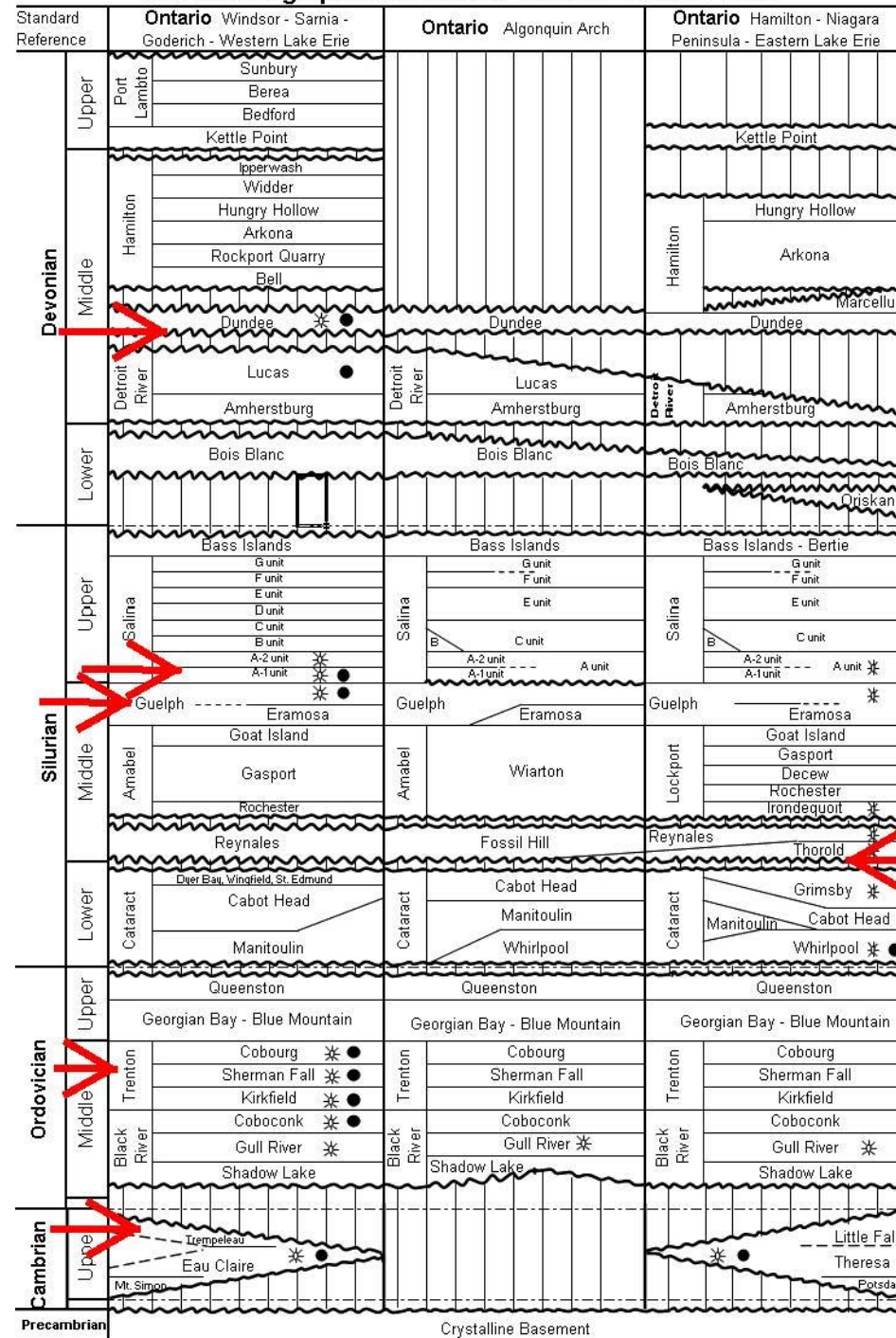


2017 OPI Conference

Economics of Various Play Types in SW Ontario

By: Jim McIntosh

Rock - Stratigraphic Succession Toronto - Windsor Area



“Thumb-Nail Economic Models”

- Devonian reservoir: Oil with water flooding, vertical wells only and vertical/horizontal wells
- Silurian A-1 Carb reservoirs: Gas, vertical well versus horizontal well development
- Silurian Guelph reservoirs: Gas partially salt-plugged pinnacle reef, Oil partially salt-plugged pinnacle reef
- Silurian Clinton reservoirs: Gas, vertical well versus horizontal well development
- Ordovician T/BR reservoirs: Gas and Oil, vertical well versus horizontal well development
- Cambrian reservoirs: Gas and Oil, vertical well versus horizontal well development

Reserve Calculation Table

Geological Formation	Assumed Depth		Ave Ø	Water Sat'n	Res Press		Res Temp		Oil FVF	Gas Compr	OOIP Factor		OGIP Factor	
	(m)	(ft)			(%)	(%)	(kPaa)	(psia)			(°C)	(°F)	(Rm ³ /STm ³)	(m ³ /ha-m)
Devonian	122	400	19%	6%	1,269	184	17	63	1.05		1,713	1,329		
Silurian A-1 Gas	425	1394	14%	15%	4,250	616	18	64.4		0.87			56.8	249
Silurian Guelph Oil	600	1969	8%	25%	6,000	870	19	66.2	1.05		571	443		
Silurian Guelph Gas	575	1887	8%	15%	5,750	834	14	57.2		0.85			45.6	199
Silurian Clinton Gas	420	1378	12%	10%	4,200	609	16	60.8		0.88			50.7	222
Ordovician Gas	900	2953	10%	10%	9,000	1,305	18	64.4		0.81			97.7	428
Ordovician Oil	830	2723	10%	10%	8,300	1,204	18	64.4	1.15		783	607		
Cambrian Gas	1189	3900	8%	20%	11,887	1,724	21	69.8		0.78			94.3	413
Cambrian Oil	1189	3900	8%	20%	11,887	1,724	21	69.8	1.2		533	414		

Devonian pool development

D&A costs: Vertical Devonian-depth well	\$80 k/well
D&A costs: Horizontal Devonian-depth well	\$300 k/well
Completion costs: Vertical Devonian-depth well	\$20 k/well
Completion costs: Horizontal Devonian-depth well	\$50 k/well
Equipping costs: Vertical Devonian-depth Producing well	\$10 k/well
Equipping costs: Horizontal Devonian-depth Producing well	\$30 k/well
Equipping costs: Injection well	\$8 k/well
Pipelines: Average/well costs	\$10 k/well
Battery Costs (Disp well, water source well, injection pump, tanks):	\$500 k
Abandonment costs: vertical well	\$3 k/well
Abandonment costs: horizontal well	\$30 k/well
Abandonment costs: battery	\$50 k

Silurian A-1/Guelph/Clinton pool development

D&A costs: Vertical Silurian/Guelph/Clinton-depth well	\$200k/well
D&A costs: Horizontal Silurian/Guelph/Clinton-depth well	\$400k/well
Completion costs: Vertical Silurian/Guelph-depth well	\$50k/well
Completion costs: Vertical Clinton-depth well	\$100k/well
Completion costs: Horizontal Silurian/Guelph-depth well	\$150k/well
Completion costs: Horizontal Clinton-depth well	\$200k/well
Equipping costs: Vertical Silurian/Guelph/Clinton-depth Producing Gas well	\$10k/well
Equipping costs: Vertical Silurian/Guelph-depth Producing Oil well	\$30k/well
Equipping costs: Horizontal Silurian/Guelph/Clinton-depth Producing Gas well	\$30k/well
Equipping costs: Horizontal Silurian/Guelph-depth Producing Oil well	\$50k/well
Equipping costs: Injection well	\$8k/well
Pipelines: Average/well costs	\$10k/well
Battery Costs (Disp well, water source well, injection pump, tanks):	\$500k
Compressor site costs (Disp well, compressor, TEG dehy, meter site):	\$400k
Abandonment costs: vertical gas well	\$10k/well
Abandonment costs: vertical oil well	\$60k/well
Abandonment costs: horizontal gas well	\$20k/well
Abandonment costs: horizontal oil well	\$150k/well
Abandonment costs: battery	\$150k
Abandonment costs: Compressor Site	\$75k

Ordovician pool development

D&A costs: Vertical Ordovician-depth well	\$400k/well
D&A costs: Horizontal Ordovician-depth well	\$900k/well
Completion costs: Vertical Ordovician-depth well	\$100k/well
Completion costs: Horizontal Ordovician-depth well	\$200k/well
Equipping costs: Vertical Ordovician-depth Producing Gas well	\$30k/well
Equipping costs: Vertical Ordovician-depth Producing Oil well	\$75k/well
Equipping costs: Horizontal Ordovician-depth Producing Gas well	\$40k/well
Equipping costs: Horizontal Ordovician-depth Producing Oil well	\$100k/well
Pipelines: Average/well costs	\$100k/well
Battery Costs (Disp well, water source well, injection pump, tanks):	\$500k
Compressor site costs (Disp well, compressor, TEG dehy, meter site):	\$400k
Abandonment costs: vertical gas well	\$60k/well
Abandonment costs: vertical oil well	\$60k/well
Abandonment costs: horizontal gas well	\$150k/well
Abandonment costs: horizontal oil well	\$150k/well
Abandonment costs: battery	\$150k
Abandonment costs: Compressor Site	\$75k

Cambrian pool development

D&A costs: Vertical Cambrian-depth well	\$400k/well
D&A costs: Horizontal Cambrian-depth well	\$900k/well
Completion costs: Vertical Cambrian-depth well	\$100k/well
Completion costs: Horizontal Cambrian-depth well	\$200k/well
Equipping costs: Vertical Cambrian-depth Producing Gas well	\$30k/well
Equipping costs: Vertical Cambrian-depth Producing Oil well	\$75k/well
Equipping costs: Horizontal Cambrian-depth Producing Gas well	\$40k/well
Equipping costs: Horizontal Cambrian-depth Producing Oil well	\$100k/well
Equipping costs: Cambrian-depth Injection well	\$75k/well
Pipelines: Average/well costs	\$100k/well
Battery Costs (Disp well, water well, injection pump, tanks, compressor):	\$700k
Compressor site costs (Disp well, compressor, TEG dehy, meter site):	\$400k
Abandonment costs: vertical gas well	\$60k/well
Abandonment costs: vertical oil well	\$60k/well
Abandonment costs: horizontal gas well	\$150k/well
Abandonment costs: horizontal oil well	\$150k/well
Abandonment costs: battery	\$150k
Abandonment costs: Compressor Site	\$75k

Natural Gas Price Forecast

Year	Average NYMEX H Hub (\$US/MMBtu)	Average Exchange (\$US/\$Cdn)	Basis to NYMEX (\$Cdn/MMBtu)	Ontario Price (\$Cdn/MMBtu)	Ont Gas Price (\$Cdn/Mcf)
2011 Act	\$4.02	\$1.012	-\$0.71	\$3.26	\$3.42
2012 Act	\$2.79	\$1.001	\$0.35	\$3.14	\$3.29
2013 Act	\$3.72	\$0.971	-\$0.09	\$3.74	\$3.92
2014 Act	\$4.30	\$0.906	\$0.52	\$5.27	\$5.52
2015 Act	\$2.62	\$0.782	\$0.08	\$3.43	\$3.59
2016 Act	\$2.52	\$0.757	\$0.05	\$3.37	\$3.53
2017	\$3.50	\$0.757	\$0.03	\$4.65	\$4.87
2018	\$3.35	\$0.786	\$0.03	\$4.29	\$4.50
2019	\$3.50	\$0.813	\$0.03	\$4.34	\$4.55
2020	\$3.79	\$0.831	\$0.03	\$4.59	\$4.81
2021	\$4.00	\$0.850	\$0.03	\$4.73	\$4.96
2022	\$4.12	\$0.850	\$0.03	\$4.87	\$5.11
2023	\$4.24	\$0.850	\$0.03	\$5.02	\$5.26
2024	\$4.35	\$0.850	\$0.03	\$5.15	\$5.39
2025	\$4.42	\$0.850	\$0.03	\$5.24	\$5.49
2026	\$4.52	\$0.850	\$0.03	\$5.35	\$5.60
2027	\$4.61	\$0.850	\$0.03	\$5.46	\$5.72
2028	\$4.70	\$0.850	\$0.03	\$5.57	\$5.83
2029	\$4.79	\$0.850	\$0.03	\$5.67	\$5.94
2030	\$4.89	\$0.850	\$0.03	\$5.78	\$6.06
2031	\$4.98	\$0.850	\$0.03	\$5.90	\$6.18

Crude Oil Price Forecast

Year	Average	Average	Average	Basis	Basis	Brk/War/P Est	Basis	Clvle/Willey	Basis	Rom 2-215-II	Basis	Rodney	Basis	Dover E
	NYMEX	Exchange	Edm Par	WTI-Edm	Srns-Edm	Oil	Srns-Edm	Oil	Srns-Edm	Oil	Srns-Edm	Oil	Srns-Edm	Oil
	WTI					Price		Price		Price		Price		Price
	(\$US/Bbl)	(\$US/\$Cdn)	(\$Cdn/Bbl)	(\$US/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)	(\$Cdn/Bbl)
2011 Act	\$95.07	\$1.012	\$95.23	-\$1.30	-\$1.11	\$94.12	\$1.46	\$96.69	\$0.80	\$96.03	\$0.75	\$95.98	\$0.08	\$95.31
2012 Act	\$94.20	\$1.001	\$86.42	\$7.73	-\$1.16	\$85.26	\$3.53	\$89.95	\$2.78	\$89.21	\$2.62	\$89.04	\$3.69	\$90.11
2013 Act	\$97.96	\$0.971	\$93.26	\$7.40	\$0.30	\$93.57	\$6.09	\$99.35	\$11.67	\$104.93	\$2.04	\$95.30	\$5.15	\$98.42
2014 Act	\$93.00	\$0.906	\$94.02	\$7.85	\$1.31	\$95.34	\$6.16	\$100.19	\$9.07	\$103.10	-\$0.66	\$93.36	\$2.46	\$96.48
2015 Act	\$48.79	\$0.782	\$57.47	\$3.84	-\$0.32	\$57.15	\$5.98	\$63.44	\$5.17	\$62.64	\$1.22	\$58.68	\$6.00	\$63.47
2016 Act	\$43.31	\$0.757	\$53.18	\$3.05	-\$0.45	\$52.73	\$6.70	\$59.89	\$5.86	\$59.04	\$1.64	\$54.82	\$5.78	\$58.97
2017	\$54.94	\$0.757	\$68.26	\$3.27	-\$0.24	\$68.02	\$4.99	\$73.24	\$5.89	\$74.15	\$1.27	\$69.52	\$3.86	\$72.12
2018	\$60.68	\$0.786	\$72.95	\$3.32	-\$0.24	\$72.71	\$4.99	\$77.93	\$5.89	\$78.84	\$1.27	\$74.21	\$3.86	\$76.81
2019	\$65.35	\$0.813	\$76.20	\$3.44	-\$0.24	\$75.96	\$4.99	\$81.18	\$5.89	\$82.09	\$1.27	\$77.46	\$3.86	\$80.06
2020	\$69.35	\$0.831	\$79.41	\$3.34	-\$0.24	\$79.17	\$4.99	\$84.40	\$5.89	\$85.30	\$1.27	\$80.68	\$3.86	\$83.27
2021	\$73.66	\$0.850	\$82.62	\$3.43	-\$0.24	\$82.39	\$4.99	\$87.61	\$5.89	\$88.52	\$1.27	\$83.89	\$3.86	\$86.48
2022	\$76.40	\$0.850	\$85.79	\$3.48	-\$0.24	\$85.55	\$4.99	\$90.77	\$5.89	\$91.68	\$1.27	\$87.05	\$3.86	\$89.65
2023	\$78.29	\$0.850	\$87.96	\$3.53	-\$0.24	\$87.72	\$4.99	\$92.94	\$5.89	\$93.85	\$1.27	\$89.22	\$3.86	\$91.82
2024	\$80.23	\$0.850	\$90.17	\$3.59	-\$0.24	\$89.93	\$4.99	\$95.15	\$5.89	\$96.06	\$1.27	\$91.43	\$3.86	\$94.03
2025	\$82.18	\$0.850	\$92.42	\$3.62	-\$0.24	\$92.19	\$4.99	\$97.41	\$5.89	\$98.32	\$1.27	\$93.69	\$3.86	\$96.28
2026	\$84.19	\$0.850	\$94.48	\$3.88	-\$0.24	\$94.24	\$4.99	\$99.47	\$5.89	\$100.37	\$1.27	\$95.75	\$3.86	\$98.34
2027	\$85.85	\$0.850	\$96.34	\$3.96	-\$0.24	\$96.10	\$4.99	\$101.33	\$5.89	\$102.24	\$1.27	\$97.61	\$3.86	\$100.20
2028	\$87.57	\$0.850	\$98.28	\$4.03	-\$0.24	\$98.04	\$4.99	\$103.27	\$5.89	\$104.18	\$1.27	\$99.55	\$3.86	\$102.14
2029	\$89.34	\$0.850	\$100.25	\$4.12	-\$0.24	\$100.01	\$4.99	\$105.24	\$5.89	\$106.14	\$1.27	\$101.52	\$3.86	\$104.11
2030	\$91.13	\$0.850	\$102.27	\$4.19	-\$0.24	\$102.04	\$4.99	\$107.26	\$5.89	\$108.17	\$1.27	\$103.54	\$3.86	\$106.13
2031	\$92.95	\$0.850	\$104.30	\$4.29	-\$0.24	\$104.06	\$4.99	\$109.29	\$5.89	\$110.20	\$1.27	\$105.57	\$3.86	\$108.16

Geological Formation	Pool Analogy	Pool Dimensions			OOIP fctr (Bbl/ac-ft)	OGIP fctr (Mcf/ac-ft)	Ave Net Pay (ft)	OOIP (MBbl)	OGIP (MMcf)
		Width	Length	Area					
		(ft)	(ft)	(Acres)					
Devonian	Rodney	4,175	4,175	400	1,329	13.4	7,127		
Silurian A-1 Gas	Mosald	2,952	2,952	200	249	16.0		796	
Silurian Guelph Oil	Wanstead	2,087	2,087	100	443	35.0	1,551		
Silurian Guelph Gas	Ashfield	1,807	1,807	75	199	120.0		1,794	
Silurian Clinton Gas	Norfolk	4,175	4,175	400	222	20.0		1,776	
Ordovician Gas	Innerkip NP	1,500	15,000	517	428	15.0		3,313	
Ordovician Oil	Goldsmith	1,500	15,000	517	607	42.0	7,379		
Cambrian Gas	N/A	7,000	7,000	1,125	413	20.0		9,288	
Cambrian Oil	Clearville	7,000	7,000	1,125	414	20.0	12,149		

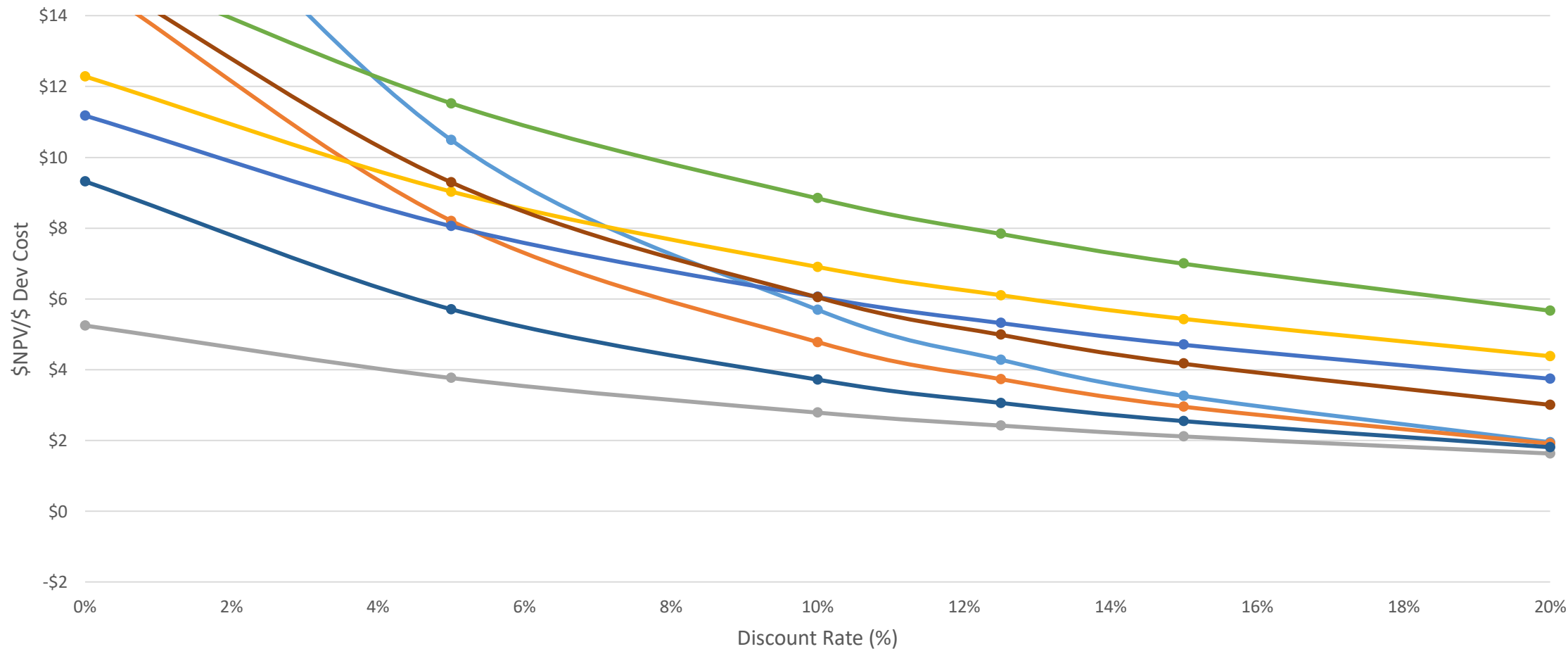
Production/Reserves

		Prod wells (acre/well)	Inj wells (acre/well)	Initial Prod Rate		Decline Rate (%/yr)	Rec Factor (%)	Recoverable Res	
				per well (bpd/w) (Mcf/d/w)	pool (bpd) (Mcf/d)			(MBbl)	(MMcf)
Devonian	Vert WF	12.5	12.5	8	256	3.2%	35.4%	2,523	
	Hor WF	25	12.5	25	400	5.1%	36.0%	2,566	
Silurian A-1 Gas	Vert	50		100	200	7.7%	70.0%		557
	Hor	100		200	400	19.5%	75.0%		597
Silurian Guelph Oil	Vert WF	50	50	60	120	17.8%	15.0%	233	
	Hor WF	50	50	150	300	19.6%	35.0%	543	
Silurian Guelph Gas	Vert	75		300	300	5.5%	80.0%		1435
	Hor	75		750	750	17.0%	80.0%		1435
Silurian Clinton Gas	Vert	100		60	240	6.3%	50.0%		888
	Hor	200		120	240	6.3%	50.0%		888
Ordovician Gas	Vert	100		400	2000	30.1%	70.0%		2,319
	Hor	200		600	1800	25.2%	75.0%		2,485
Ordovician Oil	Vert	50		70	980	18.1%	26.0%	1,919	
	Hor	100		200	1400	19.9%	34.0%	2,509	
Cambrian Gas	Vert	100		150	1650	8.8%	70.0%		6,501
	Hor	400		600	1800	9.0%	75.0%		6,966
Cambrian Oil	Vert GF	100	500	40	400	9.3%	12.0%	1,458	
	Hor GF	150	500	100	600	8.6%	20.0%	2,430	

Economic Indicators		Capital Costs			Pool Op Costs		Net Present Value		ROR
		Wells	Fac	Ttl	Fixed	Variable	NPV12.5	NPV12.5	
		(\$k)	(\$k)	(\$k)	(\$k/mo)	(\$/Bbl,\$/Mcf)	(\$k)	(\$k)	(%)
Devonian	Vert WF	\$7,619	\$500	\$8,119	\$50	\$10	\$34,792	\$26,497	53%
	Hor WF	\$10,020	\$500	\$10,520	\$60	\$10	\$39,267	\$31,063	62%
Silurian A-1 Gas	Vert	\$540	\$400	\$940	\$10	\$0.25	-\$432	-\$444	0%
	Hor	\$1,180	\$400	\$1,580	\$10	\$0.25	-\$618	-\$636	0%
Silurain Guelph Oil	Vert WF	\$1,380	\$500	\$1,880	\$10	\$10	\$4,550	\$3,971	87%
	Hor WF	\$1,920	\$500	\$2,420	\$15	\$5	\$14,763	\$13,142	204%
Silurian Guelph Gas	Vert	\$270	\$400	\$670	\$10	\$0.25	\$867	\$667	37%
	Hor	\$590	\$400	\$990	\$10	\$0.25	\$1,445	\$1,267	68%
Silurian Clinton Gas	Vert	\$1,280	\$400	\$1,680	\$10	\$0.50	-\$818	-\$857	0%
	Hor	\$1,280	\$400	\$1,680	\$10	\$0.50	-\$818	-\$857	0%
Ordovician Gas	Vert	\$3,150	\$400	\$3,550	\$10	\$0.50	\$1,332	\$1,086	32%
	Hor	\$3,720	\$400	\$4,120	\$10	\$0.50	\$892	\$635	23%
Ordovician Oil	Vert	\$9,450	\$900	\$10,350	\$50	\$8	\$55,089	\$48,731	173%
	Hor	\$9,100	\$900	\$10,000	\$50	\$8	\$78,404	\$69,981	260%
Cambrian Gas	Vert	\$6,930	\$400	\$7,330	\$10	\$0.25	\$3,230	\$2,050	22%
	Hor	\$3,720	\$400	\$4,120	\$10	\$0.25	\$6,956	\$5,599	48%
Cambrian Oil	Vert GF	\$8,100	\$700	\$8,800	\$50	\$10	\$26,930	\$22,404	75%
	Hor GF	\$9,150	\$700	\$9,850	\$50	\$10	\$49,168	\$41,101	106%

NPV/Dev Cost at Various Discount Rates

Oil Pools



Devonian Oil Vertical

Devonian Oil Horizontal

Silurian Guelph Oil Vertical

Silurian Guelph Oil Horizontal

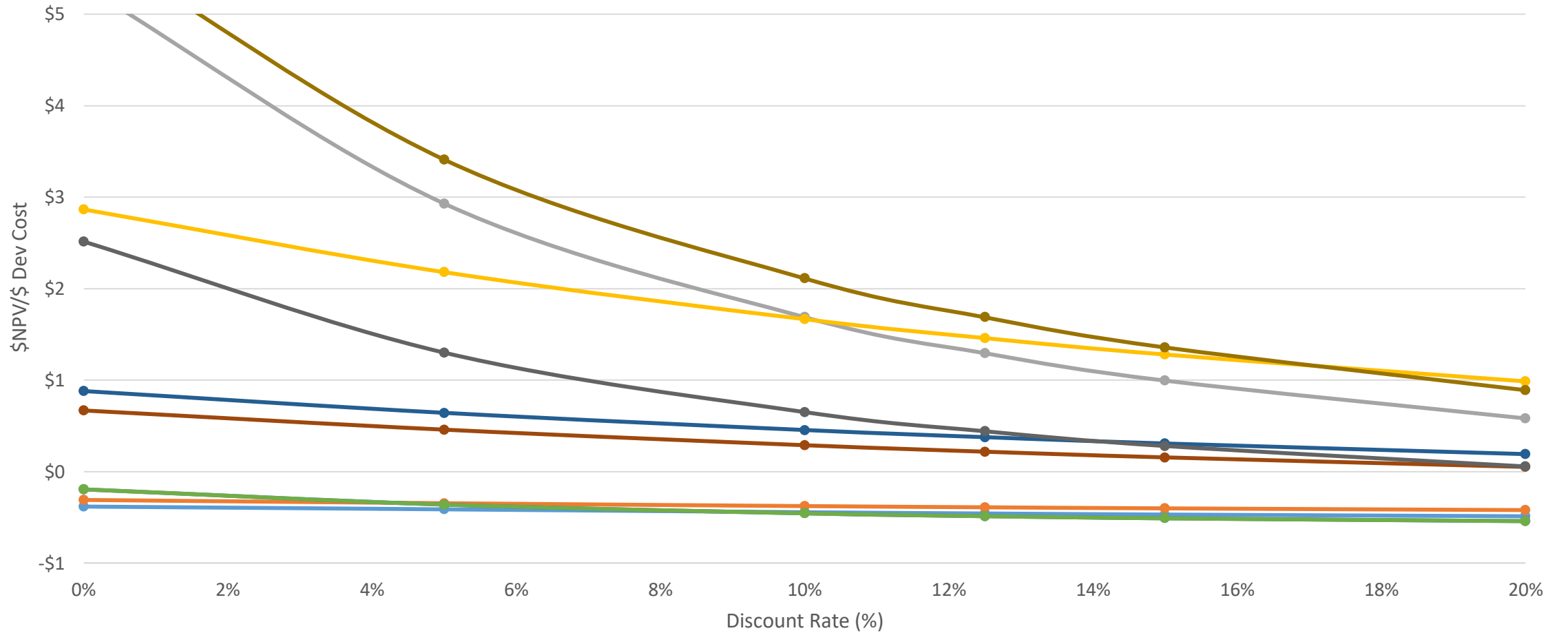
Ordovician Oil Vertical

Ordovician Oil Horizontal

Cambrian Oil Vertical

Cambrian Oil Horizontal

NPV/Dev Cost at Various Discount Rates Gas Pools



- Silurian A-1 Gas Vertical
- Silurian A-1 Gas Horizontal
- Silurian Guelph Gas Vertical
- Silurian Guelph Gas Horizontal
- Silurian Clinton Gas Vertical
- Silurian Clinton Gas Horizontal
- Ordovician Gas Vertical
- Ordovician Gas Horizontal
- Cambrian Gas Vertical
- Cambrian Gas Horizontal

Conclusions

- With the current oil prices compared to gas prices, oil pools are much more economical to develop than gas pools within similar formations
- In most reservoirs, pool development with horizontal wells will improve the economics compared to vertical wells, mostly as a result of accelerated production
- Silurian A-1 Carbonate and Silurian Clinton sandstone reservoirs are likely not economical to develop with current gas prices and development costs
- Development of Silurian Guelph oil reservoirs with horizontal wellbores and development of Ordovician oil reservoirs with either vertical or horizontal wellbores are the pool developments with the most favourable economics
- Development of Devonian oil reservoirs through waterflooding for secondary recovery provides the highest undiscounted return on investment, but at higher discount rates other oil reservoirs can return a higher return on development costs