

LTO Recovery Factor Estimates



Worldwide **Petroleum** Consultants

Topics in Presentation

- Established Plays reviewed
- Emerging plays reviewed
- Recovery factor methodology
- Summary of Recoverable volume ranges
 - Established plays Rf ranges
 - Secondary recovery increments
 - Potential marketable volumes by play

Established plays reviewed

- Bakken (SK)
- Cardium
- Lower Amaranth
- Lower Shaunavon
- Montney
- Slave Point
- Swan Hills
- Viking

Emerging plays reviewed

- Bakken (AB)
- Duvernay
- Second White Specks

Recovery Factor Methodology

- EUR range from type curves
 - Performance driven
 - Represents range of avg. EUR not individual well range
- Estimated average OOIP per section from available public data
- Back out Rf range from type curve EUR and assumed spacing
- Recovery factors are directional estimates

EUR range represents avg. type wells

- EUR estimated from actual well performance
- Type wells created by region for each play
- EUR range represents low and high best estimate type well across all regions of play
- Individual wells will be less than low end of range and higher than high end of range
- Range of EURs represent aggregate low and high EUR values for the entire play

Variability in Performance

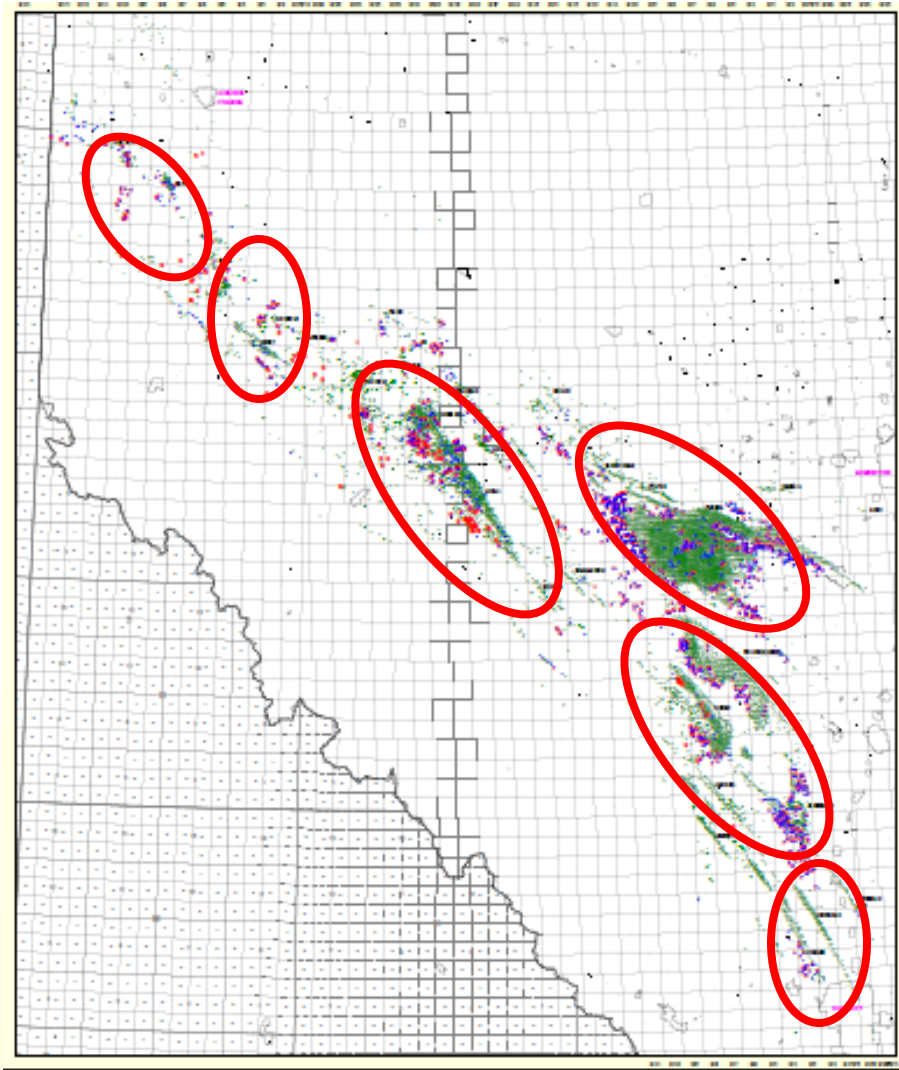
- ***By region:***
 - Regional reservoir quality variation
 - Varied fluid properties by region
 - GOR variation by region

- ***Within a region:***
 - Reservoir quality variation
 - Varied completion practices
 - Ongoing completion optimization

Type curve generation

- From normalized plots of actual performance
- Bin data by region
- Bin within region by performance indicators
- Represent current optimized well length and completion
- Capture all wells with current technology to capture the low and high avg expectation
- Wells with latest optimized completion – limited production history

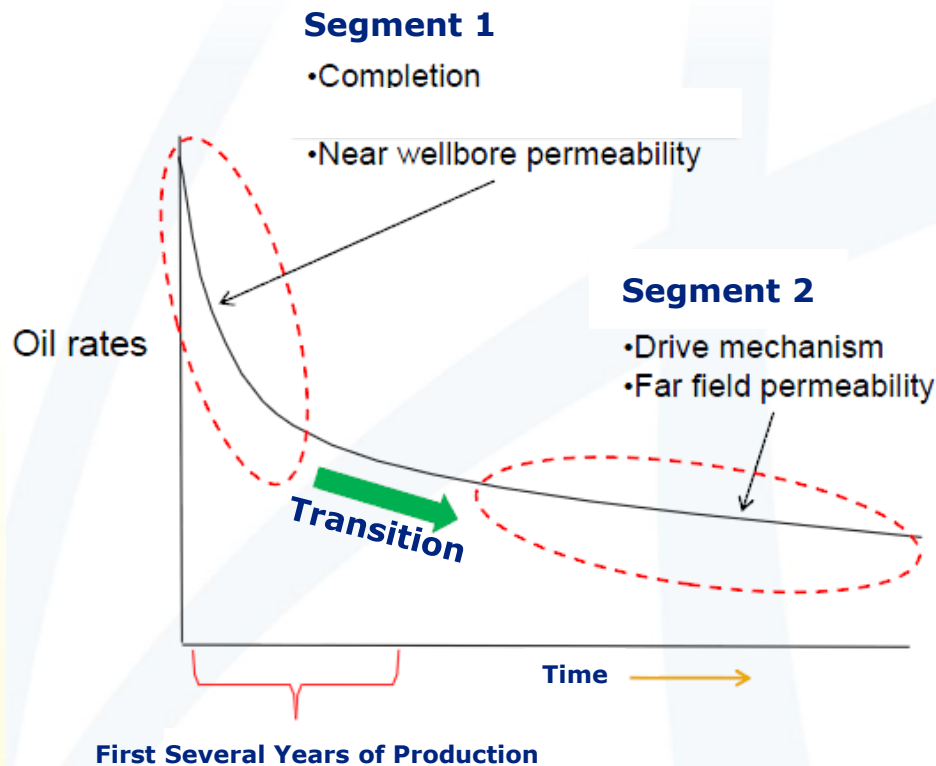
Cardium Expertise: Build Better Understanding by Analyzing Full Play Extent



**Regional
Specific
Type
Curves**

Evolution of Type Well Curves - Shape

Sproule Using Two Segment Type Wells



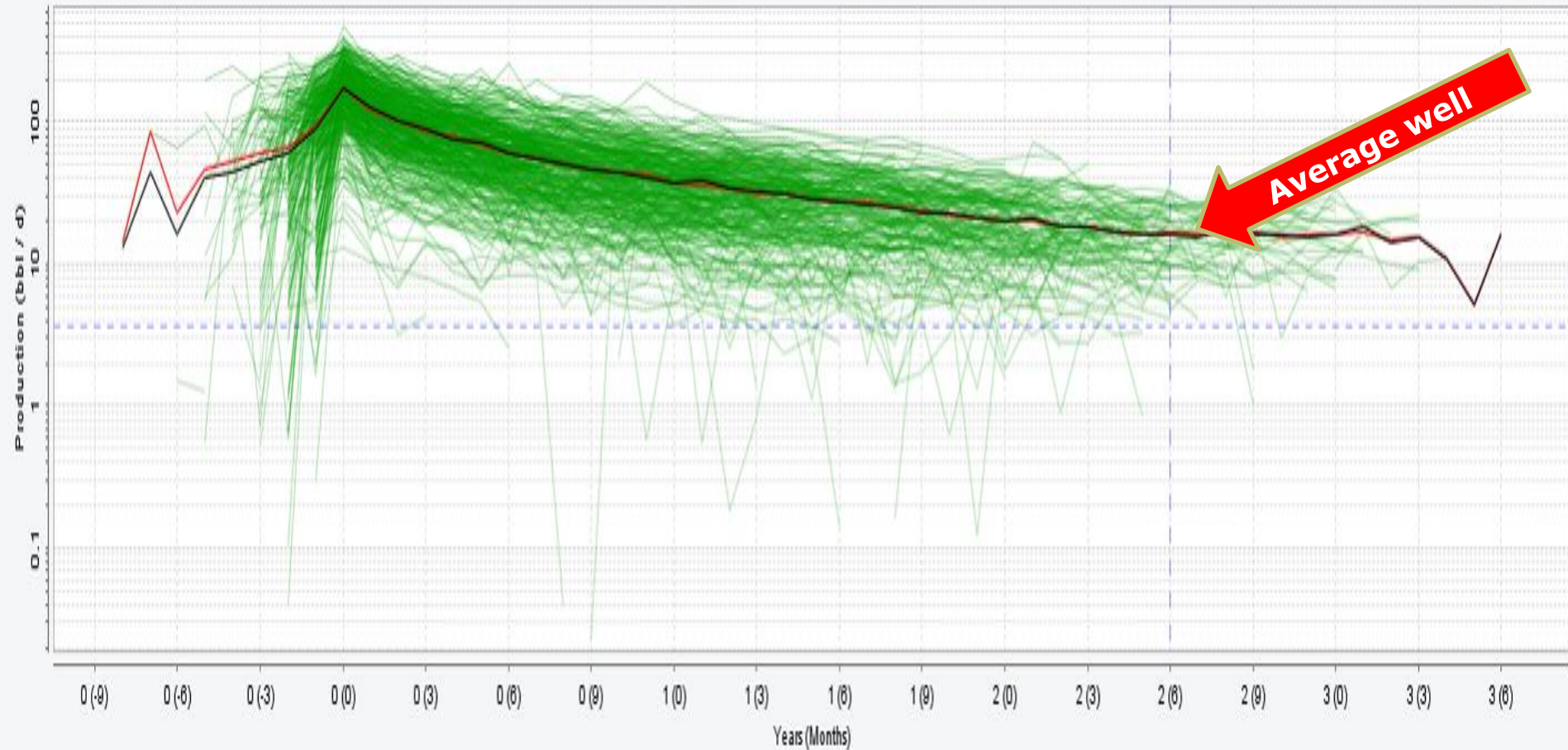
Decline rate is steep ~65%/yr in first year, generally caused by:

- Transient effects
- Pressure depletion
- Increasing gas saturation

Later life decline based on:

- matrix permeability

Cardium > 2009 Hz oil wells.



Cardium Type Curve - Areas

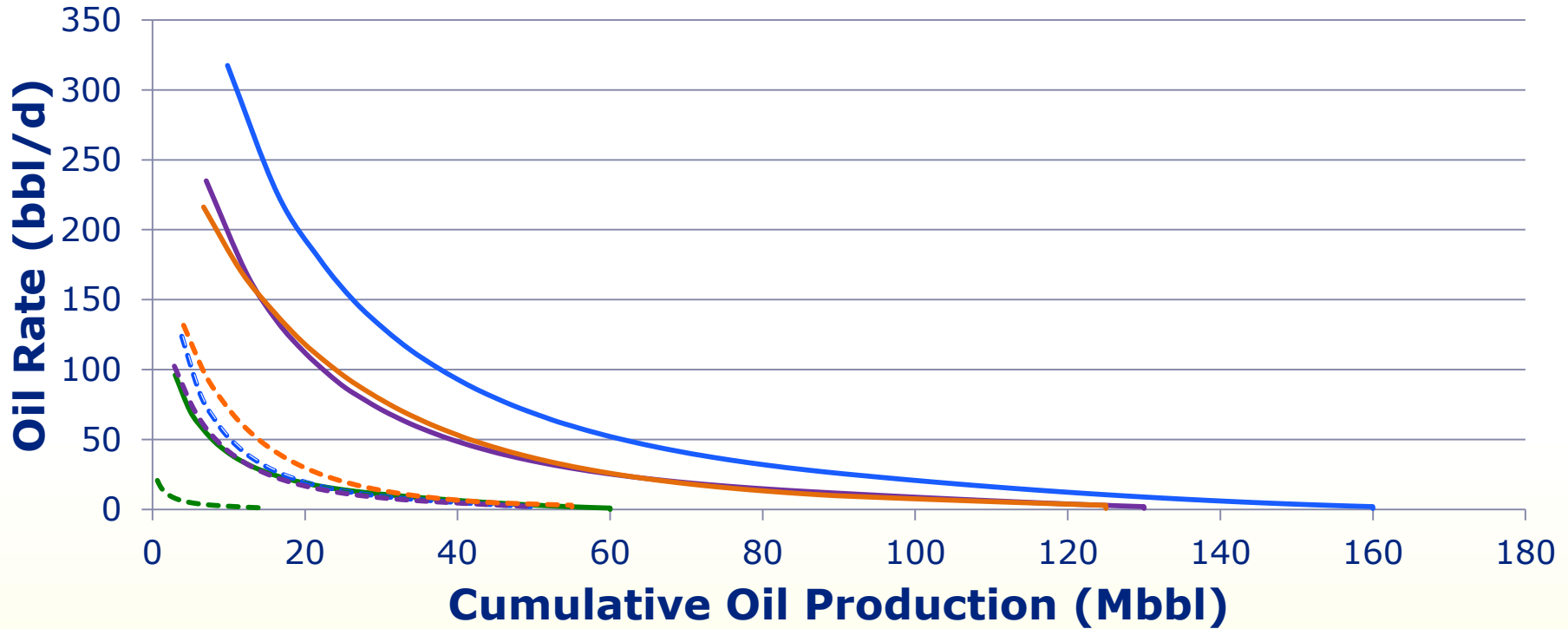
- **Central Pembina (7 curves)**
 - **SE Pembina (7 curves)**
 - **NW Pembina (4 curves)**
 - **West Pembina (7 curves)**
 - **High GOR (5 curves) – adding more areas**
 - **Edson / Carrot Creek (6 curves)**
 - **Rosevear (6 curves)**
 - **Lochend (7 curves)**
 - **Garrington/Harmattan (7 curves)**
 - **Wapiti (4 curves)**
 - **Brazeau/Ferrier / Willesden Green (4 curves) – adding more curves**
- **Currently 64 total + 1/2 curve's**

Continuing Issues with Cardium Type Wells

- **Varying well length**
- **Operating practices – clean-outs → open ports, pump depth (head), fracture conductivity reduction, wax, gas lock, efficiency, fines build up**
- **Completion – stages, volumes, spacing, fluid, pump rate, orientation, wing**
- **Transition zone – add 3rd segment to smooth curve**
- **Well spacing – see when boundary dominated flow is reached → varies**
- **Reservoir – “A”, “B”, Both, conglomerate, channel, barrier bar, shore face, natural fractures, faults, bioturbation, grain size, sand content**

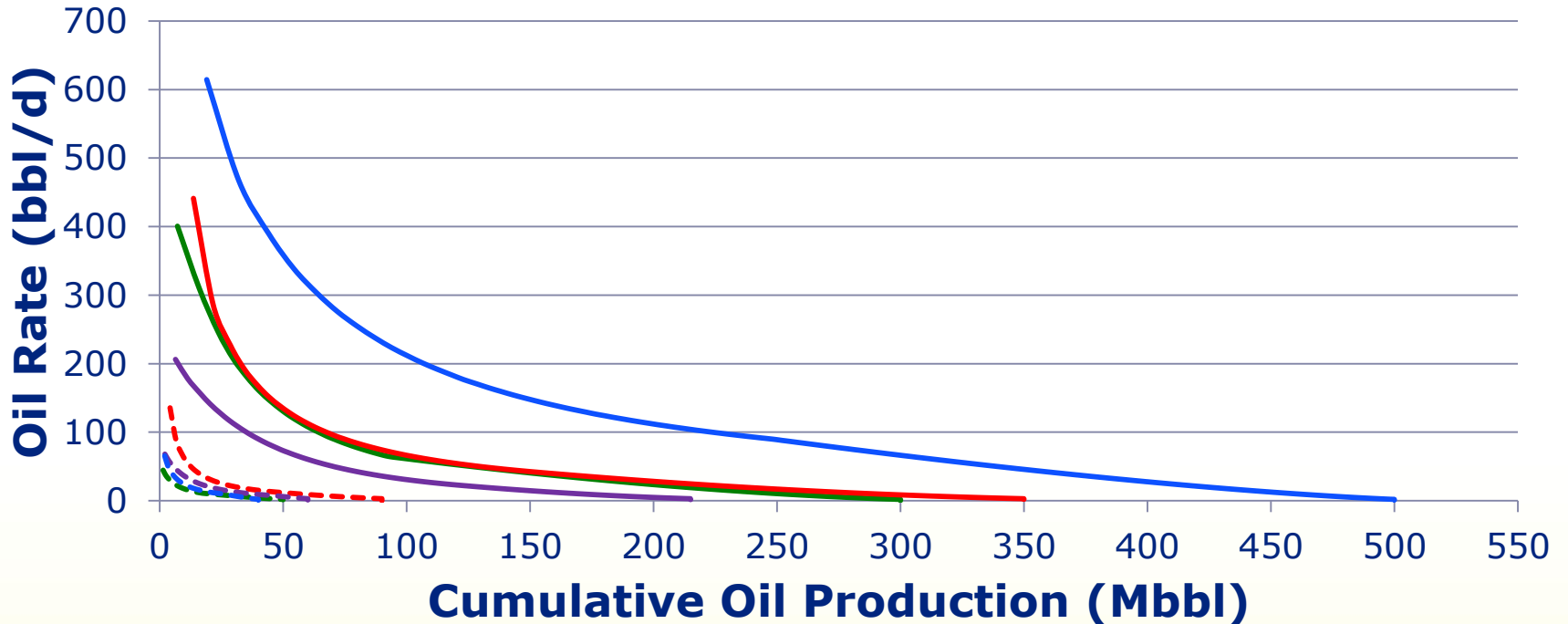
Thus Sproule uses PERFORMANCE BASED MULTI-SEGMENT type wells

LTO Primary Development Recovery Factor - SK/MB Established Plays



- Bakken High
- Viking (SW Saskatchewan) High
- - - Bakken Low
- - - Viking (SW Saskatchewan) Low
- Lower Shaunavon High
- Lower Amaranth High
- - - Lower Shaunavon Low
- - - Lower Amaranth Low

LTO Primary Development Recovery Factor - AB Established Plays



- Cardium (Lochend) High
- Slave Point High
- - - Cardium (Central Pembina) Low
- - - Slave Point Low
- Swan Hills High
- Montney High
- - - Swan Hills Low
- - - Montney Low

Well Spacing Assumption

Assumed primary development aligned with current industry approved spacing for each play

Assumed well length aligned with Industry norm for each play

Operators are moving towards longer wells and tighter spacing on most plays – upside to this study

LTO Primary Development Recovery Factor Ranges – Established Plays

Zone	Recovery Factor		EUR/Well (Mbbbl)		Spacing (Wells/Section)
	Low	High	Low	High	
Bakken - SK	3	20	50	160	4-8
Cardium	5	12	50	300	4-8
Lower Amaranth	5	12	55	125	8-16
Lower Shaunavon	4	10	50	130	8
Montney	1	12	40	500	4
Slave Point	4	25	60	215	4-8
Swan Hills	4	15	90	350	4
Viking					
- SW Sask.	2	10	15	60	16
- Redwater	2	10	15	100	4
- Provost/Halkirk	2	10	15	115	4-16

LTO Primary Development Recovery Factor Ranges – Emerging Plays

Zone	Recovery Factor		EUR/Well (Mbbbl)		Spacing (Wells/Section)
	Low	High	Low	High	
Bakken - AB	1	5	5	50	4
Duvernay - AB					
- Oil	2	6	100	250	4
- Condensate	3	20	100	300	4
Second White Specks Shale	1	10	<5	200	4

Secondary Recovery

- Considered only for established plays
- Based on projections by operators in recent waterflood applications
- Selected Sproule reservoir simulation
- Analytical projections – wide uncertainty band
- Minimal if any response to implemented projects so far
- Likely to be a focus of operators going forward

LTO Secondary Recovery Factor Increment – Established Plays

Zone	Recovery Factor Increment (%)		Comments
	Low	High	
Bakken – SK	3	10	Pilot projects in progress
Cardium	5	15	Pilot projects in progress
Lower Amaranth	5	15	Waterflood > 10 years history
Lower Shaunavon	4	8	Pilot projects initiated in last 2 years
Montney	0	5	Several pilots in low permeability regions initiated
Slave Point	2	8	Pilot projects initiated in last 2 years
Swan Hills	5	15	Expansion of existing vertical well water-floods
Viking	0	0	EOR in concept stage

Estimating Ultimate Recoverable Resources

- OOIP values for plays from PRCL
- Recovery factors for plays from Sproule type curves
- Combine to estimate Ultimate Recoverable Oil by Play
- Need to subtract current recoverable reserves to get remaining potential
- Ultimate recoverable volumes will be conservative for plays that have already have been partly developed with vertical wells – e.g. Cardium

Potential Ultimate Recoverable Oil Resources: Established Plays

Play/Formation	OOIP (Bbbl)	Rf (%)	EUR (Bbbl)
Bakken - SK	22.5	3 to 20	0.7 to 4.5
Cardium	10.6	5 to 12	0.5 to 1.3
Lower Amaranth	2.5	5 to 12	0.1 to 0.03
Lower Shaunavon	4.3	4 to 10	0.2 to 0.4
Montney	141.5	1 to 12	1.4 to 16.9
Swan Hills/Slave Point	7.5	4 to 25	0.3 to 1.9
Viking	5	2 to 10	0.1 to 0.5
TOTALS	194		3.3 to 25.9

Potential Ultimate Recoverable Resources: Emerging Plays

Play/Formation	OOIP (Bbbl)	Rf (%)	EUR (Bbbl)
Bakken (AB)	10.5 to 24.8	1 to 5	0.1 to 1.2
Duvernay (AB) Oil & Condensate	61.7 to 66.8	2 to 20	1.2 to 13.4
Second White Specks	Not Defined	1 to 10	Not Defined
TOTALS	72.2 to 91.6		1.3 to 14.6

Potential Secondary Recovery Increment for Established Plays

Play/Formation	Incremental Rf (%)	Incremental Resources (Bbbl)
Bakken - SK	3 to 10	0.7 to 2.3
Cardium	5 to 15	0.5 to 1.6
Lower Amaranth	5 to 15	0.1 to 0.4
Lower Shaunavon	4 to 8	0.2 to 0.3
Montney	0 to 5	0 to 7.1
Swan Hills/Slave Point	2 to 15	0.2 to 1.1
Viking	0	0
TOTALS		1.7 to 12.8

Potential Ultimate Recoverable Resources: Established & Emerging Plays

Play Type	OOIP (Bbbl)	Potential Ultimate Recoverable Resource Range (Bbbl)
Established Plays	194	
- Primary		3.3 to 25.9
- Waterflood Increments		1.7 to 12.8
Emerging Plays	72.2 to 91.6	
- Primary		1.3 to 14.6
Total Established (Primary and Secondary) + Emerging (Primary)	266.2 to 285.6	6.3 to 53.2

Wide Range of Marketable Resources

- Wide range of low to high ultimate recoverable volumes due to:
 - Regional performance variability
 - Reservoir quality variation
 - Well completion optimization
 - Pushing out into lower quality rock
 - Pay cutoffs evolving with completion technology

Questions?

- Regarding the OOIP estimates
- Regarding the recovery factor range estimates
- Regarding the estimated marketable resources (potential ultimate recoverable oil)