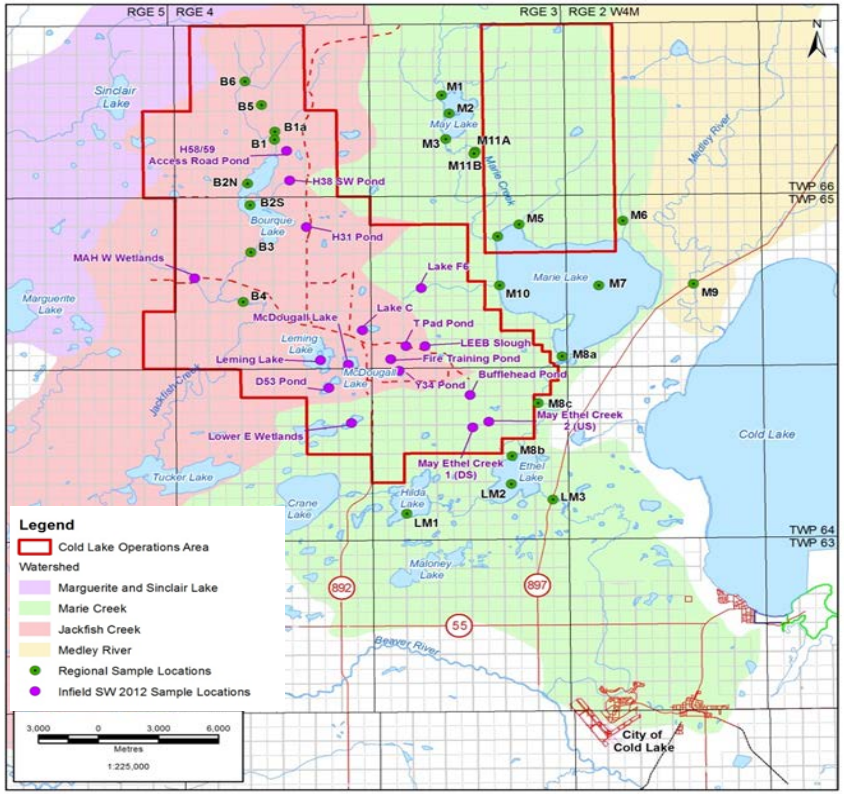
# Monitoring Programs – Surface Water

Cold Lake Operations maintains an extensive surface water monitoring program.

Comprised of the following components:

- Surface Water Quality Sampling (Regional, Infield, Wetlands)
- Annual Drainage Assessment
- Level Monitoring (Lake, creeks, wetland piezometers)
- Long-term Wetland Monitoring Plots
- Diverted Runoff

# Monitoring Programs – Surface Water




Data and observations support the absence of adverse effects directly or indirectly associated with Cold Lake operations.

**Regional**

- Regional program included spring and fall sampling at 25 sites.
- Data from this program is shared with Beaver River Watershed Association (BRWA), Alberta Lake Management Society (ALMS), Marie Lake Air and Watershed Society (MLAWS), as well as some landowners.
- Includes sites within the Jackfish Creek, Marie Creek, & Medley River Watersheds.

**Sampling**

- Spring and fall sampling of water bodies (routine water quality parameters (pH, alkalinity, hardness, etc), major cations and anions, forms of nitrogen, phosphorous, hydrocarbons, and trace elements)
- Flow measurements at selected creek sites
- Depth composite samples from canoe for both regional and infield lakes where depths are greater than 2 meters

**Infield**

- 18 Sites sampled bi-annually for field and routine parameters, total and dissolved metals, nutrients, and hydrocarbons
- Concentrations measured during 2017 are consistent with historic data, with some exceptions related to stagnant water



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# Monitoring Programs – Surface Water Drainage

Drainage and culvert assessments help monitor and minimize the environmental impact of Cold Lake Operations.

- Completed on an annual basis since 2002
- Drainage Assessment: Includes examination of drainage impediments, erosion and/or sedimentation
- Culvert assessment: culvert integrity and erosion

# Monitoring Programs – Surface Water Wetland Monitoring

Program Status:

- Groundwater levels are monitored by a combination of transducers and manual measurements.
- All upstream and downstream locations across CLO had levels consistent with the historical range.
- Water levels and water quality results were typically within expected ranges, with the exception of Maskwa wetland, which had an increase in chloride concentration (investigation underway).

# Monitoring Programs – Surface Water Long-term Wetland Monitoring Plots

Vegetative stress was not identified the field assessments.

- Established in August 2006, as per EPEA 73534-00-04 Section 4.9.2a
- Purpose: Monitor long-term effects of groundwater withdrawals on wetland health, extent and distribution
  - Establishment of 11 plots
  - Baseline data collection
- Next Monitoring Date:
  - 2020
- 2015 Results
  - Evidence indicates that wetlands studied are influenced by precipitation, rather than groundwater levels.

# Diverted Runoff

The 2017 runoff data is in compliance with the EPEA approval.

| Month (Total) | Number of Releases | Total Volume Released ($m^3$) | Chlorides (mg/L) | pH |
|---|---|---|---|---|
| | | | Maximum (lab data has 2 decimals) | Minimum / Maximum (lab data has 2 decimals) |
| Leming Plant | 78 | 2,890 | 219.39 | 7.19 / 8.83 |
| Leming & Mahkeses Field | 296 | 82,585 | 116 | 6.0 / 7.85 |
| Maskwa Plant | 51 | 19,249 | 131.96 | 7.03 / 8.59 |
| Maskwa Field | 333 | 129,986 | 90 | 6.5 / 7.89 |
| Mahihkan Plant | 136 | 15,312 | 331.9 | 6.86 / 8.41 |
| Mahihkan Field | 230 | 74,257 | 101.96 | 6.5 / 8.08 |
| Nabiye Field | 45 | 10,025 | 30 | 6.5 / 7.5 |

# Monitoring Programs – Vegetation

No impact to species richness have been observed.

**Overview:**

- In 2006 a long-term vegetation monitoring program was established, per the commitments made in Section 9, Subject 10 of the Imperial Nabiye and Mahihkan North EIA
- The monitoring program was revised and improved in 2009
- The extent of the program is expected to increase as monitoring plots are identified and established in the Nabiye Operating Area

**Monitoring Results:**

- 2015 edge effects and rare plants monitoring – consultant's conclusion:
  - Edge effects at the transects have been variable.
  - Overall, no significant difference between baseline and species richness values during the Rare Plant survey.
  - Next survey performed in 2018; results under review.
- Vegetation stress assessment conducted in 2016 (5 years frequency). Consultant (AMEC) concluded that there was no vegetation stress due to $SO_2$, nor in 2010 nor in 2016.

Pitcher Plant (Sarracenia purpurea)



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# Monitoring Programs – Air Emissions

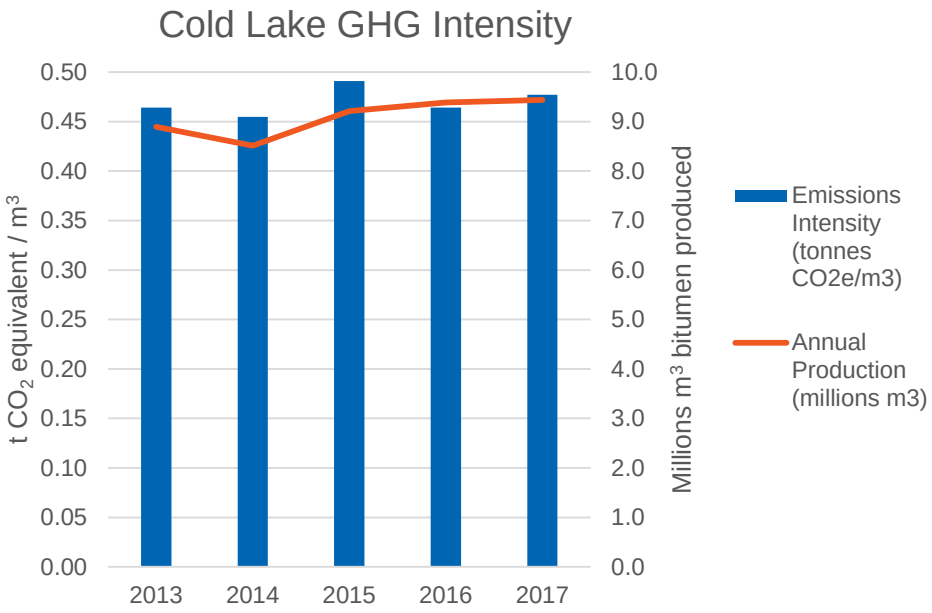
Cold Lake's greenhouse gas (GHG) emission intensity has been stable. Next generation technologies reducing emissions are being leveraged.

Examples include:

- **Liquid Addition to Steam for Enhancing Recovery** (LASER) reduces GHG intensity by 20 to 25% by adding solvent to the current Cyclic Steam Simulation process. LASER has been commercially demonstrated at 10 pads and deemed successful; it was implemented at an additional 9 pads.

- **Cyclic Solvent Process** (CSP) is a non-thermal process that injects solvent instead of steam to recover bitumen. A $100-million pilot facility was initiated in 2014. Direct GHG emissions are reduced by approximately 90%.

- **Solvent-Assisted Steam-Assisted Gravity Drainage** (SA-SAGD) is a recovery process enhanced by the addition of solvent to the steam. It is the technology of choice for the Cold Lake Expansion Project (Grand Rapids reservoir) and other SAGD developments such as Aspen. Cold Lake has operated a $50M field pilot since 2010. A 25% reduction in GHG intensity compared to SAGD is expected.




Note: GHG intensity estimation included cogeneration credits.

[1)] Cold Lake and Kearl Operations combined.



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# Monitoring Programs – Air Emissions

Satisfactory air quality is measured at the air monitoring station located at Cold Lake Operations and operated by LICA[1]. Data is shared with communities.

- The Maskwa station is maintained and operated by LICA (Lakeland Industry and Community Association).
  - Maskwa station performs continuous and passive monitoring of various compounds, such as $SO_2$, $H_2S$, $NO_x$, Total Hydrocarbons.
  - Alberta Ambient Air Quality Objectives (AAAQO) includes target concentrations for certain compounds. Hourly averages measurements are below the AAQO targets.

- Fugitives emissions detection program
  - Annual program; each location sampled on a 3 years frequency
  - Fugitives emissions are minor; represent less than 0.5% of Cold Lake Operations green house gas (GHG) emissions
  - Leak Detection and Repair (LDAR) program is implemented to detect unintentional hydrocarbon emissions (seals, valves, flanges, etc.).

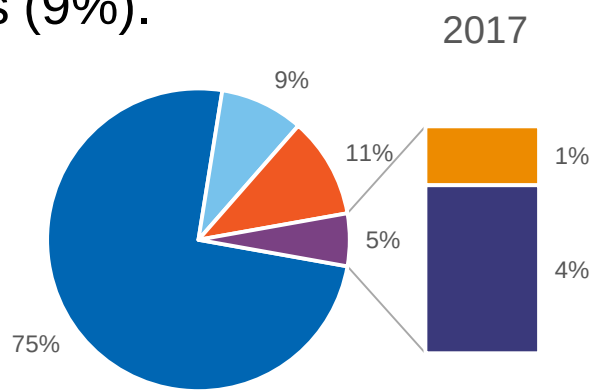
[1] Sept 2017 – Aug 2018 data available on LICA website.

Wildfires caused $PM_{2.5}$ measurements to exceed the AAAQO thresholds in the summer of 2018. One (1) $H_2S$ exceedance was observed in February 2018.

# Monitoring – Reclamation

Reclamation is integral to Cold Lake Operations' activities.

- More land is being reclaimed (17%) than the footprint disturbed for Operations (9%).




- 75% Undisturbed / Disturbed by Others (Surface water, lands, forest and distrubed by others)
- 9% Disturbed for Operations (Areas cleared and disturbed by operations)
- 11% Temporary Reclaimed (Areas that are reclaimed and have the potential to be re-disturbed in the future)
- 1% Undergoing Remediation and Reclamation (Remediation, recontouring, soils placed, revegetation or wetland reclamation trial)
- 4% Reclaimed (Areas reforested, natural reclamation, created habitat and reclaimed weltands)

2017 – Cold Lake Operations Mineral Surface Lease = 14240.4 ha

| Year | Total Area Disturbed (ha) | % Undergoing Temporary Reclamation, Remediation and Reclamation | % Reclaimed | Total % Undergoing Reclamation Activity |
|---|---|---|---|---|
| 2013 | 3,482 | 47% | 14% | 61% |
| 2014 | 3482 | 47% | 15% | 62% |
| 2015 | 3534 | 48% | 15% | 63% |
| 2016 | 3558 | 47% | 17% | 64% |
| 2017 | 3551 | 47% | 17% | 64% |



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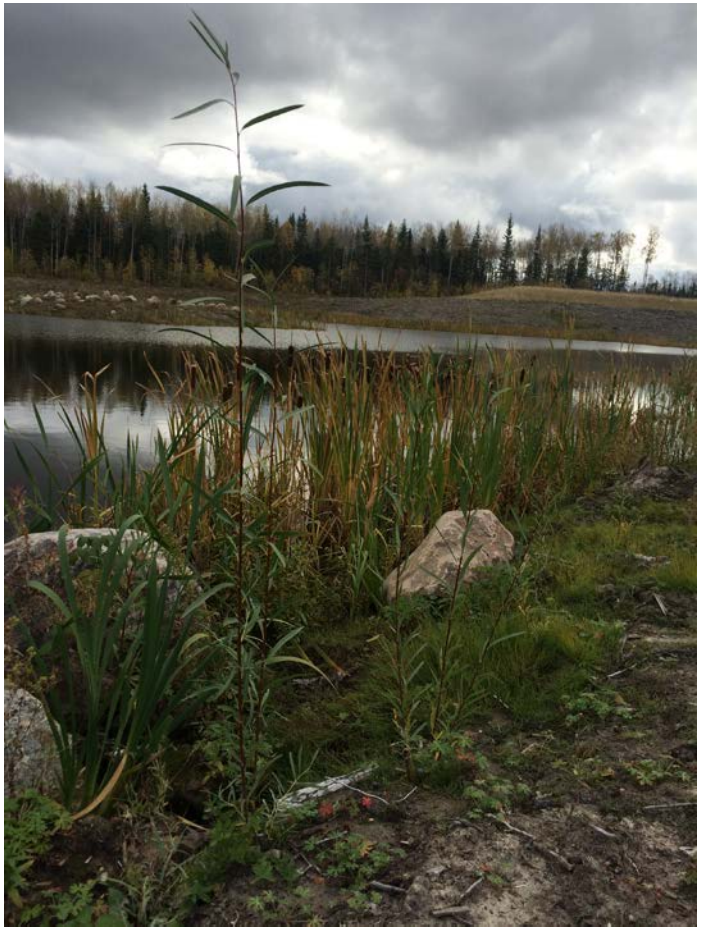
# Monitoring – Reclamation (cont'd)

## Soil and Terrain

- Site stability - annual observations for the first 5 years
- Soil sampling first year following reclamation to demonstrate replacement of soils to an appropriate depth
  - > 2016 results - sites have adequate topsoil replaced

## Revegetation

- Monitoring has been deferred until the approved Project-Level Conservation, Reclamation and Closure Plan (PLCRCP) is implemented.
- Fall assessments ongoing to ensure re-vegetation establishment



# Environmental and Community Initiatives

Imperial Cold Lake Operations continues to support environmental initiatives through both financial contributions and participation in regional committees.

- Cold Lake Operations provides significant annual funding to the arms-length joint provincial-federal government Oil Sands Monitoring (OSM) program
- Imperial continues to be involved with COSIA (Canada's Oil Sands Innovation Alliance).
- Imperial continues to sit on the LICA (Lakeland Industry and Community Association) board and committees as an industry member and to fund local environmental programs.
- Imperial holds the annual "Neighbor Night" that allows the community to learn and enquire about Cold Lake Operations.
- Imperial engages with Marie Lake Air and Watershed Society (MLAWS) and domestic well owners.

# Sulphur

# Sulphur Removal

**Mahihkan Site – Plant Sulphur Removal**

- Sustained reliability achieved over reporting period
- Achieved greater than 69.7% recovery in all quarters of 4Q17, 1/2/3Q18 and was continuously below emissions limit
- Achieved 95% uptime in 2017/2018
- Downtime related to SRU piping repairs and cold weather loading delays

**Mahkeses Site – Plant Sulphur Removal**

- Sustained reliability achieved over reporting period
- Achieved greater than 69.7% recovery in all quarters of 4Q17, 1/2/3Q18 and was continuously below emissions limit
- Achieved 100% uptime in 4Q17, 1/2/3/Q18

**Leming Site – No Plant Sulphur Removal**

- Leming $SO_2$ emissions were below limits in all quarters of 4Q17, 1/2/3/Q18 and was continuously below daily emissions limit

**Maskwa Site – No Plant Sulphur Removal**

- Maskwa $SO_2$ emissions were below limits in all quarters of 4Q17, 1/2/3/Q18 and was continuously below daily emissions limit (3Q18 ID 2001-03 Exception)

**Nabiye Site – Plant Sulphur Removal**

- Sustained reliability achieved over reporting period
- Achieved greater than 69.7% recovery in all quarters of 4Q17, 1/2/3Q18 and was continuously below emissions limit
- Achieved 100% uptime in 4Q17, 1/2/3Q18

# Sulphur Removal, $SO_2$ Emissions

- Compliant with D56, EPEA, and ID2001-3 over the review period

| Calendar Quarter Average Sulphur Emissions By Plant (tonnes/day) | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calendar Quarter | Leming Plant | | Maskwa Plants | | Mahihkan Plants | | | Mahkeses Plant | | | Nabiye Plant | | | District | |
| | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Removal | Sulphur | $SO_2$ | Removal | Sulphur | $SO_2$ | Removal | Sulphur | $SO_2$ |
| Q4 2017 | 0.43 | 0.87 | 0.98 | 1.96 | 0.44 | 0.88 | 70.65% | 0.43 | 0.86 | 70.61% | 0.33 | 0.66 | 70.13% | 2.61 | 5.22 |
| Q1 2018 | 0.30 | 0.60 | 1.00 | 1.99 | 0.54 | 1.09 | 70.05% | 0.34 | 0.67 | 70.20% | 0.23 | 0.45 | 70.39% | 2.41 | 4.81 |
| Q2 2018 | 0.21 | 0.41 | 0.79 | 1.58 | 0.55 | 1.10 | 69.74% | 0.20 | 0.41 | 72.56% | 0.31 | 0.62 | 70.13% | 2.06 | 4.13 |
| Q3 2018 | 0.19 | 0.38 | 1.02 | 2.05 | 0.36 | 0.72 | 73.44% | 0.30 | 0.60 | 70.20% | 0.49 | 0.97 | 70.10% | 2.36 | 4.72 |
| | <1.0 t/d Sulphur | | <1.0 t/d Sulphur* | | <1.80 t/d SO2 | | ≥69.7.% | <1.08 t/d SO2 | | ≥69.7.% | <1.08 t/d SO2 | | ≥69.7.% | - | |

| Calendar Quarter Peak Day Sulphur Emissions By Plant (tonnes/day) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Calendar Quarter | Leming Plant | | Maskwa Plants | | Mahihkan Plants | | Mahkeses Plant | | Nabiye Plant | | District | |
| | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Sulphur | $SO_2$ | Sulphur | $SO_2$ |
| Q4 2017 | 0.67 | 1.34 | 1.43 | 2.85 | 1.16 | 2.31 | 0.65 | 1.30 | 0.54 | 1.09 | 3.33 | 6.66 |
| Q1 2018 | 0.41 | 0.82 | 1.40 | 2.80 | 1.82 | 3.64 | 0.84 | 1.68 | 0.72 | 1.43 | 3.44 | 6.89 |
| Q2 2018 | 0.31 | 0.61 | 1.52 | 3.04 | 1.16 | 2.33 | 0.31 | 0.62 | 0.70 | 1.41 | 2.96 | 5.92 |
| Q3 2018 | 0.25 | 0.51 | 1.22 | 2.43 | 0.76 | 1.51 | 0.38 | 0.76 | 0.63 | 1.26 | 3.05 | 6.10 |

# NOx

# $NO_x$ Emissions

The October 2017 – September 2018 NOx emissions from the Mahkeses and Nabiye gas turbines / heat recovery steam generator exhaust stacks are in compliance with the EPEA approval.

**Table 1. $NO_2$ Emissions for the Co-generation Units at Mahkeses Plant**

| Unit ID | Parameters | 17-Oct | 17-Nov | 17-Dec | 18-Jan | 18-Feb | 18-Mar | 18-Apr | 18-May | 18-Jun | 18-Jul | 18-Aug | 18-Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14641 | Total hours $NO_2$ exceeding Stack Licenced Limits of 63 (kg/h) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Maximum $NO_2$ (kg/h) | 46 | 49 | 49 | 50 | 49 | 49 | 51 | 39 | 28 | 29 | 28 | 33 |
| | Average NO2 (kg/h) | 39 | 43 | 40 | 38 | 43 | 43 | 25 | 27 | 24 | 25 | 24 | 29 |
| 14642 | Total hours $NO_2$ exceeding Stack Licenced Limits of 63 (kg/h) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Maximum $NO_2$ (kg/h) | 35 | 47 | 40 | 40 | 38 | 38 | 37 | 34 | 29 | 29 | 30 | 34 |
| | Average $NO_2$ (kg/h) | 31 | 34 | 33 | 33 | 34 | 33 | 26 | 27 | 25 | 26 | 26 | 30 |

**Table 2. $NO_2$ Emissions for the Co-generation Units at Nabiye Plant**

| Unit ID | Parameters | 17-Oct | 17-Nov | 17-Dec | 18-Jan | 18-Feb | 18-Mar | 18-Apr | 18-May | 18-Jun | 18-Jul | 18-Aug | 18-Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 25573 | Total hours $NO_2$ exceeding Stack Licenced Limits of 63 (kg/h) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Maximum $NO_2$ (kg/h) | 30 | 24 | 35 | 28 | 29 | 27 | 25 | 24 | 21 | 21 | 20 | 21 |
| | Average $NO_2$ (kg/h) | 17 | 20 | 24 | 23 | 23 | 23 | 21 | 21 | 19 | 18 | 17 | 19 |
| 25572 | Total hours $NO_2$ exceeding Stack Licenced Limits of 63 (kg/h) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Maximum $NO_2$ (kg/h) | 26 | 29 | 34 | 34 | 33 | 32 | 29 | 29 | 28 | 26 | 26 | 26 |
| | Average $NO_2$ (kg/h) | 21 | 24 | 28 | 26 | 27 | 25 | 25 | 25 | 22 | 21 | 21 | 9 |

# Compliance

# AER Compliance

Cold Lake Operations activities pursued without long-term adverse impact on the environment.

Inspections and Compliance

- 37 satisfactory inspections
  - E.g.: related to the Water Act Codes of Practice, etc
- 5 voluntary self-disclosures
  - Proactive identification of improvement opportunities. Example: replacement of impermeable liner.
- 13 non-compliances and 5 contraventions
  - Non-compliances: secondary containment (9), management of runoff (2), waste manifesting and well licensing.
  - Contraventions: 3 overflow, clearing of small area without approval, and siltation.

# Future Plans

# Future Plans

- Continue to pursue freshwater reduction opportunities

- Continue industry sharing and participation

# AER Approvals 8558 and 4510

- Imperial is in compliance with all conditions of Approval 8558
- Imperial is in compliance with all conditions of Amendment F to Approval 4510 (details are enclosed in Attachment 2)

# Attachments

Attachment 1

# Approval 858800

## Compliance Conditions

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 2 | The Operator shall notify the AER of any proposed alteration or modification of the scheme or to any equipment proposed for use therein, prior to effecting the alteration or modification. | Angela Rupp (CLRE), Geoff Pearse (CL Fac) | 8558JJ – N10 pad drainage area and inter-well spacing<br>8558KK – Sulphur Recovery Unit uptime extension to Dec 31, 2018<br>8558LL – Maskwa facility temporary variance from sulphur recovery requirements in Table 1 of Interim Directive 2001-03<br>8558MM – Cold Lake Expansion Project approval<br>8558OO – LASER and infills approval |
| 3 | Where, in the opinion of the AER, any alteration or modification of any equipment proposed for use therein<br>a) is not of a minor nature,<br>b) is not compatible with the scheme approved herein, or<br>c) may not result in an improved or more efficient scheme or operation,<br>the alteration or modification shall not be proceeded with or effected without the further authorization of the AER. | Angela Rupp (CLRE), Geoff Pearse (CL Fac) | See above |
| 4 | Unless otherwise stipulated by the AER, the production from the project area outlined in Appendix A shall not exceed 40 000 cubic metres per day (m3/d) on annual average basis. | Jack Fraser, Seann Strandberg (CLO) | No plan to exceed 40,000 m3 |
| 5 | The Operator shall conduct all operations to the satisfaction of the AER and in a manner that, under normal operating conditions, will permit<br>a) the recovery of the practical maximum amount of crude bitumen,<br>b) the conservation of the practical maximum volume of produced gas at the well pads and central facilities,<br>c) the practical minimum use of off-site gas for project fuel, and<br>d) the efficient transportation of crude bitumen to market. | Jack Fraser, Seann Strandberg (CLO) | In compliance with all requirements. |
| 6.1 | The Operator shall log all wells from total depth to surface by means of a spontaneous potential - resistivity or gamma ray-resistivity log and such other logs as may be required to ensure sufficient depth and directional control. | Mark Wood (CLGeo) | Operating practice is for one or more wells per pad and all OV wells to be logged by LWD, wireline or pipe conveyed methods. Exceptions are requested for some Passive Seismic wells and the horizontal sections of Injection-Only-Infill wells. AER logging waivers are obtained for any wells unable to achieve TD due to mechanical issues |
| 6.2 | The Operator, unless otherwise authorized by the AER, shall take full diameter cores of the entire bitumen bearing section of the Clearwater Formation from not less than four vertical evenly-spaced wells per section, and take fill diameter cores of the remaining bitumen bearing sections of the Mannville Group from at least one vertical well per section, and at the AER's request<br>a) analyze portions of such cores,<br>b) provide a summary of core analysis, and<br>c) provide suitable photographs of the clean-cut surface of each core slabbed. | Mark Wood (CLGeo) | All OV wells cored through the Clearwater Formation. On average four wells per section drilled prior to development. On average, one well per section cored in Grand Rapids in hydrocarbon zones >8m not encumbered by gas. Core and analysis from cored wells in the 2017 / 18 winter program submitted to AER. All core related submissions from the program were completed in August 2018. |
| 6.3 | At least one well per pad and each of the wells referred to in clause 6, paragraph 2 shall be logged over the entire Mannville Group by means of a gamma ray-neutron density log. | Mark Wood (CLGeo) | All OV wells and one well per pad were logged using wireline or pipe conveyed Gamma Ray - Neutron-Density tools. Wireline data from 2017 / 18 winter program submitted to AER February – May. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 7.1 <rescinded> | The Operator shall take such steps and effect such measures as may be necessary in the completing and operation of wells to prevent production-casing failures. | Keith Dares (CLSSE) | Well casing failure prevention / detection practices discussed with AER through annual casing integrity submission. |
| 7.2 | The Operator shall submit an annual summary report on casing integrity and remedial efforts to the AER by March 31 the following year. | Keith Dares (CLSSE) | Annual casing integrity report submitted May 22, 2018, followed by review on May 28, 2018. No follow-ups. |
| 8.1 <rescinded> | The Operator shall conduct additional sampling, testing, and studies to help assess formation integrity and to provide baseline geological and geotechnical information and further knowledge on properties that can influence groundwater flow, water quality, and corrosion of casing and degradation of cement. | Charles Wierstra (CLO) | Ongoing data collection and analysis in multiple areas: groundwater, passive seismic, gas composition, purge compliance, casing shroud installations, bentonite top ups. |
| 8.2 <rescinded> | The Operator shall design and implement monitoring programs to specifically address the potential that its operations may have on liberating or introducing arsenic into the groundwater. | Kelly Wiebe (SSHE) | Current field monitoring is focused on understanding the fate and transport of arsenic in different hydrogeological conditions. Field results have demonstrated that both peak concentrations and mass of arsenic are declining as the plume migrates down-gradient.<br><br>A technical update was submitted in March 2015. Imperial conducts reviews of arsenic every 2 years to confirm that arsenic concentrations have not increased on a regional scale due to thermal operations at Imperial CLO and are comparable to domestic wells in the Cold Lake area. This was confirmed in 2017 based on 2015/2016 data. |
| 9 <rescinded> | The Operator shall install surface casing, in a manner satisfactory to the AER, through the glacial drift on all disposal wells. | Sarah Mason (D&C) | With the exception of wells that have had an AER approved surface casing depth reduction waiver, surface casing has been installed on all wells consistent with AER Directive 008: Surface Casing Depth Requirements. |
| 10 <rescinded> | The Operator, unless given the express written consent of the AER to do otherwise, shall maintain between the location of steamed wells and wells being drilled, a separation adequate to ensure that zones pressured by injected steam are not encountered by wells being drilled. | Nathan Toone (CLRS) | In full compliance. Drilling program coordinated with steaming schedule to ensure adequate separation. |
| 11 | The Operator shall conduct pressure surveys prior to the commencement of steaming and thereafter in any Grand Rapids gas wells that it operates within the project area. | Angela Rupp (CLRE) | Submitted the annual pressure survey to the AER in May 2018 |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 12<br><rescinded> | The Operator shall conduct recovery tests, satisfactory to the AER, in the McMurray and Grand Rapids Formations in the project area to determine the practicality of recovering bitumen from these formations and provide the results of such tests to the AER. | Angela Rupp (CLRE) | Submitted Cold Lake Expansion project application in Mar 2016 for bitumen recovery from the Grand Rapids formation using the SA-SAGD process. Approval received August 2018. |
| 13.1<br><rescinded> | Unless otherwise permitted by the AER, cyclic steam stimulation (CSS) operations, having commenced at a well pad, shall continue until the well pad has produced a minimum of 20 per cent of the in-place volume of crude bitumen assigned to that well pad by the AER. | Angela Rupp (CLRE) | Nothing new to report |
| 13.2 | Where the Operator proposes to cease CSS operations at a well pad that has produced less than 20 per cent of the in-place volume of crude bitumen, and the AER's consent therefore is sought, the Operator shall advise the AER as to the following:<br>a) the reason for proposing to cease CSS operations,<br>b) details of individual well workovers and recompletions attempted,<br>c) details of any infill drilling attempted,<br>d) the effect of ceasing CSS operations on the bitumen recovery ultimately achievable from that part of the reservoir associated with the pad and immediately offsetting pads,<br>e) detailed economics of continuing operations, and<br>f) future plans for the well pad with reference to possible follow-up recovery techniques that could be applied and other zones that could be exploited. | Angela Rupp (CLRE) | Nothing new to report |
| 13.3 | Where the Operator proposes to cease SA-SAGD/SAGD operations at a well pad that has produced less than 50 per cent of the in-place volume of crude bitumen and the AER's consent therefore is sought, the Operator shall advise the AER as to the following:<br>a) the reason for proposing to cease SA-SAGD/SAGD operations,<br>b) details of individual well workovers and recompletions attempted,<br>c) detailed economics of continuing operations,<br>d) the effect of ceasing SA-SAGD/SAGD operations on the bitumen recovery ultimately achievable from that part of the reservoir associated with the pad and immediately offsetting pads, and<br>e) future plans for the well pad with reference to possible follow-up recovery techniques that could be applied and other zones that could be exploited. | Keith Dares (CLSSE) | Pad abandonment approvals are sought prior to commencement of well abandonment on the pad, in accordance with the requirements. |
| 14 | The Operator is permitted to implement continuous steam injection (steam flooding) for late life optimization as per Application No. 1776745. | Nathan Toone (CLRS) | Steamflood is still active within target rates and pressures at listed pads. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 15 | The Operator shall implement a monitoring program for the Grand Rapids Formation in the Nabiye area, as per Application No. 1703441. This will include, but is not limited to, passive seismic monitoring wells located on each pad, a dual completed Grand Rapids pressure monitoring well on Pad N01 and Pad N05, a hybrid passive seismic and Upper Grand Rapids monitoring well on Pad N07 near the fault. | Angela Rupp (CLRE) | Continuous monitoring of the Grand Rapids Formation has been incorporated into Cold Lake operational practices. |
| 16 <rescinded> | Describe the Operator participation in regional multistakeholders initiatives. Discuss recommendations that have been generated from these regional initiatives and how these recommendations have been incorporated into the project. | Jack Fraser, Seann Strandberg (CLO) | Imperial continues to support and participate in regional monitoring programs and initiatives such as the ones conducted by the Lakeland Industry and Community Association (LICA). Imperial acts as an industry representative on the LICA Board of Directors. Recommendations from industry and the community are incorporated into LICA's programs, which have included air quality monitoring and education about environmental receptors.<br><br>Imperial participates in the environmental monitoring programs as dictated by the Joint Oil Sands Monitoring (JOSM). JOSM activities represent a significant portion of the provincial (Alberta Environment and Parks (AEP)) monitoring program. The data collected by JOSM is provided to management agencies to help support decision-making with scientific knowledge about provincial biodiversity.<br><br>Cold Lake Operations periodically hosts information sessions and tours addressed to community members. Questions or suggestions from members drive change in operating practices. For example, noise levels have been reduced at CLO following discussion with a community member.<br><br>Imperial continues to be involved with Canada's Oil Sands Innovation Alliance (COSIA). |
| 17.1 | The Operator shall ensure that sulphur recovery will be operational at the Leming, Maskwa, Mahihkan, Mahkeses, and Nabiye sites before total sulphur emissions from flaring and combustion of gas containing hydrogen sulphide (H2S) reach one tonne/day per site on a calendar quarter-year average basis, unless otherwise stipulated by the AER. The calendar quarter-year sulphur recovery shall not be less than set out in Table 1 of AER *Interim Directive (ID) 2001-03: Sulphur Recovery Guidelines for the Province of Alberta* on the basis of the calendar quarter-year daily average sulphur content of produced gas streams flared and used as fuel at each central processing facility. | Jack Fraser, Seann Strandberg (CLO) | Sulphur recovery units are installed and operational at Nabiye, Mahihkan and Mahkeses Plants. Maskwa and Leming manage sulphur limits below the 1 t/day threshold. |
| 17.2 | The Operator is required to meet the minimum sulphur recovery requirements as set out in Table 1 of AER *Interim Directive (ID) 2001-03: Sulphur Recovery Guidelines for the Province of Alberta* based on the number of days in the quarter that the non-regenerative sulphur recovery unit is operational. The Operator must maintain a minimum of 95% uptime for the non-regenerative sulphur recovery units. This clause will expire on December 31, 2018. | Jack Fraser, Seann Strandberg (CLO) | All of the sulfur recovery guidelines were met during the period of Q4 2017 to Q3 2018. |
| 17.3 | The Operator is exempt from meeting the recovery requirements as set out in Table 1 of AER *Interim Directive 2001-03: Sulphur Recovery Guidelines for the Province of Alberta* for the Maskwa facility. This clause will expire on December 31, 2018. | Jack Fraser, Seann Strandberg (CLO) | Remained in compliance of EPEA sulphur dioxide emission limit of 4.0 t/d. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 18 | The bottomhole location of a scheme well shall not be closer than 100 metres to the offset owner's oil sands lease boundary unless, upon application by the Operator, the drilling and operation of such a closer well is approved by the AER. | Angela Rupp (CLRE) | No scheme wells have been drilled within 100m of a lease boundary |
| 19.1 <rescinded> | Steam injection into the D23 pad wells must not commence until all E07 pad wells have been properly abandoned. Cement bond logs must be run over the entire intermediate casing interval in all E07 pad wells to confirm hydraulic isolation and determine the need for remediation. A non-routine well abandonment plan must be submitted for all E07 pad wells to the Well Operations Section of the AER's Technical Operations Group for review and approval in accordance with Section 2 of Directive 020: Well Abandonment. The non-routine well abandonment plan must include the interpreted cement bond logs and plans to ensure hydraulic isolation of all primary formation interfaces and across all non-saline aquifers. | Keith Dares (CLSSE) | All E07 wells were initially abandoned to 15 meters above the depth of the oil-in-shale anomaly, allowing D23 to steam. The 'Flow Behind Pipe' assessment was completed, confirming hydraulic isolation behind casing on Cold Lake wells. Final review Sept 17/12. Final E07 non-routine abandonment application submitted Dec 3/13 and approved Jan 31/14 by AER to complete full subsurface abandonment of the E07 wells, excluding E07-14 which remains as an observation well. This abandonment work was completed in Dec/14. This item is complete. |
| 20 | The Operator is permitted to abandon the Q and S Pads as described in Application No. 1684454. For the abandonment of wells on these pads a non-routine well abandonment plan must be submitted for each well to the Well Operations Section of the AER's Technical Operations Group for review and approval in accordance with Section 2 of *Directive 020: Well Abandonment*. The AER notes many wells on the Q and S Pads have been zonally abandoned; any wells which were previously zonally abandoned across the Clearwater Formation that do not have plugs set at the appropriate depth must be drilled out and reabandoned as per *Directive 020*. Additionally, cement bond logs must be run over the entire intermediate casing interval, to the depth of the zonal abandonment plug in all wells where present, to confirm hydraulic isolation and determine the need for remediation. The non-routine well abandonment plan must include the interpreted cement bond logs and discussion on how hydraulic isolation of all primary formation interfaces and across all non-saline aquifers will be maintained. | Keith Dares (CLSSE) | Bond logging on Q and S pads complete. Next steps include development and submission of Q and S well specific non-routine abandonment plans for approval. |
| 21 | The Operator is permitted to abandon the 0DD Pad as described in Application No. 1797105. For abandonment of wells on these pads a non-routine well abandonment plan must be submitted for each well to the AER's Operational Authorization Group for review and approval in accordance with Section 2 of *Directive 020: Well Abandonment*. | Keith Dares (CLSSE) | DD pad scheme approval in place, abandonments to follow CC, GG. All wells remain D013 compliant. |
| 22 | The Operator is permitted to use Steam-Assisted Gravity Drainage (SAGD), utilizing steam as the injection fluid, or Solvent Assisted-Steam Assisted Gravity Drainage (SA-SAGD), utilizing solvents and steam as the injection fluids, as the recovery process at the following Pad T13 wells producing from the Clearwater deposit:<br>AB/01-30-064-03W4/0 (producer)<br>AC/01-30-064-03W4/0 (injector)<br>AB/02-30-064-03W4/0 (producer)<br>AC/02-30-064-03W4/0 (injector) | Angela Rupp (CLRE) | T-13 SAGD and SA-SAGD operations ongoing. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 23 | The Operator shall ensure the operations in the Nabiye development area meet the following requirements: | | |
| 23.a | Before commencing initial steam injection of a CSS well, a risk assessment of the integrity of wellbores within 1000 metres of the well must be conducted, and any wellbores with integrity concerns must be remediated. The Operator must ensure that the wellbore integrity of the CSS well be maintained thereafter. | Keith Dares (CLSSE) | All new CSS development pads undergo the risk assessment as described in the requirement. |
| 23.b | For CSS wells with eight acres of drainage area per equivalent bottom hole spacing (EBHS), the total steam injection volume of cycles 1,2, and 3 is limited to 5,000 m3/EBHS, 7,000 m3/EBHS, and 8,000 m3/EBHS, respectively. Steam injection volume over fill-up for subsequent cycles is limited to 10,000 m3/EBHS. | Nathan Toone (CLRS) | All Nabiye steam cycles followed this criteria for the reporting period. |
| 23.c | For CSS wells with 4.7 acres of drainage area per equivalent bottom hole spacing (EBHS), at least two commissioning cycles are required during which the total steam volume for each cycle is limited to 2500 m3/EBHS. The total steam injection volume for cycles 1 and 2 is limited to 5000 m3/EBHS and 6000 m3/EBHS, respectively. Steam injection volume over fill-up for subsequent cycles is limited to 6000 m3/EBHS. | Nathan Toone (CLRS) | Current steam cycles for N10 planned according to clause. |
| 23.d | All steaming operations must have adequate Grand Rapids Formation water sand pressure monitoring coverage over the drainage area. Monitoring networks must be designed based on area-specific properties of the water sand within the Lower and Upper Grand Rapids Formations where both zones are present. | Angela Rupp (CLRE) | Drilled three new Nabiye Grand Rapids monitoring wells in 2018: N09-W, N10-FMW, N10-PSW. |
| 23.d.i | The Operator must notify the AER within 24 hours from the time the Operator becomes aware that the pressure of the Grand Rapids Formation exceeds 80 per cent of the fracture closure pressure calculated at the base of the Joli Fou Formation. The Operator must shut-in steam to a specific well, or multiple wells, which are suspected to be contributing to the pressure increase and provide operational strategies to stabilize the pressure. | Angela Rupp (CLRE) | All relevant events disclosed to the AER and acted upon during the reporting period. |
| 23.d.ii | When the pressure of the Grand Rapids Formation exceeds 60 per cent of the fracture closure pressure calculated at the base of the Joli Fou Formation, the Operator must shut-in steam to a specific well or multiple wells which are suspected to be contributing to the pressure increase. The Operator must document the events. | Angela Rupp (CLRE) | All relevant events documented and acted upon during the reporting period. |
| 23.d.iii | The Operator must notify the AER within 24 hours from the time the Operator becomes aware that the pressure in the Grand Rapids Formation increases by more than 200 kilopascals in a 24 hour period. The Operator must shut-in steam to a specific well, or multiple wells, which are suspected to be contributing to the pressure increase and provide operational strategies to stabilize the pressure. | Angela Rupp (CLRE) | All relevant events disclosed to the AER and acted upon during the reporting period. |
| 23.d.iv | The Operator must shut-in steam to a specific well, or multiple wells, which are suspected to be contributing to a pressure increase that exceeds 100 kilopascals over a 24 hour period in the Lower Grand Rapids Formation, or 50 kilopascals over a 24 hour period in the Upper Grand Rapids Formation. The Operator must document the events. | Angela Rupp (CLRE) | All relevant events documented and acted upon during the reporting period. |
| 23.d.v | When an injectivity event is detected and pressure increase in the Grand Rapids Formation is observed associated with the injectivity event, the Operator must notify the AER within one week from the time the pressure increase is observed and provide operational strategies to stabilize the pressure in the Grand Rapids Formation. | Angela Rupp (CLRE) | All relevant events disclosed to the AER and acted upon during the reporting period. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 24.1 | The recovery process approved for the project in the Lower Grand Rapids Deposit is Steam Assisted Gravity Drainage utilizing steam and solvent as the injection fluid (SA-SAGD) unless otherwise stipulated by the AER. | Angela Rupp (CLRE) | Lower Grand Rapids development planned to use SA-SAGD recovery process. |
| 24.2 | The recovery process approved for the project in the Clearwater Deposit is High Pressure Cyclic Steam Stimulation (HPCSS) unless otherwise stipulated by the AER. | Angela Rupp (CLRE) | All Clearwater development is HPCSS unless otherwise stated. |
| 25 | Prior to drilling SA-SAGD and CSS wells in an area, all wells that could be impacted by thermal operations must be completed or abandoned in a manner that is compatible with the thermal operations. The Operator must contact the AER for discussion of and obtain approval for the manner in which to complete or abandon wells not considered to be compatible with the thermal operations. | Keith Dares (CLSSE) | All wells potentially impacted by thermal operations will meet this criteria. |
| 26 | The Operator shall verify the facility's noise impact at the residences, which are represented by the Marie Lake Air and Watershed Society (MLAWS), when one or more of the surrounding well pads are in normal operational condition (including but not limited to the well pads 37, 40, 84 and 85). The Operator shall conduct a site noise survey and use the survey data to update the acoustical model, and should conduct a comprehensive sound level survey if necessary, to verify whether the Operator maintains its commitment to the MLAWS to strive to keep its facility sound below 33 dBA. The noise study report shall be submitted to the AER for a technical review and shall be shared with the MLAWS. | Kelly Wiebe (SSHE) | Noise monitoring is performed on an annual basis. 2017 nighttime isolated values met the 33 dBA commitment around Marie Lake; 2018 results are under review.<br>Noise monitoring results are submitted to the AER and discussed with MLAWS. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 27 | Any plans for operations or development outside the approved development area shall be applied for to the AER for review. Such applications must:<br><br>a) Include a complete geologic, reservoir and caprock integrity characterization to reduce uncertainty and improve understanding of subsurface properties for both the Clearwater and the Lower Grand Rapids 030/020 zones. Information should include, but is not limited to<br>i) Grand Rapids delineation:<br>(1) 8 wells per section; or<br>(2) 4 wells per section plus 3D seismic; or<br>(3) as authorized by the AER,<br>(4) minimum amount of wells to be cored per section is 4 wells<br>ii) Clearwater delineation:<br>(1) 6 wells per section; or<br>(2) 4 wells per section plus 3D seismic; or<br>(3) as authorized by the AER,<br>(4) minimum amount of wells to be cored per section is 4 wells<br>iii) summary of core analysis and annotated representative core well photographs of the rcaprock,<br>iv) reference clause 6 for reservoir core requirements,<br>v) tabulation of reservoir properties,<br>vi) tabulation of reserve and resource estimates for drainage patterns, the development area and any expansion outside of the development area,<br>vii)tabulation of caprock properties,<br>viii) discussion with supporting information of any geologic findings that have the potential to compromise caprock integrity,<br>ix) submit the most current isopach maps of the gross, and net bitumen, lean zones and bottom water, and<br>x) any other information required by the AER.<br><br>b) Provide a detailed description of the proposed amendment, including the number and type of wells per drainage area, the lateral spacing between wells, the length and trajectory of each deviated and horizontal well, the horizontal well elevations, and the subsurface drainage area corresponding to each horizontal well. Provide an annotated log cross section for one representative well or well pair per drainage area to demonstrate that the well locations and drainage area designs have been optimized.<br><br>c) Provide a discussion of the scheme performance to date, with specific emphasis on key factors affecting the success of the scheme, and how this experience will be incorporated into the design and operation of the scheme within the proposed additional area, including:<br>i) the impact of top gas,<br>ii) the impact of top water,<br>iii) the impact of bottom water, and<br>iv) state of steam chamber development and the effectiveness of the caprock.<br><br>d) provide a discussion on bitumen recovery and pad production profiles for the well pads within the proposed additional development area. The information must include:<br>i) key performance predictions (e.g., injection and production rates, steam oil ratio), including the methodology utilized and supporting information, and<br>ii)\ cumulative steam injection volume per injection cycle for HPCSS wells. | Angela Rupp (CLRE) | All applications to the AER for operations or development outside the approved development area will meet this criteria. |

# AER Approval 8558

| Clause | Requirement Summary - | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 28 <rescinded> | Appendix A represents project area for the recovery of crude bitumen from Clear Water deposit in the Cold Lake Oil Sands Area, and Appendix B represents project area for the recovery of bitumen from Lower Grand Rapid deposit in the Cold Lake Expansion Area. | Angela Rupp (CLRE) | No comments. |
| 29 | The Operator may co-inject diluent to a maximum of 8% by volume with steam, as a cold water equivalent, for each injection cycle at the pads within the development area identified in Appendix A. | Nathan Toone (CLRS) | Currently co-injecting diluent at Mahihkan North within development area identified in Appendix A. |
| 30 | The Operator may drill and operate infill wells within the approved development area identified in Appendix A. | Nathan Toone (CLRS) | Continue to use infill drilling to maximize recovery within approved development area. |

Attachment 2

# Approval 4510

## Compliance Conditions

# AER Approval 4510

| Clause | Requirement Summary | Responsibility | 2018 Status/Comments |
|---|---|---|---|
| 4510_2 | The disposal of fluids...in the wells...which have satisfied Guide 51 requirements, may commence or continue. | Keith Dares (CLSSE) | Injection follows the conditions of the Directive 051 approvals. |
| 4510_3 | The reservoir pressure at the observation wells must be monitored on a minimum of an annual basis. | Ali Loeffelmann (CLO) | In compliance. All N Pad injection has ceased as of November 2015 . Injection line to N-pad has been discontinued and no longer able to injected. |
| 4510_4 | If the reservoir pressure increases to 7500 kPa (ga), all of the following disposal wells must be re-logged to ensure there is no migration of the disposal fluid out of the zone via micro-annuli:<br>AB/06-05-065-03W4/0<br>AU/06-05-065-03W4/0<br>AJ/06-05-065-03W4/0<br>AG/07-05-065-03W4/0<br>AM/06-05-065-03W4/0<br>AH/07-05-065-03W4/0 | Ali Loeffelmann (CLO) | In compliance. All N Pad injection has ceased as of November 2015. Injection line to N Pad has been discontinued and no longer able to injected. |
| 4510 | Submit an annual report for Approval 4510 Nov. 2016 | Nathan Toone (CLRS) | Due to N-Pad inactivity, the AER has temporarily discontinued the N-Pad annual report submission requirement unless injection restarts. Any changes to the status of N Pad will immediately be reported to the AER. |

Attachment 3

# Water Disposal and Storage

# Water Disposal and Storage

## PW Disposal & Storage
## District Summary – Volumes in $m^3$

| | Oct-17 | Nov-17 | Dec-17 | Jan-18 | Feb-18 | Mar-18 | Apr-18 | May-18 | Jun-18 | Jul-18 | Aug-18 | Sep-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Disposal Volume, m3 | 54,664 | 43,609 | 18,413 | 15,295 | 46,250 | 22,955 | 84,618 | 33,374 | 42,602 | 64,868 | 81,578 | 73,885 |
| Disposal Limit, m3 | 255,194 | 252,148 | 246,065 | 239,965 | 213,385 | 252,129 | 239,167 | 223,610 | 201,543 | 253,265 | 252,440 | 228,419 |
| Actual Disposal, % | 1.5% | 1.2% | 0.5% | 0.4% | 1.5% | 0.7% | 2.2% | 1.0% | 1.4% | 1.7% | 2.2% | 2.1% |
| Disposal Limit, % | 6.9% | 6.9% | 6.8% | 6.8% | 6.7% | 7.2% | 6.3% | 6.7% | 6.5% | 6.6% | 6.7% | 6.5% |

Actual Disposal (%) = Actual disposal / (Total produced water + Total Fresh water including run off and remediation + brackish water)

Disposal Limit (%) = Disposal Limit / (Total produced water + Total Fresh water including run off and remediation + brackish water)

Attachment 4

# Facility Performance by Plant

# Cold Lake Facility Performance

| | 12/1/2016 | 1/1/2017 | 2/1/2017 | 3/1/2017 | 4/1/2017 | 5/1/2017 | 6/1/2017 | 7/1/2017 | 8/1/2017 | 9/1/2017 | 10/1/2017 | 11/1/2017 | 12/1/2017 | 1/1/2018 | 2/1/2018 | 3/1/2018 | 4/1/2018 | 5/1/2018 | 6/1/2018 | 7/1/2018 | 8/1/2018 | 9/1/2018 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Maskwa Plant** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 6913.8 | 6734.4 | 6925.6 | 7025.5 | 6820.4 | 6717.0 | 6672.4 | 6863.3 | 6613.1 | 6359.7 | 7197.5 | 6401.0 | 6295.7 | 6199.5 | 5872.5 | 5825.8 | 6285.5 | 3901.2 | 3205.5 | 6424.3 | 6749.2 | 6565.7 |
| Produced Water $m^3/d$ | 26784.1 | 27406.1 | 28510.9 | 26224.8 | 26216.6 | 25946.9 | 25634.7 | 26605.9 | 25818.3 | 23213.8 | 27895.3 | 25520.5 | 24708.4 | 26131.2 | 24083.5 | 25417.2 | 26268.8 | 16080.4 | 12135.6 | 30497.5 | 31342.7 | 27229.3 |
| HP Steam Generation $m^3/d$ | 24442.3 | 24228.8 | 22777.7 | 22783.7 | 24061.1 | 23342.6 | 22419.2 | 23564.1 | 23347.9 | 23920.5 | 24971.8 | 25154.1 | 24968.5 | 23530.0 | 21971.0 | 26273.1 | 25955.9 | 14038.3 | 10607.9 | 24555.0 | 26833.3 | 26373.7 |
| HP Steam Injection $m^3/d$ | 22788.7 | 22593.2 | 21015.0 | 20673.7 | 22225.9 | 21711.0 | 20657.1 | 21657.1 | 21397.8 | 21969.9 | 22641.7 | 22905.3 | 22555.5 | 21507.9 | 19928.3 | 23521.5 | 23455.4 | 12478.1 | 9132.0 | 22703.0 | 24606.6 | 24101.5 |
| Steam Quality % | 73.2 | 71.4 | 71.4 | 59.1 | 70.4 | 73.6 | 74.3 | 72.3 | 67.8 | 67.8 | 69.9 | 72.2 | 70.3 | 68.2 | 70.7 | 73.5 | 73.1 | 69.3 | 69.1 | 74.4 | 68.5 | 62.2 |
| Produced Gas $km^3/d$ | 257.1 | 275.1 | 281.2 | 257.0 | 270.3 | 275.9 | 291.5 | 356.8 | 350.1 | 303.9 | 351.3 | 346.1 | 275.1 | 308.9 | 288.9 | 249.3 | 329.5 | 211.3 | 119.7 | 351.3 | 336.4 | 300.6 |
| Purchased Gas $km^3/d$ | 1271.5 | 1258.7 | 1172.1 | 1084.1 | 1220.0 | 1201.0 | 1141.8 | 1177.9 | 1169.1 | 1226.8 | 1253.7 | 1299.7 | 1285.6 | 1190.8 | 1115.8 | 1347.2 | 1307.6 | 675.8 | 553.9 | 1235.7 | 1329.9 | 1280.2 |
| **Mahihkan Plant** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 8680.3 | 8940.0 | 8776.2 | 8888.7 | 8831.6 | 8722.6 | 8936.8 | 9266.7 | 9293.8 | 9701.1 | 9847.6 | 9521.3 | 9187.0 | 8579.8 | 7493.1 | 8069.9 | 7463.7 | 8087.2 | 7719.2 | 8026.0 | 7858.9 | 7385.3 |
| Produced Water $m^3/d$ | 34169.2 | 32267.4 | 34955.4 | 33512.4 | 34267.7 | 33898.3 | 32605.0 | 32791.4 | 33163.4 | 33710.2 | 35105.7 | 35643.4 | 34162.8 | 31138.2 | 28364.6 | 32229.4 | 30696.7 | 34646.4 | 31358.0 | 32885.1 | 33000.9 | 30499.9 |
| HP Steam Generation $m^3/d$ | 39030.0 | 38193.6 | 38296.8 | 37459.8 | 40342.8 | 39745.8 | 38297.8 | 38781.3 | 38543.4 | 39180.3 | 39905.1 | 39044.2 | 37911.1 | 35001.2 | 31864.5 | 34580.4 | 34376.8 | 39756.0 | 38230.2 | 40632.5 | 39778.3 | 40408.6 |
| HP Steam Injection $m^3/d$ | 36213.0 | 35076.7 | 35310.0 | 34384.4 | 37264.8 | 36578.4 | 35655.0 | 36163.5 | 35717.8 | 36394.9 | 36795.5 | 36019.9 | 34721.4 | 31988.0 | 28945.9 | 31282.4 | 31388.1 | 36660.2 | 35028.6 | 37399.1 | 36619.6 | 36568.5 |
| Steam Quality % | 72.8 | 71.7 | 72.1 | 71.5 | 72.7 | 72.0 | 71.4 | 71.6 | 71.5 | 72.1 | 71.0 | 71.8 | 71.3 | 70.0 | 67.3 | 71.2 | 70.2 | 70.9 | 70.5 | 71.7 | 69.7 | 70.5 |
| Produced Gas $km^3/d$ | 372.0 | 394.5 | 411.9 | 415.4 | 420.8 | 415.2 | 444.5 | 473.1 | 484.6 | 471.3 | 478.2 | 472.4 | 493.3 | 471.6 | 431.0 | 484.6 | 446.6 | 482.5 | 441.6 | 435.4 | 414.2 | 404.6 |
| Purchased Gas $km^3/d$ | 1778.6 | 1732.4 | 1738.8 | 1709.3 | 1851.8 | 1827.6 | 1791.4 | 1808.0 | 1794.1 | 1817.8 | 1863.4 | 1769.9 | 1719.6 | 1576.1 | 1398.3 | 1480.4 | 1486.6 | 1737.4 | 1667.4 | 1802.9 | 1758.8 | 1850.6 |
| **Mahkeses Plant** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 4298.9 | 4181.4 | 4504.9 | 4410.3 | 4448.6 | 4228.0 | 4551.9 | 4594.2 | 4622.2 | 4993.5 | 5376.7 | 5751.2 | 6268.5 | 6120.1 | 5390.2 | 5683.7 | 5379.1 | 5578.5 | 5179.4 | 5457.1 | 5246.3 | 5121.6 |
| Produced Water $m^3/d$ | 17865.8 | 18293.0 | 19238.1 | 19184.1 | 15614.9 | 14841.8 | 16389.6 | 17669.5 | 18786.6 | 20373.5 | 22754.6 | 21128.8 | 22312.5 | 21627.5 | 18978.3 | 19555.3 | 18692.4 | 21122.2 | 18845.3 | 20638.4 | 21967.9 | 22764.3 |
| HP Steam Generation $m^3/d$ | 22387.8 | 22583.7 | 22896.5 | 21407.4 | 14620.0 | 18710.3 | 21773.8 | 22649.2 | 21834.2 | 21983.9 | 23741.3 | 22860.5 | 23325.9 | 23309.5 | 21372.4 | 21753.3 | 16203.6 | 21423.2 | 20870.5 | 23858.6 | 23462.2 | 22985.8 |
| HP Steam Injection $m^3/d$ | 20571.8 | 26226.9 | 25518.7 | 24836.1 | 15578.1 | 20459.2 | 24454.4 | 26752.5 | 24889.6 | 23241.1 | 26216.8 | 23578.4 | 22333.3 | 21886.4 | 20132.5 | 22719.6 | 17106.0 | 23391.8 | 22034.4 | 25847.3 | 25168.2 | 25384.2 |
| Steam Quality % | 69.7 | 69.9 | 68.9 | 69.6 | 67.8 | 65.5 | 68.3 | 68.0 | 66.1 | 65.7 | 67.8 | 66.7 | 65.8 | 65.4 | 64.8 | 63.3 | 67.6 | 66.6 | 63.6 | 65.1 | 64.0 | 65.2 |
| Produced Gas $km^3/d$ | 251.9 | 254.4 | 287.1 | 272.1 | 260.5 | 270.0 | 311.1 | 314.2 | 291.1 | 279.2 | 297.2 | 337.4 | 335.5 | 310.2 | 285.7 | 322.5 | 287.7 | 304.1 | 293.7 | 318.4 | 307.5 | 301.0 |
| Purchased Gas $km^3/d$ | 1614.7 | 1622.8 | 1604.9 | 1557.5 | 957.3 | 1281.8 | 1482.2 | 1518.2 | 1474.1 | 1512.3 | 1650.1 | 1591.6 | 1612.2 | 1617.8 | 1498.9 | 1531.8 | 1075.5 | 1474.2 | 1411.1 | 1546.8 | 1525.4 | 1566.4 |
| **Leming Plant** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 1085.0 | 1145.5 | 1179.1 | 994.7 | 916.2 | 1025.3 | 1149.9 | 1199.3 | 1295.5 | 1173.4 | 1277.1 | 1236.7 | 1305.0 | 1260.5 | 1091.3 | 1256.6 | 1188.3 | 1294.1 | 1199.6 | 1184.1 | 1207.8 | 1166.4 |
| Produced Water $m^3/d$ | 5187.0 | 5762.3 | 5744.0 | 4571.6 | 4284.2 | 5347.8 | 5969.7 | 5508.4 | 5849.0 | 4695.7 | 5999.8 | 6656.9 | 6413.0 | 5781.9 | 5393.1 | 6470.0 | 5939.0 | 7005.8 | 6550.4 | 6148.5 | 5932.9 | 6084.9 |
| HP Steam Generation $m^3/d$ | 4312.6 | 6048.1 | 6785.6 | 6768.8 | 4587.7 | 6049.0 | 7489.3 | 8373.0 | 8763.0 | 7587.6 | 7319.3 | 7245.8 | 6994.4 | 8119.2 | 6790.2 | 8106.4 | 7997.4 | 7124.8 | 7506.7 | 9654.9 | 8651.5 | 9084.4 |
| HP Steam Injection $m^3/d$ | 4023.0 | 1793.8 | 2523.2 | 2021.8 | 2059.8 | 1994.4 | 2813.5 | 2484.9 | 4016.1 | 4840.5 | 3252.9 | 4589.3 | 5562.8 | 6757.0 | 5461.4 | 4121.9 | 4575.8 | 3526.6 | 4162.9 | 5177.8 | 4531.1 | 4679.6 |
| Steam Quality % | 57.0 | 68.5 | 69.5 | 72.7 | 65.4 | 68.9 | 66.3 | 67.5 | 68.8 | 66.7 | 63.6 | 69.1 | 70.4 | 67.1 | 64.4 | 65.8 | 70.2 | 70.7 | 69.0 | 71.4 | 68.5 | 64.6 |
| Produced Gas $km^3/d$ | 73.1 | 59.5 | 61.2 | 45.9 | 44.8 | 44.8 | 76.2 | 77.7 | 77.1 | 74.1 | 75.3 | 73.9 | 76.3 | 76.0 | 63.5 | 67.9 | 53.0 | 55.2 | 55.4 | 59.8 | 63.1 | 63.9 |
| Purchased Gas $km^3/d$ | 164.4 | 301.1 | 337.8 | 360.1 | 189.5 | 303.3 | 363.5 | 421.9 | 455.8 | 401.7 | 355.0 | 371.8 | 354.0 | 420.9 | 349.1 | 411.5 | 425.8 | 364.4 | 375.4 | 493.4 | 431.0 | 463.2 |
| **Nabiye** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 4429.3 | 4703.6 | 2945.8 | 4029.3 | 4424.5 | 3898.5 | 4985.0 | 4159.6 | 3732.0 | 3980.7 | 3467.3 | 4110.1 | 4816.4 | 4287.8 | 3101.0 | 2794.1 | 2611.1 | 2601.8 | 2783.8 | 3346.4 | 4077.2 | 3461.6 |
| Produced Water $m^3/d$ | 11652.8 | 12071.4 | 12495.4 | 12813.3 | 10578.1 | 11617.1 | 13912.9 | 11773.7 | 13538.7 | 13426.0 | 11726.6 | 13114.0 | 13440.6 | 11909.8 | 10034.6 | 11544.6 | 11521.1 | 12325.4 | 14379.4 | 15046.8 | 15206.1 | 13515.2 |
| HP Steam Generation $m^3/d$ | 19103.0 | 16628.3 | 18790.1 | 18631.5 | 18843.4 | 19326.3 | 18453.7 | 19374.1 | 16663.0 | 13336.4 | 19960.0 | 20671.9 | 22724.1 | 21554.9 | 19688.7 | 21679.1 | 20878.8 | 21749.9 | 20303.1 | 21185.8 | 20513.9 | 14534.2 |
| HP Steam Injection $m^3/d$ | 18028.1 | 15686.4 | 17965.8 | 17733.4 | 17710.2 | 18435.5 | 17692.7 | 18360.8 | 16013.1 | 12837.9 | 18833.6 | 19832.1 | 21643.9 | 20527.8 | 18717.3 | 20833.8 | 20045.4 | 21024.1 | 19847.2 | 20775.0 | 20161.9 | 14116.9 |
| Steam Quality % | 56.9 | 56.8 | 62.0 | 63.4 | 69.2 | 66.5 | 63.6 | 69.4 | 66.8 | 61.9 | 64.8 | 67.3 | 69.7 | 63.7 | 64.7 | 68.4 | 65.7 | 68.0 | 69.2 | 69.3 | 68.4 | 40.4 |
| Produced Gas $km^3/d$ | 145.7 | 154.3 | 118.8 | 137.4 | 142.7 | 150.6 | 163.0 | 168.3 | 166.4 | 170.8 | 171.1 | 170.2 | 150.9 | 140.1 | 110.6 | 124.5 | 108.1 | 105.7 | 113.2 | 131.1 | 134.8 | 123.2 |
| Purchased Gas $km^3/d$ | 1579.5 | 1318.9 | 1578.3 | 1543.8 | 1542.2 | 1488.8 | 1428.0 | 1482.6 | 1247.2 | 984.8 | 1505.2 | 1695.5 | 1851.5 | 1718.1 | 1602.0 | 1767.5 | 1663.0 | 1662.9 | 1530.5 | 1554.3 | 1506.6 | 1065.5 |
| **SA-SAGD** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 38.5 | 37.3 | 33.3 | 45.2 | 39.4 | 32.1 | 26.2 | 21.6 | 23.0 | 16.5 | 2.7 | 15.2 | 12.1 | 56.8 | 123.4 | 104.6 | 94.0 | 43.2 | 64.8 | 79.8 | 54.9 | 59.1 |
| Produced Water $m^3/d$ | 176.7 | 196.3 | 210.9 | 220.6 | 184.2 | 184.1 | 151.1 | 141.1 | 99.3 | 85.2 | 14.7 | 81.7 | 68.1 | 225.6 | 368.7 | 412.8 | 317.7 | 135.0 | 210.8 | 272.8 | 254.6 | 248.3 |
| HP Steam Injection $m^3/d$ | 244.7 | 260.9 | 228.2 | 177.9 | 186.7 | 256.2 | 227.1 | 123.5 | 42.1 | 60.6 | 1.4 | 0.0 | 60.3 | 262.3 | 226.5 | 403.3 | 193.8 | 0.0 | 334.3 | 490.3 | 463.1 | 232.1 |
| Produced Gas $km^3/d$ | 0.5 | 0.3 | 0.3 | 0.6 | 0.8 | 0.3 | 0.1 | 0.0 | 0.1 | 0.1 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.7 | 1.3 | 1.7 | 2.5 | 1.5 | 1.5 | 1.8 |
| **District** | | | | | | | | | | | | | | | | | | | | | | |
| Bitumen Production $m^3/d$ | 25407.4 | 25705.0 | 24364.8 | 25393.7 | 25480.8 | 24623.5 | 26322.1 | 26104.6 | 25579.6 | 26224.9 | 27168.9 | 27035.3 | 27884.7 | 26504.5 | 23071.5 | 23734.8 | 23021.7 | 21505.9 | 20152.3 | 24517.6 | 25194.3 | 23759.9 |
| Produced Water $m^3/d$ | 95658.9 | 95800.3 | 101154.5 | 96526.8 | 91145.7 | 91836.0 | 94662.9 | 94490.0 | 97255.3 | 95504.4 | 103496.7 | 102145.4 | 101105.3 | 96814.2 | 87222.8 | 95629.2 | 93435.8 | 91315.2 | 83479.5 | 105489.0 | 107705.0 | 100341.9 |
| HP Steam Generation $m^3/d$ | 109275.6 | 107682.5 | 109546.7 | 107051.1 | 102455.0 | 107173.9 | 108433.7 | 112741.7 | 109151.6 | 106008.7 | 115897.5 | 114976.5 | 115923.9 | 111514.7 | 101686.8 | 112392.2 | 105412.6 | 104092.2 | 97518.4 | 119886.8 | 119239.2 | 113386.7 |
| HP Steam Injection $m^3/d$ | 101624.7 | 101377.0 | 102560.9 | 99827.3 | 95025.5 | 99434.6 | 101499.8 | 105542.3 | 102076.4 | 99344.9 | 107741.8 | 106925.0 | 106877.2 | 102929.4 | 93411.7 | 102882.4 | 96764.5 | 97080.9 | 90539.2 | 112392.6 | 111550.6 | 105082.8 |
| Produced Gas $km^3/d$ | 1100.3 | 1138.1 | 1160.4 | 1128.3 | 1139.9 | 1156.7 | 1286.5 | 1390.1 | 1369.3 | 1299.4 | 1373.0 | 1400.0 | 1331.2 | 1307.0 | 1179.9 | 1249.5 | 1226.3 | 1160.4 | 1026.1 | 1297.6 | 1257.5 | 1195.1 |
| Purchased Gas $km^3/d$ | 4829.2 | 6233.9 | 6431.7 | 6254.9 | 5760.8 | 6102.5 | 6206.8 | 6408.6 | 6140.3 | 5943.4 | 6627.3 | 6728.5 | 6822.9 | 6523.7 | 5964.0 | 6538.4 | 5958.4 | 5914.7 | 5538.2 | 6633.2 | 6551.8 | 6225.8 |
| Fresh Water $m^3/d$ | 5314.5 | 6048.6 | 6523.1 | 5928.6 | 5163.3 | 6025.9 | 6758.8 | 6643.9 | 6332.9 | 5657.6 | 5780.2 | 6795.1 | 6083.5 | 6505.1 | 6841.5 | 5930.0 | 5703.9 | 7062.7 | 6589.9 | 6239.5 | 6546.1 | 5671.6 |
| Brackish Water $m^3/d$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 41.0 | 0.0 | 0.0 | 313.2 | 512.9 | 1108.8 | 264.1 | 0.0 | 1814.4 | 0.0 | 66.9 | 0.0 | 45.2 | 9.0 | 46.7 |
| Ground Water $m^3/d$ | 11.9 | 7.8 | 9.7 | 20.8 | 16.1 | 13.0 | 9.2 | 19.7 | 82.0 | 22.7 | 20.1 | 10.3 | 9.9 | 11.7 | 30.7 | 18.5 | 209.2 | 8.7 | 69.8 | 17.0 | 71.8 | 638.8 |
| Disposal Water $m^3/d$ | 0.0 | 3045.6 | 2824.3 | 4274.4 | 3624.4 | 2580.7 | 1341.0 | 224.1 | 2818.8 | 3071.8 | 1763.4 | 1453.6 | 594.0 | 493.4 | 1651.8 | 740.5 | 2820.6 | 1112.5 | 1420.1 | 2092.5 | 2631.5 | 2462.8 |
| PW Recycle % | 0.9 | 0.9 | 0.8 | 0.9 | 0.8 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.0 | 0.9 | 0.9 | 0.9 | 0.7 | 0.9 | 0.8 | 0.9 | 0.9 | 0.9 |
| Power Generation MW-h | 344.5 | 320.3 | 340.6 | 335.1 | 270.6 | 290.6 | 291.0 | 306.3 | 283.1 | 261.8 | 314.3 | 350.6 | 344.5 | 336.3 | 349.6 | 347.9 | 288.2 | 325.7 | 303.7 | 307.7 | 303.8 | 274.5 |
| Power Import from Grid MW-h | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.7 | 0.8 | 0.7 | 0.7 | 0.7 | 0.7 |
| Power Export from Grid MW-h | 193.0 | 169.7 | 188.8 | 186.2 | 127.0 | 155.5 | 150.5 | 169.2 | 148.9 | 129.8 | 171.2 | 194.4 | 189.7 | 183.7 | 193.9 | 199.8 | 141.7 | 196.2 | 187.4 | 182.7 | 168.6 | 139.5 |
| Power Consumption MW-h | 152.3 | 151.4 | 152.6 | 149.7 | 144.3 | 135.8 | 141.2 | 137.8 | 134.8 | 132.7 | 143.8 | 156.9 | 155.6 | 153.4 | 156.5 | 148.8 | 147.2 | 130.2 | 117.0 | 125.6 | 135.9 | 135.7 |
| Flare Gas $km^3/d$ | 1.83 | 4.56 | 8.56 | 13.23 | 3.61 | 5.97 | 11.04 | 4.63 | 22.94 | 6.32 | 18.88 | 1.91 | 10.98 | 11.81 | 3.62 | 2.21 | 6.22 | 7.93 | 14.10 | 4.75 | 3.24 | 6.33 |
| Vent Gas $km^3/d$ | 0.33 | 0.51 | 0.60 | 0.80 | 0.49 | 0.42 | 0.82 | 0.78 | 0.81 | 0.82 | 0.57 | 1.31 | 0.95 | 0.59 | 1.76 | 0.55 | 1.12 | 1.10 | 1.09 | 1.44 | 1.93 | 1.48 |
| Produced Gas Recovery % | 99.8 | 99.6 | 99.2 | 98.8 | 99.6 | 99.4 | 99.1 | 99.6 | 98.3 | 99.4 | 98.6 | 99.8 | 99.1 | 99.1 | 99.5 | 99.8 | 99.4 | 99.2 | 98.5 | 99.5 | 99.6 | 99.3 |
| Total Water License $m^3$ | 5787.6 | 6310.9 | 7054.5 | 7023.7 | 18989.5 | 10139.2 | 10220.4 | 12707.3 | 8399.3 | 6446.8 | 6713.3 | 7238.0 | 6429.3 | 6823.8 | 7108.4 | 6421.7 | 20945.2 | 7914.9 | 14204.0 | 11111.5 | 9681.1 | 13823.6 |
| Runoff $m^3$ | 78.4 | 22.6 | 309.8 | 858.4 | 13509.3 | 3670.2 | 3110.6 | 5692.3 | 1665.3 | 516.9 | 689.5 | 221.6 | 122.7 | 103.2 | 39.3 | 286.5 | 14828.5 | 534.5 | 7269.6 | 4535.9 | 2750.4 | 7260.3 |
| TWT | 1361.3 | 1182.4 | 1228.0 | 2098.4 | 2969.6 | 1291.4 | 2204.0 | 2142.5 | 2517.9 | 2748.2 | 2211.8 | 1216.3 | 847.9 | 1944.0 | 2126.2 | 1720.3 | 4338.8 | 1179.8 | 3409.6 | 4167.8 | 3183.6 | 2999.5 |
| Source Water | 5326.4 | 6056.3 | 6532.8 | 5949.3 | 5179.3 | 6038.8 | 6768.0 | 6663.6 | 6414.9 | 5680.3 | 5800.4 | 6805.4 | 6093.5 | 6516.7 | 6872.2 | 5948.5 | 5913.2 | 7071.3 | 6659.7 | 6256.5 | 6617.9 | 6310.5 |



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Attachment 5

# Sulphur Balances by Plant

# Cold Lake Plant Sulphur Balances

As per AER approval 8558 clause 24.2, Imperial is required to report monthly sulphur and comply on a calendar quarter year average basis for each plant.

| Tonnes/Day | Month | Oct-17 | Nov-17 | Dec-17 | Jan-18 | Feb-18 | Mar-18 | Apr-18 | May-18 | Jun-18 | Jul-18 | Aug-18 | Sep-18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| District | Sulphur Inlet | 171.49 | 174.99 | 151.53 | 140.43 | 140.37 | 157.44 | 142.82 | 131.15 | 135.12 | 173.47 | 157.23 | 147.80 |
| | Sulphur Removed | 87.57 | 92.61 | 77.66 | 69.62 | 67.79 | 84.22 | 71.01 | 67.25 | 83.03 | 97.08 | 85.84 | 78.37 |
| | Sulphur Emissions | 83.92 | 82.38 | 73.87 | 70.81 | 72.58 | 73.22 | 71.80 | 63.90 | 52.09 | 76.39 | 71.39 | 69.44 |
| | $SO_2$ Emissions | 167.84 | 164.76 | 147.74 | 141.62 | 145.16 | 146.44 | 143.61 | 127.81 | 104.18 | 152.77 | 142.77 | 138.87 |
| | Sulphur Recovery | 51.06% | 52.92% | 51.25% | 49.58% | 48.29% | 53.49% | 49.72% | 51.28% | 61.45% | 55.97% | 54.60% | 53.02% |
| Leming | Sulphur Inlet | 10.98 | 16.49 | 12.42 | 10.51 | 8.50 | 8.20 | 6.58 | 6.66 | 5.44 | 6.26 | 5.74 | 5.43 |
| | Sulphur Removed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sulphur Emissions | 10.98 | 16.49 | 12.42 | 10.51 | 8.50 | 8.20 | 6.58 | 6.66 | 5.44 | 6.26 | 5.74 | 5.43 |
| | $SO_2$ Emissions | 21.97 | 32.98 | 24.84 | 21.02 | 17.01 | 16.40 | 13.15 | 13.32 | 10.87 | 12.51 | 11.48 | 10.86 |
| | Sulphur Recovery | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Maskwa | Sulphur Inlet | 35.46 | 31.45 | 23.26 | 29.43 | 32.07 | 28.23 | 38.40 | 22.35 | 11.17 | 34.59 | 31.43 | 28.06 |
| | Sulphur Removed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sulphur Emissions | 35.46 | 31.45 | 23.26 | 29.43 | 32.07 | 28.23 | 38.40 | 22.35 | 11.17 | 34.59 | 31.43 | 28.06 |
| | $SO_2$ Emissions | 70.92 | 62.90 | 46.51 | 58.86 | 64.15 | 56.45 | 76.81 | 44.71 | 22.34 | 69.18 | 62.86 | 56.12 |
| | Sulphur Recovery | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| Mahihkan | Sulphur Inlet | 44.76 | 46.76 | 40.74 | 40.07 | 44.46 | 65.31 | 57.80 | 53.89 | 45.06 | 49.59 | 39.55 | 35.45 |
| | Sulphur Removed | 30.58 | 35.82 | 25.50 | 23.79 | 29.31 | 47.75 | 41.91 | 33.04 | 31.53 | 38.74 | 29.50 | 23.03 |
| | Sulphur Emissions | 14.18 | 10.94 | 15.24 | 16.29 | 15.15 | 17.56 | 15.88 | 20.85 | 13.53 | 10.84 | 10.05 | 12.41 |
| | $SO_2$ Emissions | 28.36 | 21.88 | 30.48 | 32.57 | 30.29 | 35.12 | 31.77 | 41.70 | 27.06 | 21.69 | 20.10 | 24.83 |
| | Sulphur Recovery | 68.32% | 76.61% | 62.60% | 59.36% | 65.93% | 73.12% | 72.52% | 61.31% | 69.97% | 78.13% | 74.59% | 64.98% |
| Mahkeses | Sulphur Inlet | 54.52 | 38.66 | 40.72 | 33.22 | 31.64 | 36.67 | 19.75 | 22.69 | 24.29 | 31.59 | 28.68 | 32.21 |
| | Sulphur Removed | 38.39 | 27.77 | 28.38 | 23.46 | 22.34 | 25.47 | 13.87 | 15.93 | 18.38 | 22.31 | 20.08 | 22.54 |
| | Sulphur Emissions | 16.12 | 10.89 | 12.34 | 9.76 | 9.30 | 11.20 | 5.88 | 6.76 | 5.91 | 9.28 | 8.60 | 9.67 |
| | $SO_2$ Emissions | 32.25 | 21.78 | 24.69 | 19.51 | 18.61 | 22.40 | 11.76 | 13.52 | 11.82 | 18.57 | 17.21 | 19.34 |
| | Sulphur Recovery | 70.42% | 71.83% | 69.69% | 70.63% | 70.60% | 69.46% | 70.23% | 70.21% | 75.67% | 70.61% | 70.00% | 69.98% |
| Nabiye | Sulphur Inlet | 25.77 | 41.63 | 34.39 | 27.20 | 17.62 | 25.11 | 20.29 | 25.56 | 49.17 | 51.45 | 51.83 | 46.66 |
| | Sulphur Removed | 18.60 | 29.02 | 23.78 | 22.37 | 13.23 | 13.91 | 15.23 | 18.28 | 33.13 | 36.03 | 36.27 | 32.79 |
| | Sulphur Emissions | 7.17 | 12.62 | 10.61 | 4.83 | 4.39 | 11.20 | 5.06 | 7.28 | 16.05 | 15.41 | 15.56 | 13.87 |
| | $SO_2$ Emissions | 14.35 | 25.23 | 21.22 | 9.66 | 8.78 | 22.40 | 10.12 | 14.56 | 32.09 | 30.82 | 31.12 | 27.73 |
| | Sulphur Recovery | 72% | 70% | 69% | 82% | 75% | 55% | 75% | 72% | 67.37% | 70.04% | 69.98% | 70.28% |

# Sulphur Measurement & Reporting

**Sulphur ($H_2S$) Sampling Process**

- Manual gas samples taken to monitor $H_2S$ concentration
- Additional gas samples may be taken if increased frequency is desired (e.g. approaching license limits and/or increased variability in samples expected or performance control improvements)

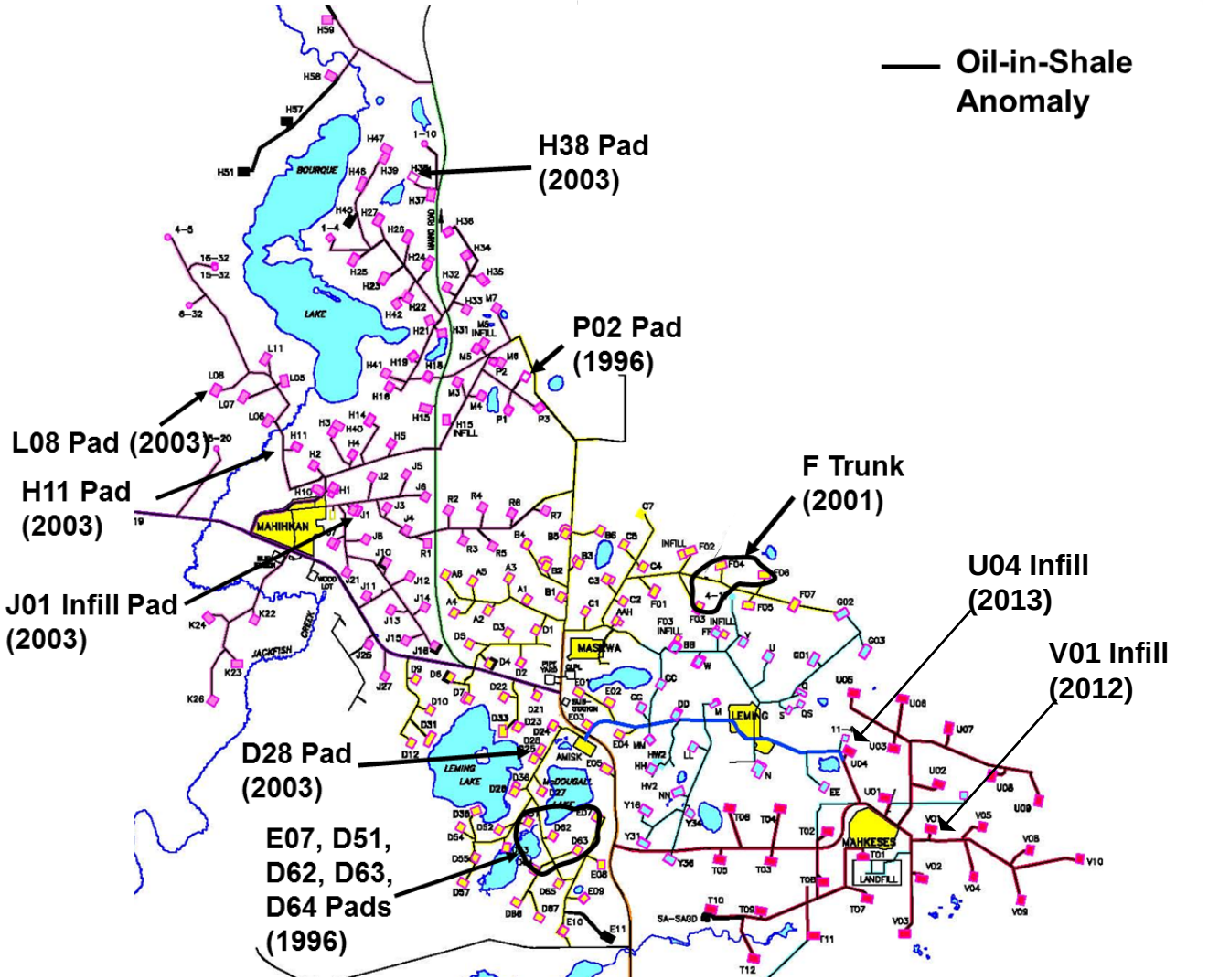
| | Gas sample locations | Sampling Frequency |
|---|---|---|
| Maskwa Plant | Inlet gas P1 & P3 | Weekly |
| Mahihkan Plant | Inlet gas P2/P4, P4 SRU outlets, P4 Treater gas, P4 Combined gas | Weekly (P2) \| MWF (P4) |
| Leming Plant | Inlet gas | Weekly |
| Mahkeses Plant | Inlet gas, SRU outlet, Treater Gas, Combined gas | TTh |
| Nabiye Plant | Inlet gas, SRU outlet, Treater Gas, Combined gas | TTh |

- Sulphur measurement process accuracy is within the requirements of ID 2001-03 for reporting (+/- 0.1 tonnes S and +/- 0.1 $km^3$ gas)
- Sulphur emissions are documented on a daily basis and monitored against the quarterly limits for each plant

Attachment 6

# 2018 Bitumen in Shale Report

# Oil in Shale Summary



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# Oil In Shale Summary

***No new oil in shale events to report***

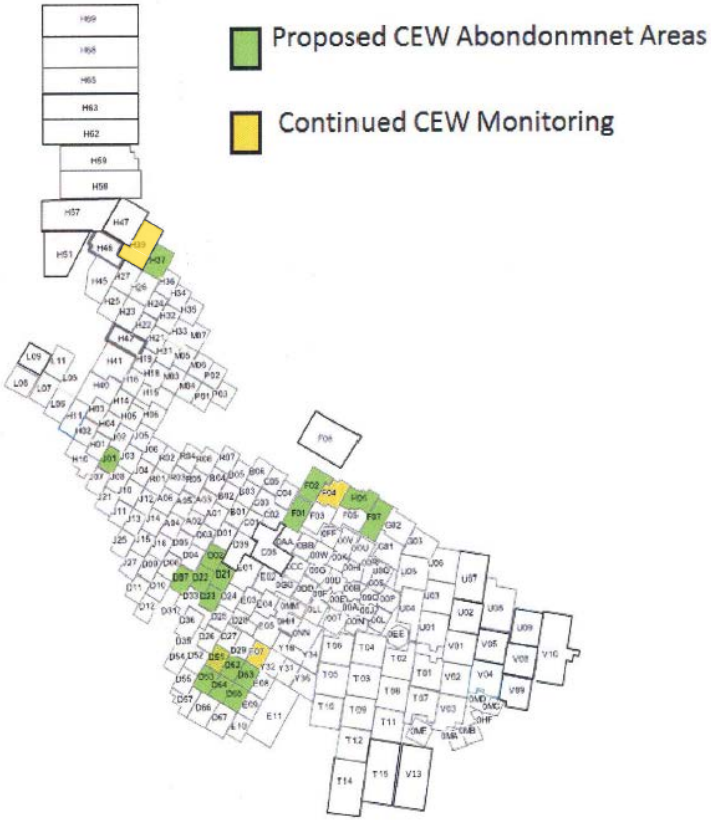
| Location | Issue | Date of Discovery | Current Restriction? | Comments/ Commitments/ Results | Next Scheduled Steam Date |
|---|---|---|---|---|---|
| **E07** | Oil in Shale found during drilling at E07 pad | 1997 | No | E07 wells abandoned. Resource accessed via D29 horizontal wells. Shale pressure monitored while steaming. | 2019; resource steamed via D29 |
| **F trunk** | Oil in Shale found during re-drill at F03-16A | 2001 | No | Steaming restrictions lifted Sept 10, 2003. Anomaly area steamed 2006, including new infill wells. Shale pressure monitored and steam pattern adjusted to minimize shear stresses. One GEW shows <1.5 ppb benzene and below Canadian drinking water quality guidelines (CDWQG), consistent with thermally mobilized BTEX. | Steam Flood Ongoing (via infills) |
| **L08** | Oil reported during drilling of L08-01 and PS well on pad. | 2003 | No | Steaming restriction lifted June 13, 2003. No anomalous pressures in CEW observed since then. Closest GEW well has shown BTEX levels over CDWQG in the past but are now below detection limits. | None |
| **H38/H39** | Oil reported during drilling of H38-12 and H38-22. | 2003 | No | Steaming restriction lifted Nov 25, 2004. No anomalous pressures in CEW observed since then. In Feb 2011 groundwater had benzene concentrations above CDWQG on H39. Since April 2013, PHC chemistry has been below CDWQG. | ~2020 |
| **H11** | Oil reported during drilling of H11-02 and H11-05 | 2003 | No | No anomalous pressures in CEW observed since 2003. Benzene observed in 2004 and 2005 but was subsequently below detection limit. Benzene was seen in GEW 11-7 in 2012, but has since been below CDWQG. | None |

# Oil In Shale Summary

| Location | Issue | Date of Discovery | Current Restriction? | Comments/ Commitments/ Results | Next Scheduled Steam Date |
|---|---|---|---|---|---|
| **J01 Infills** | Oil reported during drilling of J01-H1 | 2003 | No | No abnormal pressures at CEW during infill well steaming cycles. Groundwater shows no abnormal hydrocarbons. | Steam Flood Operations Ongoing |
| **D28** | Oil reported during drilling of D28-07 and D28-09. | 2003 | No | Steaming area via infill wells since 2012 with no anomalous pressure response at the CEW. Groundwater shows no abnormal hydrocarbons. | Steam Flood Ongoing (via infills) |
| **V01** | Oil in Shale found during drilling of V01-H28 infill | Nov 2012 | No | Deep groundwater monitoring well installed – no impacts were observed | ~2023 (via infills) |
| **U04** | Oil in Shale found during drilling of U04-H26 | Feb 2013 | No | No groundwater monitoring drilled as there is no deep continuous aquifer to monitor | Q2 2021 (via infills) |

# Colorado Shale Monitoring Wells

- AER has approved Imperial's application to discontinue monitoring at 28 Colorado Shale monitoring wells in areas which have converted to low pressure steaming operations
- Of the 28 wells, 20 will be abandoned and eight will be returned to low pressure operation
- In a few areas with either high pressure steaming plans, or high pressure in the Colorado Shale, four monitoring wells will be maintained
- A list of these wells is on the next page



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# Colorado Shale Monitoring Wells

**Table 1 – Monitoring wells proposed for conversion to low-pressure producers**

| Well | UWI | License # | Comments |
|---|---|---|---|
| D51-05 (Colorado) | 102/13-36-64-4W4/0 | 127833 | Retain D51-10 as the pad monitoring well |
| D51-17 (Colorado) | 100/09-35-64-4W4/0 | 127845 | Retain D51-10 as the pad monitoring well |
| D02-02 (Colorado) | 102/09-11-65-4W4/0 | 114515 | |
| D21-12 (Colorado) | 102/01-11-65-4W4/0 | 114815 | |
| D21-15 (Colorado) | 106/04-12-65-4W4/0 | 114818 | |
| D22-14 (Colorado) | 105/02-11-65-4W4/0 | 115055 | |
| D23-13 (Lloydminster and Colony) | 109/16-2-65-4W4/0 | 116121 | |
| D65-11 (Colony) | 105/04-36-64-4W4/0 | 188547 | Run temperature log and take manual pressure reading before conversion |

**Table 2 – Colorado Evaluation Wells (CEWs) proposed for abandonment**

| Well | UWI | License # | Comments |
|---|---|---|---|
| D62-OB2 | 1AB/11-36-64-4W4/0 | 194968 | Run temperature log and take manual pressure reading before abandonment |
| D63-OB2 | 112/11-36-64-4W4/0 | 199930 | Run temperature log and take manual pressure reading before abandonment |
| D64-OB2 | 1AA/05-36-64-4W4/0 | 196036 | Run temperature log and take manual pressure reading before abandonment |
| D07-CEW-5 | 112/03-11-65-4W4/0 | 265162 | Run temperature log and take manual pressure reading before abandonment |
| F01 CEW-8 | 110/06-18-65-3W4/0 | 267431 | |
| F02 CEW-6 | 112/10-18-65-3W4/0 | 265998 | |
| F03 CEW-1 | 115/02-18-65-3W4/0 | 263666 | Previously suspended |
| F03 CEW-2 | 111/08-18-65-3W4/0 | 263374 | |
| F03 CEW-3 | 112/04-17-65-3W4/0 | 263493 | Previously suspended |
| F03-16A | 110/08-18-65-3W4/0 | 260559 | |
| F04 CEW-9 | 103/13-17-65-3W4/0 | 265997 | Previously suspended |
| F06 CEW-10 | 112/06-17-65-3W4/0 | 267585 | |
| F07 CEW-13 | 112/02-17-65-3W4/0 | 267537 | |
| 14-17 CEW-12 | 102/14-17-65-3W4/0 | 268171 | Previously suspended |
| FF CEW4 | 100/16-7-65-3W4/0 | 268445 | Previously suspended |
| H37-CEW-18 | 111/09-3-66-4W4/0 | 284934 | |
| H38-CEW-26 | 103/16-3-66-4W4/0 | 275128 | |
| H38-CEW-27 | 107/15-3-66-4W4/0 | 277163 | |
| J01-CEW-21 | 112/04-22-65-4W4/0 | 289972 | No plans for this pad |

**Table 3 – Wells proposed for continued monitoring**

| Well | UWI | License # | Comments |
|---|---|---|---|
| D51-10 | 100/16-35-64-4W4/0 | 127838 | Retain D51-10 as the pad monitoring well |
| E07-PM1 | 112/15-36-64-4W4/0 | 218719 | Retain E07-PM1 –continued HP steaming from D29 –failed sensor recently repaired |
| E07-14 | 108/15-36-64-4W4/0 | 189068 | Retain E07-14 –continued HP steaming from D29 |
| F04 CEW-7 | 114/09-18-65-3W4/0 | 265997 | Retain F04 CEW-7 to monitor anomaly |
| H38-CEW-24 | 106/16-3-66-4W4/0 | 297208 | |



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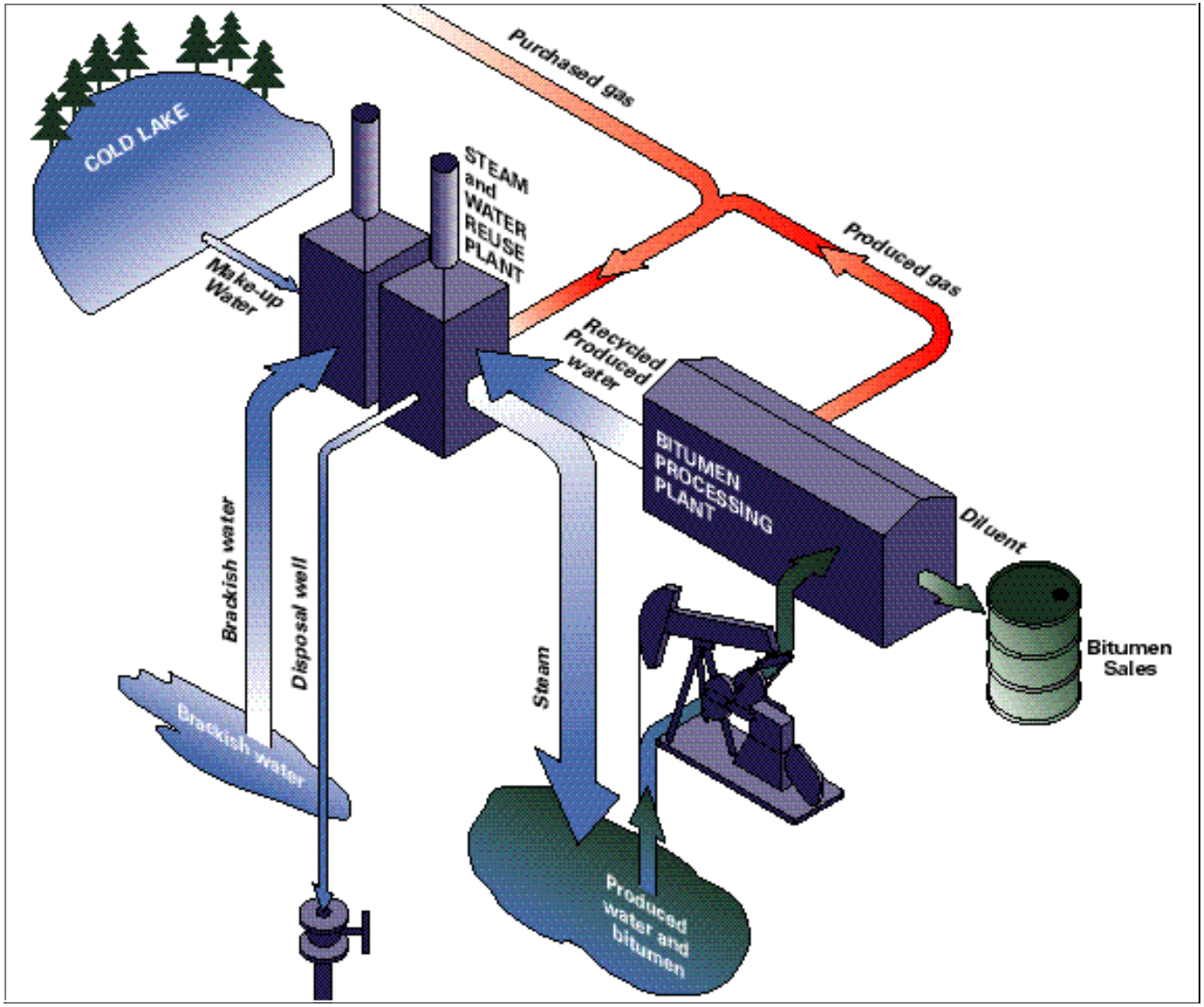
Attachment 7

# Process Flow Schematics

# Cold Lake Operations Process Overview



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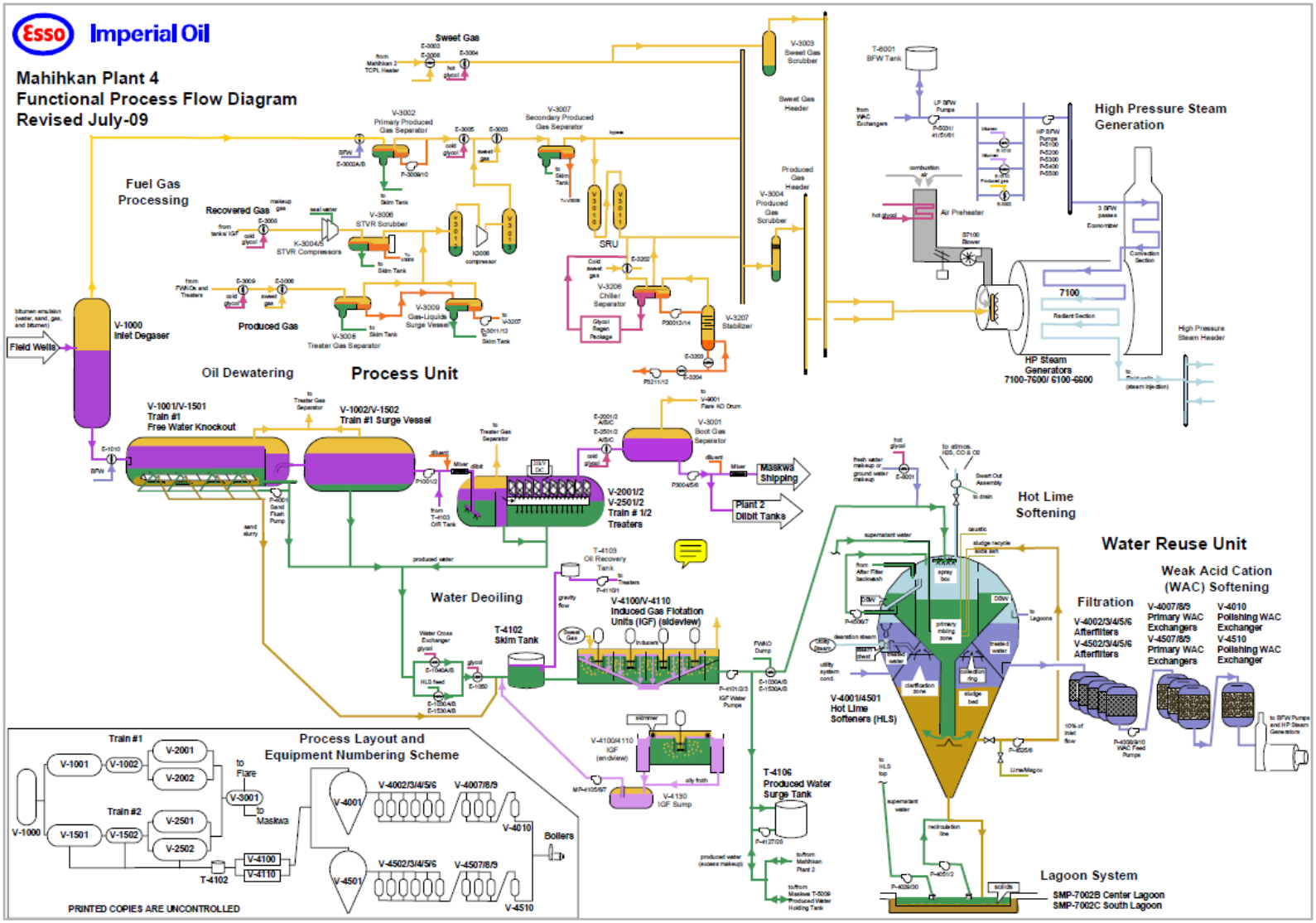
# Process Flow Schematics



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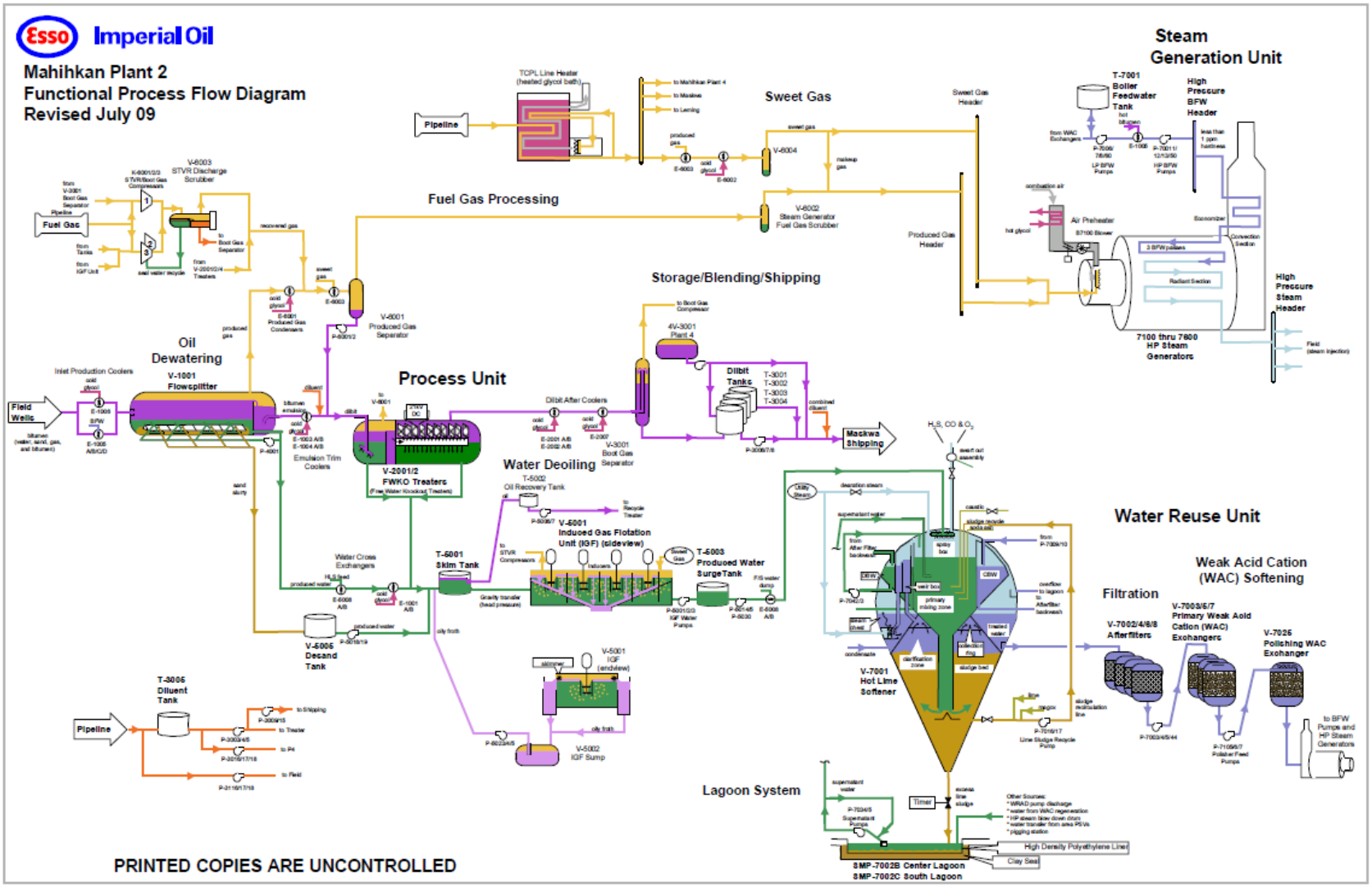
# Process Flow Schematics



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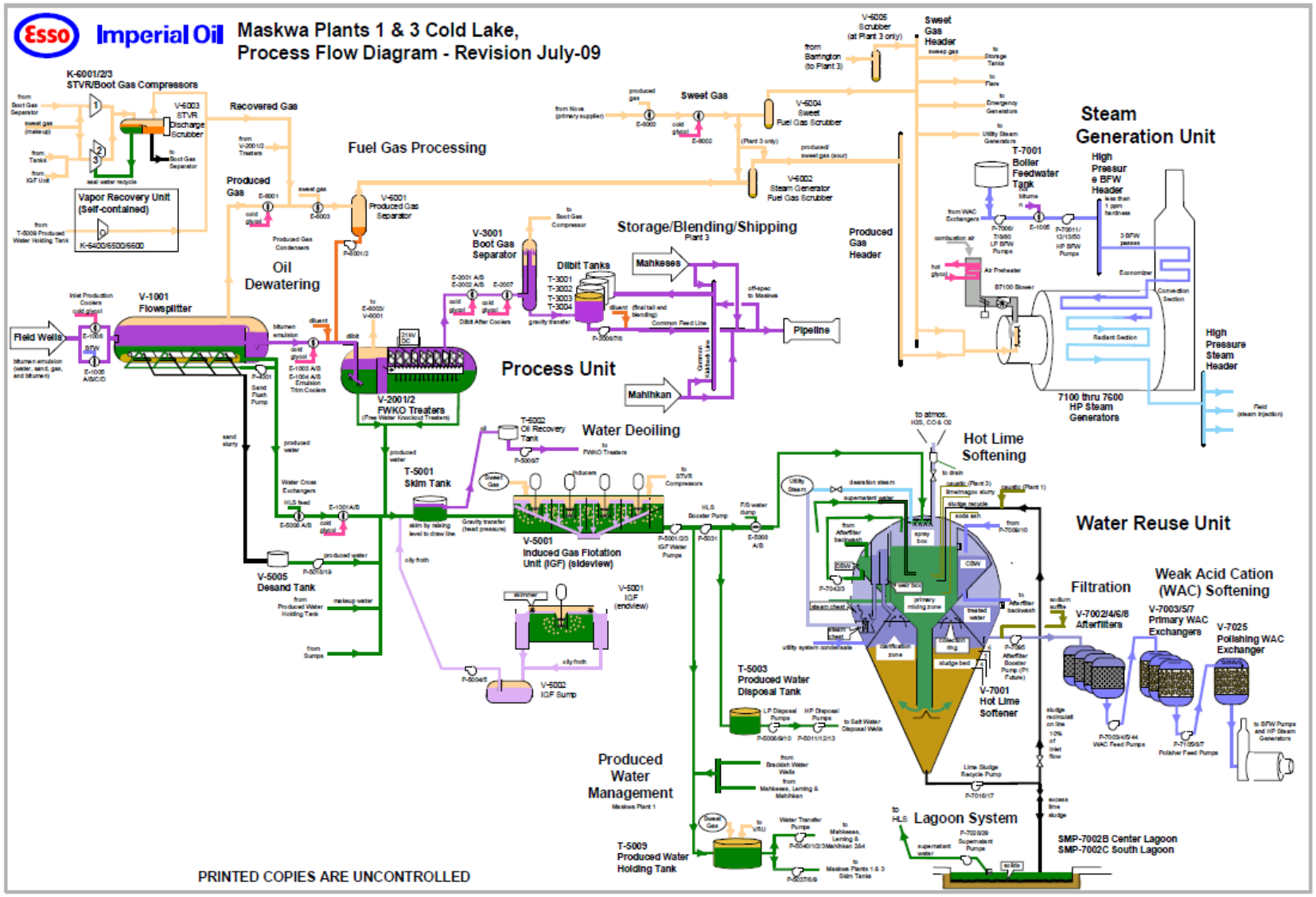
# Process Flow Schematics



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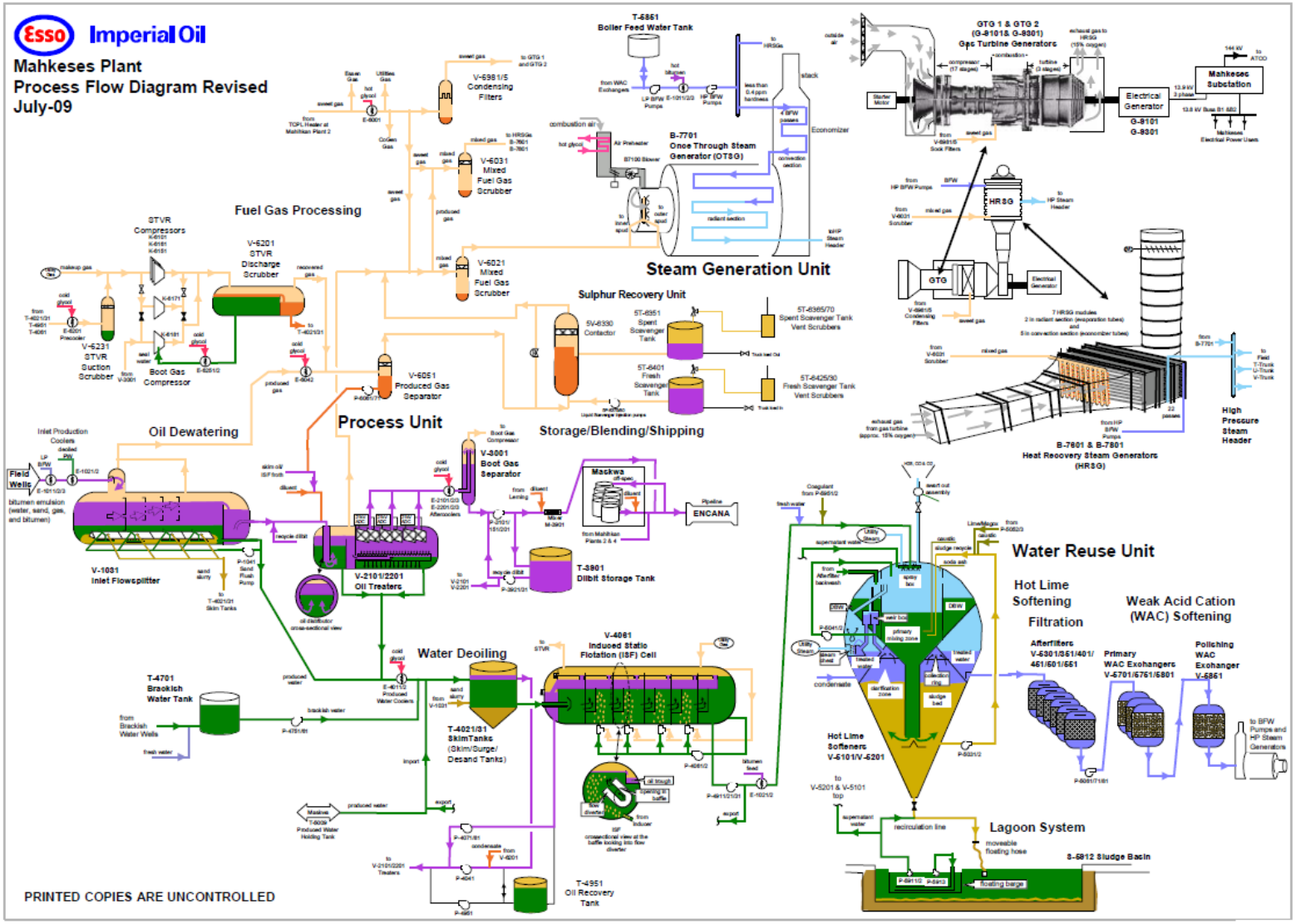
# Process Flow Schematics



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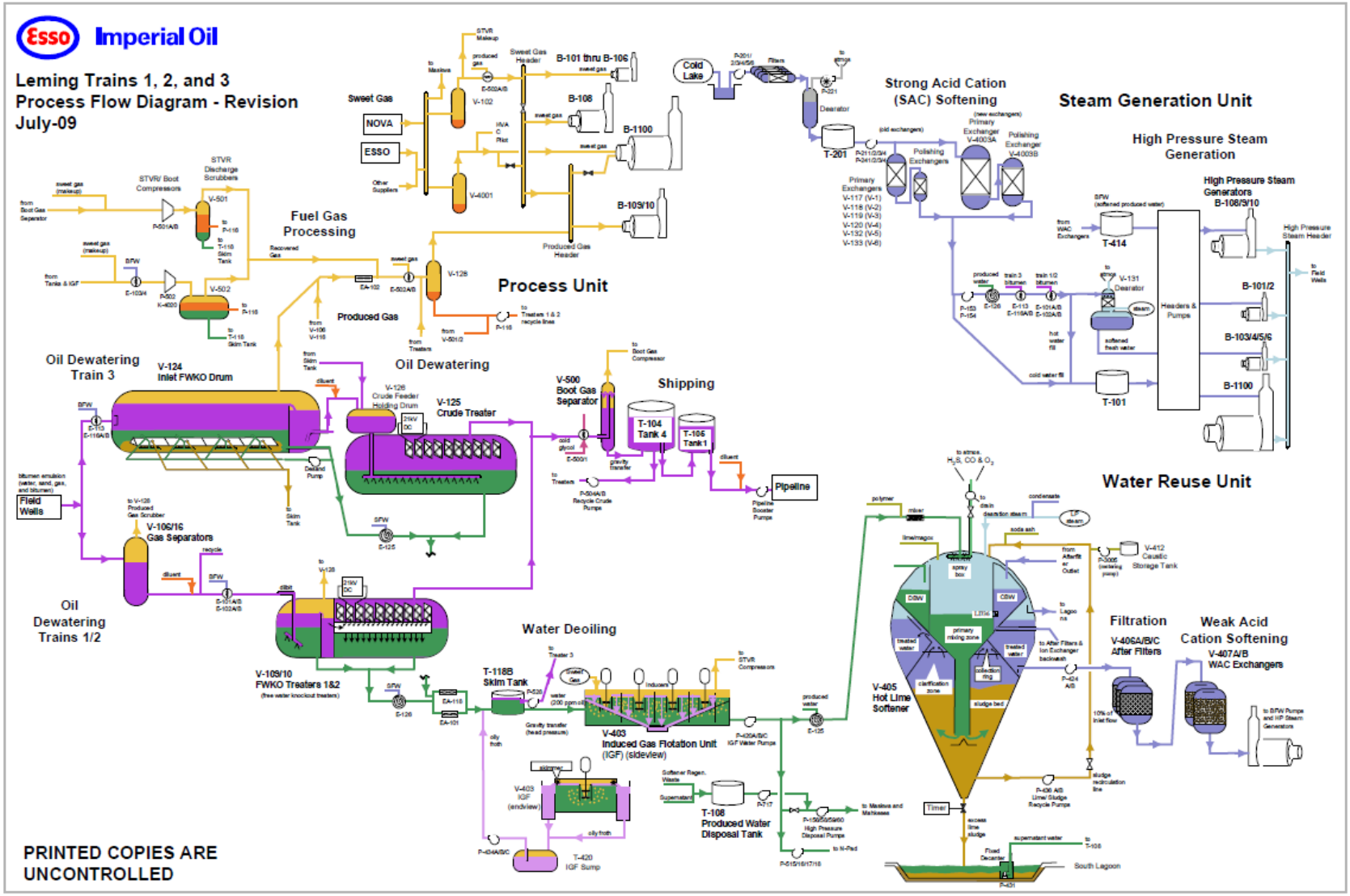
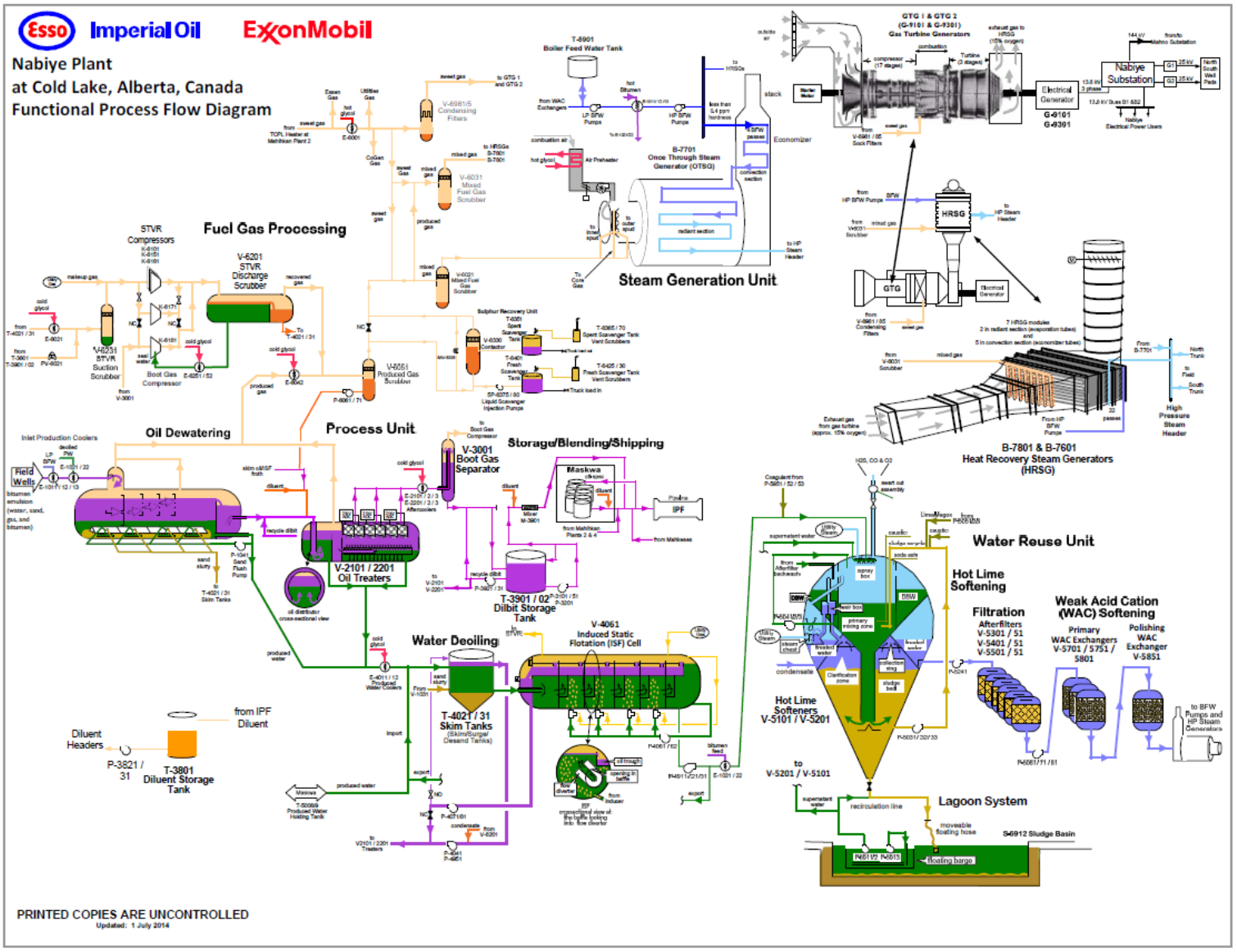
# Process Flow Schematics






Imperial | Cold Lake

# Process Flow Schematics



Attachment 8

# Cold Lake Water Use

# Cold Lake Water Use (cont'd)

**Cold Lake Operations Water Management Strategy**

- Maximize produced water recycling
- Minimize the need for non-saline water
- Utilize brackish make-up water where appropriate
- Use the non-saline groundwater withdrawal licence for Cold Lake water system maintenance or as a contingency source in the event of lower water levels in Cold Lake

**Cold Lake Fresh Water Uses:**

- Leming production inlet cooling and HP steam boiler feed water makeup
- Domestic use, safety showers/eyewashes
- Utility boiler feed water for low-pressure steam
- Utility water; sample cooling, seal flush water for pump seals and compressors
- Field wellhead and rig work activities
- Emergency firewater supply

**Water Conservation & Improvements**

- Early 90's developed capability to utilize brackish water to supplement produced water
- Inter-site produced water transfer systems reduce make-up water requirements and limit disposal of produced water
- Mahkeses & Nabiye freshwater consumption significantly lower than other plants (<100 m3/d)
- Treated water transferred from Maskwa & Mahkeses to Leming reduces freshwater usage
- Brackish water deliverability not an issue to date
- Inter-site steam transfer provide additional water use flexibility
- Completed fresh water reduction initiatives which reduced freshwater consumption on site by 30% (reduction based on average consumption, 2006-2008)
- 20% of Cold Lake Water Diversion Licence released with 2017 renewal
- Commitment in 2017 renewal to continue to evaluate opportunities for non-saline water use reduction

# Cold Lake Water Use (cont'd)

- Produced water and Brackish water both contain TDS (Total Dissolved Solids)
- Produced water contains silica (requires MgO treatment)
- Natural waters do not contain silica, tannin and are higher in magnesium
- Produced water contains tannin (helps mitigate Caustic Stress Corrosion Cracking)
- Produced water pH is a function of dissolved $CO_2$

## Brackish and Fresh water well summary:

| *Well ID* | *UWI* | *Regulatory Name* |
|---|---|---|
| ***Brackish water (1-05-65-02-W4M)*** | | |
| *BRAK1CLD* | *1F1010506502W 400* | *BRAKISH WATER WELL #1* |
| *BRAK2CLD* | *1F2010506502W 400* | *BRAKISH WATER WELL #2* |
| *BRAK3CLD* | *1F3010506502W 400* | *IMP MARIE 3 COLDLK 1-5-65-2* |
| ***Groundwater (5-22-65-04-W4M) – Licence 00148301-02-00*** | | |
| *FW1-1 CLD* | *1F1052206504W 400* | *ESSO FW E1-1 COLD LAKE WW 5-22-65-4* |
| *FW1-2 CLD* | *1F3052206504W 400* | *ESSO FW E1-2 COLD LAKE WW 5-22-65-4* |
| ***Cold Lake water (14-02-65-02-W4M) – Licence 00079923-02-00*** | | |
| *LEMFWCLD* | *1L1140206502W 400* | *COLD LAKE FRESH WATER SOURCE* |

## Water properties summary:

| Parameter | Produced Water | Brackish Water | Cold Lake Water | Ground Water | Disposal Water |
|---|---|---|---|---|---|
| pH | ~6 to 7.5 | ~7.5 | ~7.5 | ~8 | ~6 to 7.5 |
| Ca as CaCO3 | 150 - 300 ppm | 85 ppm | 90 ppm | 200 ppm | 150 - 400 ppm |
| Mg as CaCO3 | 5–25 ppm | 95 ppm | 40 ppm | 150 ppm | 5–100 ppm |
| Total Hardness as CaCO3 | 155–325 ppm | 180 ppm | 130 ppm | 350 ppm | 155–500 ppm |
| Alkalinity "M"<br>Alkalinity "TIC" | 450 ppm<br>300 ppm | 1000 ppm<br>1000 ppm | 150 ppm<br>150 ppm | 550 ppm<br>550 ppm | 450 ppm<br>300 ppm |
| Silica | 150–350 ppm | < 10 ppm | < 5 ppm | < 15 ppm | 50–350 ppm |
| Chloride | 5000–8000 ppm | 4000 ppm | < 5 ppm | < 20 ppm | 2000–10000 ppm |
| TDS | ~12000 ppm | ~7000 ppm | ~300 ppm | ~800 ppm | 5000-12000 ppm |
| Tannin | 100–200 ppm | 0 ppm | 0 ppm | 0 ppm | 50–200 ppm |
| Dissolved Gases | CH4, CO2, H2S | CH4, CO2 | Dissolved Oxygen | CO2 | CH4, CO2, H2S |

Attachment 9

# Plant Licence Limits

# Plant Licence Limits

## Cold Lake Operations – Operating Plant Licence Limits

| Agency | Maximum Daily Inlet Limits | Units | Maskwa | Mahihkan | Mahkeses | Leming | Nabiye | District |
|---|---|---|---|---|---|---|---|---|
| AER | Bitumen Inlet | $m^3/d$ | 11,000 | 15,000 | 8,000 | 5,000 | 8,000 | 40,000 |
| AER | Gas Inlet | $km^3/d$ | 600 | 600 | 400 | 250 | 280 | -- |
| AER | Water Inlet | $m^3/d$ | 38,000 | 50,000 | 28,000 | 13,500 | 22,665 | -- |
| AER | $H_2S$ Inlet Composition | mol/kmol | 9.99 | 10.00 | 9.99 | 9.99 | 20.00 | -- |
| AER | Sulphur Inlet | t/d | 8.13 | 3.00 | 4.43 | 3.39 | 3.76 | -- |
| **Agency** | **Maximum Daily Emission Limits** | **Units** | **Maskwa** | **Mahihkan** | **Mahkeses** | **Leming** | **Nabiye** | **District** |
| AER | Sulphur | t/d | 2.00 | 3.00 | 2.00 | 1.05 | 1.11 | -- |
| AER | NOx | kg/hr | 196.66 | 167.3 | 135.00 | 80.24 | 135.75 | -- |
| AER | $CO_2$ | t/d | 4,532.00 | 4,500.00 | 4,917.00 | 1,596.40 | 4323.00 | -- |
| AER | Continuous Flaring | $km^3/d$ | 0 | 0 | 0 | 0 | 0 | -- |
| AER | Continuous Venting | $km^3/d$ | 0 | 0 | 0.02 | 0 | 0.16 | -- |
| AENV | Sulphur Dioxide ($SO_2$) | t/d | 4.00 | -- | -- | 2.10 | -- | 13.15 |
| AENV | NOx | kg/hr | -- | -- | 126.00 | -- | 135.75 | -- |
| **Agency** | **Calendar Quarter-Year Daily AVERAGE Emission Limits** | **Units** | **Maskwa** | **Mahihkan** | **Mahkeses** | **Leming** | **Nabiye** | **District** |
| AER | Sulphur | t/d | 1.00 | -- | -- | 1.00 | -- | -- |
| AER | Inlet Produced Gas Sulphur Recovery | % | -- | 69.7% | 69.7% | -- | 70.0% | -- |
| AENV | Sulphur Dioxide ($SO_2$) | t/d | -- | 1.80 | 1.08 | -- | 1.08 | -- |

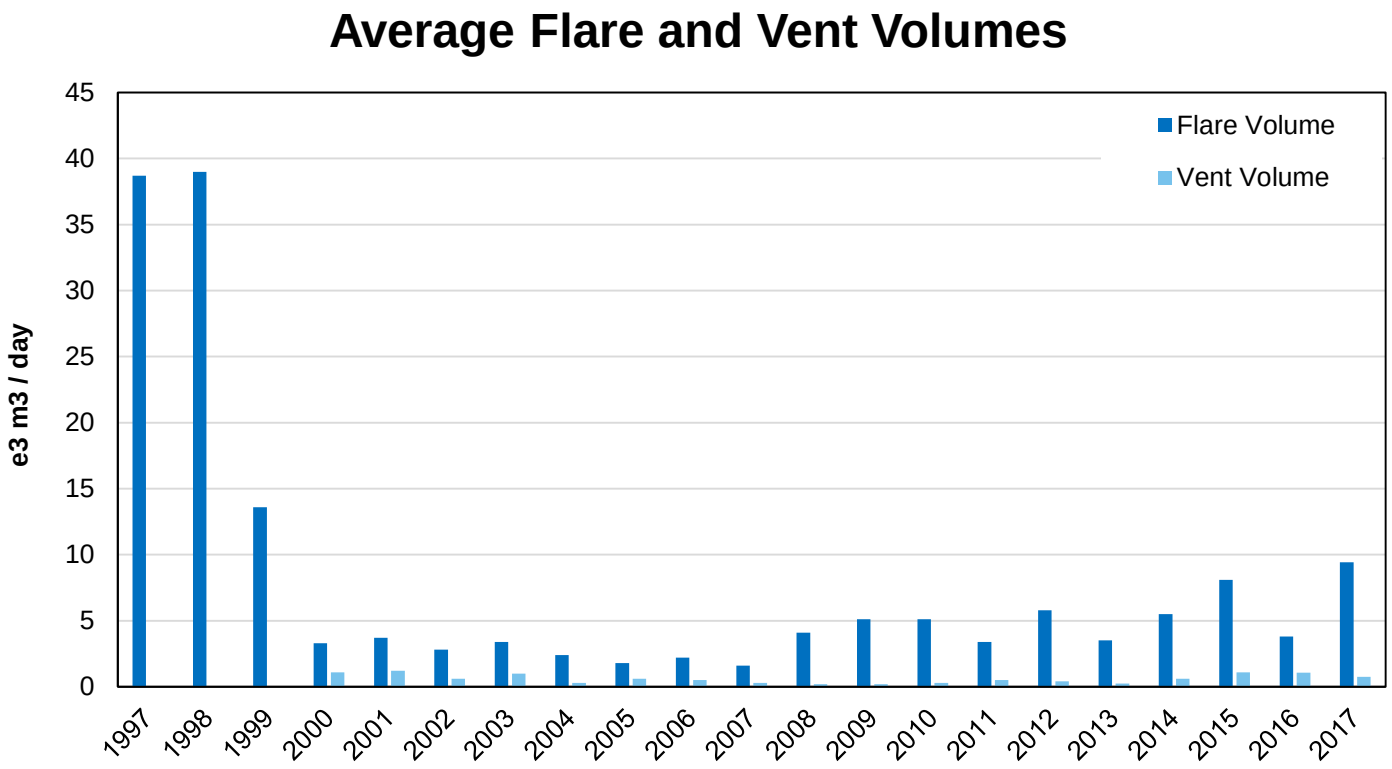
Attachment 10

# Monitoring Programs

## Flare and Vent

# Monitoring Programs – Air Flare and Vent

Flare and vent volumes remain minimal.
Increase in flaring volumes attributable to scrubber repair work at Mahihkan Plant and few plant upsets.




Note: Flare volume does not include 'pilot & purge' gas flaring.



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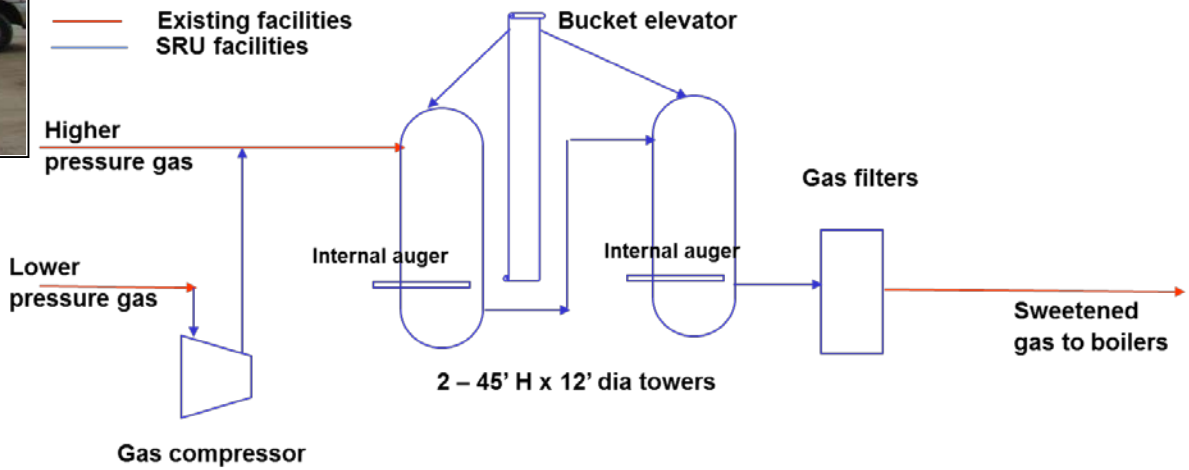
Attachment 11

# SRU Description

## Mahihkan and Mahkeses

# Mahihkan SRU Description

- 2 identical towers for batch operation: 12 ft Diameter by 45 ft Height
- Solid media H2S scavenger Sulphatreat XLP ®
- Piping and switching valves to allow parallel or series (lead/lag) operation. Bypass included for control of gas rate (pressure drop)
- Screw compressor skid to boost low pressure gas streams to SRU
- Media sock filters at outlet of SRU
- External portable auger and bucket elevator for media loading at top of contactor
- Internal auger for tower unloading



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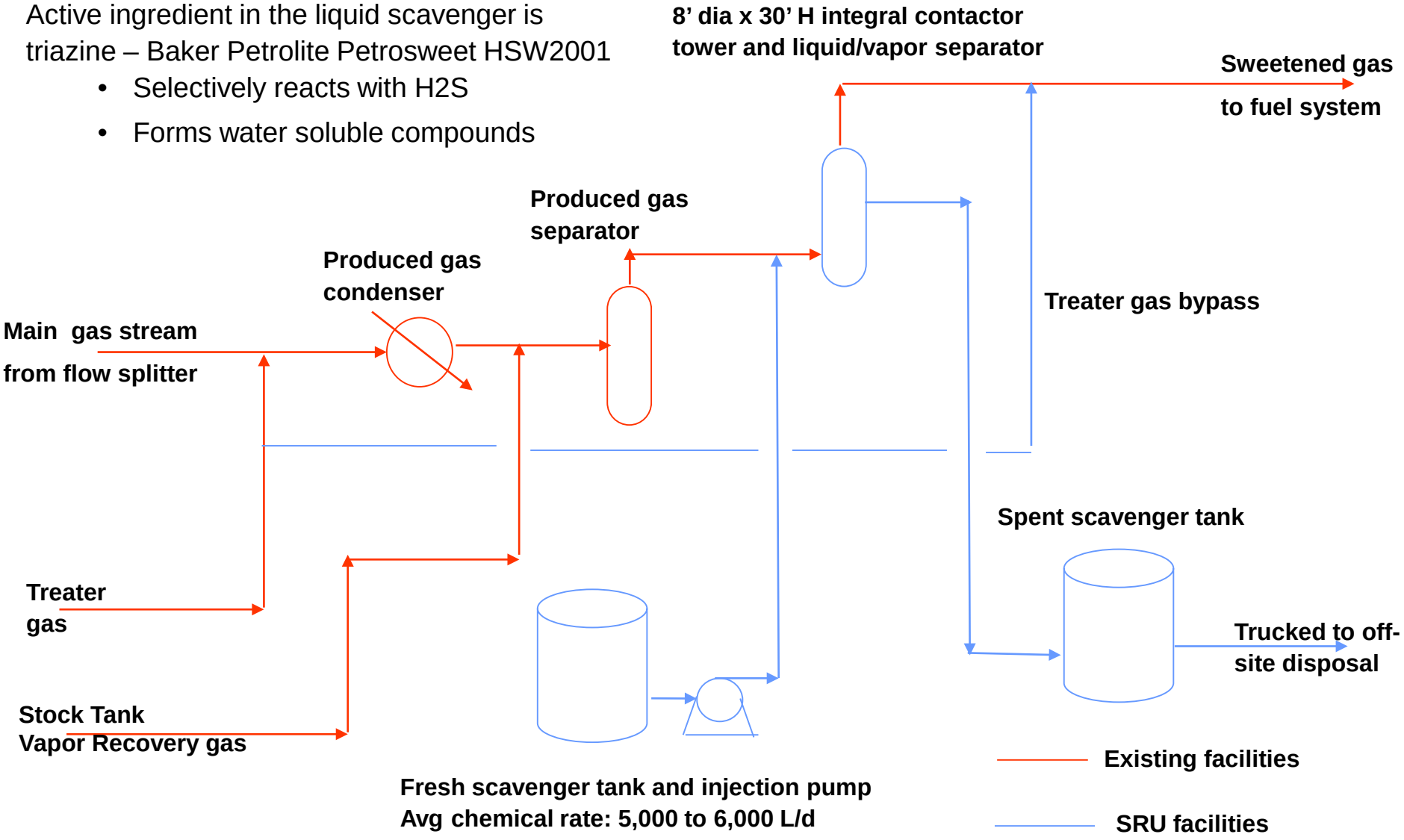
# Mahkeses SRU Description

Active ingredient in the liquid scavenger is triazine – Baker Petrolite Petrosweet HSW2001

- Selectively reacts with H2S
- Forms water soluble compounds



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