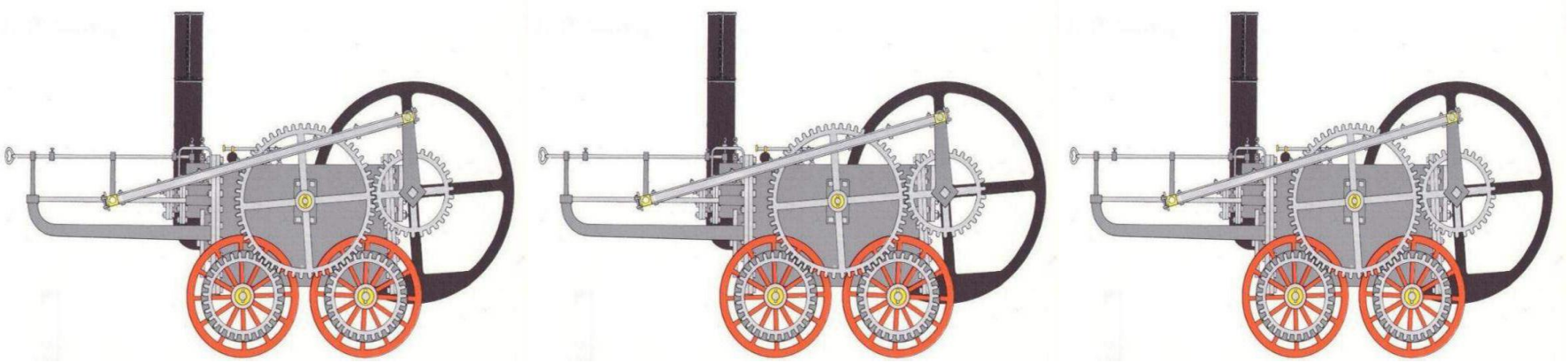
CRUDE OIL BY RAIL : PARTS I AND II
Potential for the movement of Alberta Oil Sands crude oil and related products by Canadian railways



First Steam Locomotive – 1802 built by Trevithick at the Penydarren iron works, South Wales

Dr. Malcolm Cairns
Research and Consulting

CTRF June 11, 2013

Outline

Dr. Malcolm Cairns

PART I

- Background
- Alberta Oil Sands
- Liquid Pipelines and Rail Lines
- Feeder Pipeline Network
- Storage Capacity at Edmonton and Hardisty
- Transmission Pipeline Network: Existing and Proposed Expansions
- Outlook for Alberta Oil Sands Production
- Discount Pricing

PART II

- Recent Movements of Crude Oil by Canadian Railways
- Rail Service for the Alberta Oil Sands
- Potential Train Capacity and Equipment needed to Move Alberta Oil Sands Crude Oil
- Additional Cost of Moving Oil by Rail versus Pipeline
- Conclusions

POSTSCRIPT Comparison of Rail and Pipeline: Spillage, Safety and GHG emissions
International Perspective

Background

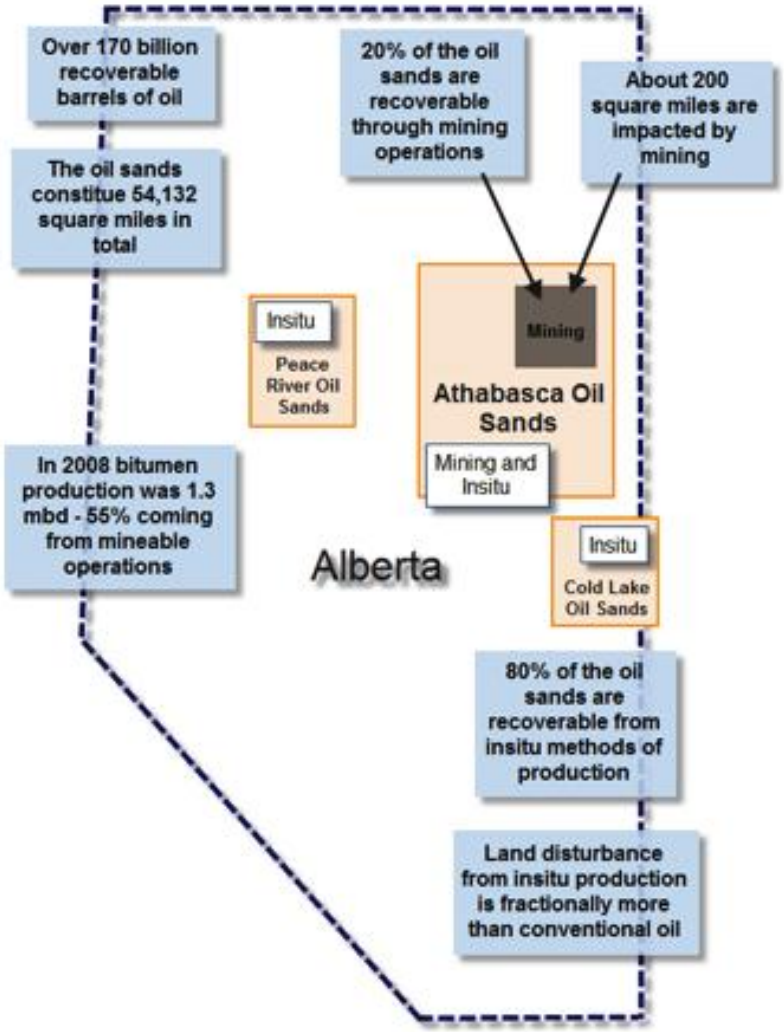
Dr. Malcolm Cairns

- The Alberta Oil Sands have the potential to significantly increase the production of heavy crude oil
- Crude oil is traditionally moved to market by pipelines
- Transmission pipeline capacity needs expansion to handle increased production
- There are current controversies over the construction of additional pipeline capacity
  - The Northern Gateway pipeline
  - The Keystone XL pipeline
  - The Kinder Morgan Trans Mountain expansion
- Pipeline capacity constraints have led, in part, to a discount price for Alberta Oil Sands crude oil
- The issue for this paper is whether Canadian rail can move Alberta Oil Sands crude oil – economically and in what volumes?

Alberta Oil Sands

Dr. Malcolm Cairns

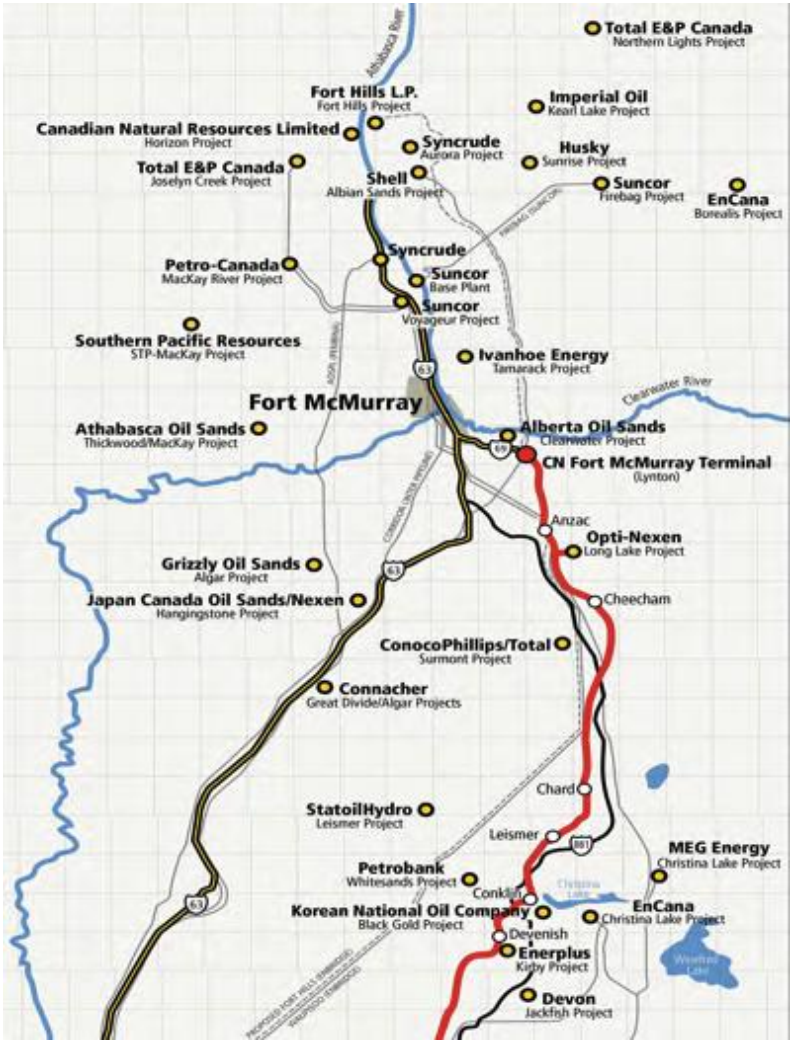
- Canadian oil sands are situated in Alberta
  - Athabasca, Cold Lake and Peace River locations
  - The immediate product is bitumen which is very viscous oil
  - At an extraction rate of 5 million b/d, recoverable deposits will last 90 years
- Extraction is by Mining (20%) and In Situ (80%)
  - Mining is limited to Athabasca with a square footprint of 15 miles
  - Mined bitumen is typically upgraded in Athabasca to Synthetic Crude Oil (SCO) for pipeline distribution
  - In situ bitumen is typically mixed with a diluent in order to flow for pipeline distribution
- The focus of this paper is the outbound movement of SCO and especially bitumen



Liquid Pipelines and Rail Lines

Dr. Malcolm Cairns

- Oil field products are typically handled in three stages
  - Gathering lines of small diameter move oil from the well head to oil batteries
  - Feeder pipelines move oil from oil batteries to nearby refineries and to long-haul pipelines
  - Transmission pipelines of large diameter move oil across the continent
- All Alberta Oil Sands product is currently handled by gathering and feeder pipelines
- There is currently no direct rail service to the Alberta Oil Sands
  - CN's rail line reaches Fort McMurray but does not cross the Athabasca River
  - A bridge across the river would require prohibitive costs of several $100 million
  - CP has no rail line into the Alberta Oil Sands but does serve Edmonton and Hardisty – these locations are the termini of the feeder pipelines



Feeder Pipeline Network

Dr. Malcolm Cairns

- Feeder network owned by 5 companies: Enbridge, Inter Pipeline, Pembina, Access and Suncor
- Network crisscrosses the region with Termini at Edmonton and Hardisty
- Products moved are SCO and diluted bitumen southbound, diluent northbound
- Total southbound feeder capacity some 2 million b/d
- The construction of additional capacity requires approval of the Energy Resources Conservation Board

EXHIBIT 4

Feeder Pipeline

Company	Name	Origin	Destination	Length (km)	Product	Shipper	Capacity (b/d)
ENBRIDGE							
	Athabasca	Fort McMurray	Hardisty	540	Crude Oil		570,000
	Athabasca Twinning	Cold Lake (Christiana Lake)	Hardisty	345	Crude Oil	Cenovus	450,000-800,000
	Waupisoo	Cheecham (70km south of Ft M)	Edmonton	380	Crude Oil		600,000
	Waupisoo Expansion	Cheecham (70km south of Ft M)	Edmonton	380	Crude Oil		65,000-255,000
	Woodland	Fort McMurray (Kearl Lake)	Cheecham (70km south of Ft M)	140	Blended Bitumen	Imperial Oil	200,000
INTER PIPELINE							
35%	Corridor	Fort McMurray	Edmonton (Scotford)	500	Diluted Bitumen	Shell/Chevron/Marathon	296,000
	Cold Lake	Cold Lake (La Corey)	Edmonton	250	Blended Bitumen	Cenovus/CNRL/Imperial Oil and Shell	490,000
		Cold Lake (Foster Creek)	Hardisty	320	Blended Bitumen		
	Cold Lake Expansion	Cold Lake (Narrows Lake)	Cold Lake (Foster Creek)	85	Blended Bitumen	Cenovus	190,000
		Cold Lake (Foster Creek)	Cold Lake (La Corey)	80	Blended Bitumen	Cenovus	710,000
		Cold Lake (La Corey)	Hardisty	240	Blended Bitumen	Cenovus	540,000
	Polaris	Edmonton (Scotford)	Fort McMurray (Muskeg River)	460	Diluent		90,000
	Polaris Expansion	Edmonton	Cold Lake (Christina Lake)	240	Diluent		700,000
		Cold Lake (Christina Lake)	Cold Lake (Foster Creek)	75	Diluent		120,000
		Cold Lake (Christina Lake)	Cold Lake (Narrows Lake)	20	Diluent		55,000
PEMBINA							
30%	Syncrude	Fort McMurray (Syncrude)	Edmonton	500	Synthetic Crude Oil	Syncrude	389,000
	Horizon	Fort McnMurray (CNRL)	Edmonton	550	Synthetic Crude Oil	CNRL	250,000
	Cheecham Lateral	Syncrude pipeline outlet	Cheecham	56	Synthetic Crude Oil	Conoco/Total/Nexen/CNOOC	136,000
	Nipisi	Peace River (Seal)	Edmonton	190	Diluted Bitumen	CNRL/Cenovus	100,000
	Mitsue	Edmonton	Peace River (Seal)	255	Diluent	CNRL/Cenovus	22,000
ACCESS							
	Access (1)	Edmonton	Cold Lake (Christiana/Jackfish)	345	Diluent	MEG Energy/Devon	na
	Access (2)	Cold Lake (Christiana/Jackfish)	Edmonton	345	Blended Bitumen	MEG Energy/Devon	na
	Northeast Expansion	Cold Lake (near Conklin)	Edmonton	297	Blended Bitumen		350,000
SUNCOR							
	Firebag	Fort McMurray (Firebag project)	Fort McMurray (Suncor base plant)	40	Diluted Bitumen	Suncor	368,000

Sources: Various industry websites

Storage Capacity at Edmonton and Hardisty

Dr. Malcolm Cairns

- Five companies have storage capacity at the termini of the feeder pipelines
- Storage capacity at Edmonton exceeds 8 million barrels
- Storage capacity at Hardisty exceeds 12 million barrels

EXHIBIT 7	Storage Capacity (milions of barrels)	
	HARDISTY	EDMONTON
ENBRIDGE		
Cavern Storage	3.1	
Surface Stoage Facility	7.5	
TRANSCANADA	2.6	
KINDER MORGAN		4.5
INTER PIPELINE		3.5
PEMBINA		>0.3

Source: Various Industry websites

Transmission Pipeline Network - Existing

Dr. Malcolm Cairns

- Enbridge System
  - Edmonton and Hardisty to Montreal and US gulf Coast
  - Total capacity 2.5 million b/d
- Kinder Morgan
  - Trans mountain from Edmonton to Burnaby BC and Washington State – 300,000 b/d
  - Express and Platte pipelines from Hardisty to Casper, Wyoming and then east to Wood River, Illinois – 440,000 b/d
- TransCanada Keystone System
  - Phase 1 Hardisty to Steele City, Nebraska then east to Wood River, Illinois
  - Phase 2 Steele City to Cushing, Oklahoma
  - Total capacity 590,000 b/d

EXHIBIT 5

Company	Transmission Pipeline Name	Origin	Destination	Length (km)	Product	Capacity (b/d)
I EXISTING						
ENBRIDGE						
	Enbridge and Lakehead System	Edmonton and Hardisty	Montreal, US mid-west, Cushing Oklahoma and US Gulf Coast	5,363	Crude oil, Natural Gas Liquids and Refined Petroleum	2,500,000
	Southern Lights	Manhatten, Illinois	Edmonton	1,086	Diluent	180,000
KINDER MORGAN						
	Trans Mountain	Edmonton	Burnaby, BC and Washington State	1,150	Crude oil and Refined Petroleum	300,000
	Express	Hardisty	Casper, Wyoming	1,263	Crude oil	280,000
	Platte	Casper, Wyoming	Wood River, Ilinois	1,500	Crude oil	164,000
TRANSCANADA						
	Keystone - Phase 1	Hardisty	Steele City, Nebraska and Wood River, Illinois	3,456	Crude oil	590,000
	Keystone - Phase 2	Steele City, Nebraska	Cushing, Oklahoma	480		
II PROPOSED NEW AND EXPANSIONS						
ENBRIDGE						
	Northern Gateway	Edmonton	Kitimat, BC for offshore	1,177	Crude oil	525,000 - 850,000
		Kittimat, BC	Edmonton	1,177	Diluent	193,000
KINDER MORGAN						
	Trans Mountain expansion	Edmonton	Burnaby, BC and Washington State	900	Crude oil	600,000
TRANSCANADA						
	Keystone XL - Phase 4	Hardisty	Steele City, Nebraska	1,897	SCO and blended bitumen	830,000
	Keystone XL - Phase 3	Cushing, Oklahoma	Houston, Texas	856		

Sources: Various Industry websites

Transmission Pipeline Network – Proposed Expansions

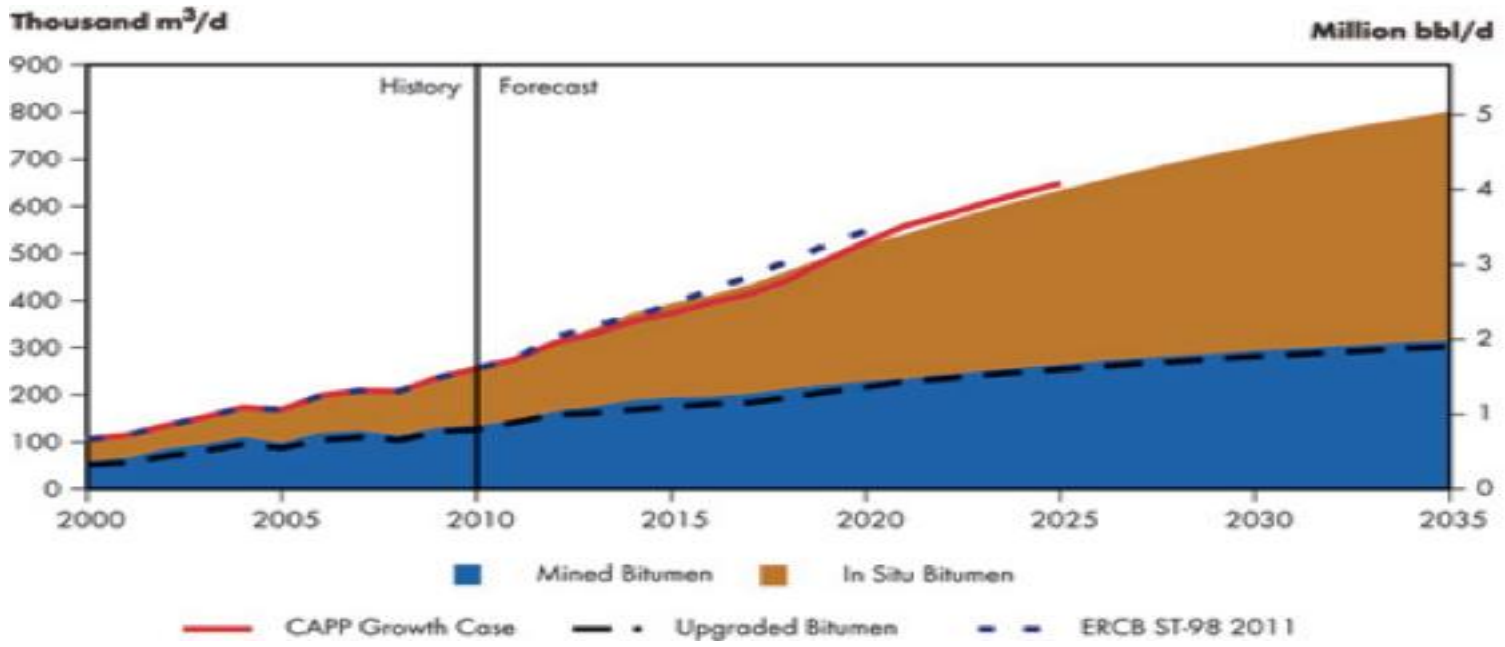
Dr. Malcolm Cairns

- Enbridge System
  - New Northern Gateway Edmonton to Kitimat, BC
  - Total capacity 525,000 to 850,000 b/d
- Kinder Morgan
  - Expansion of Trans mountain from Edmonton to Burnaby BC and Washington State
  - Total additional capacity 600,000 b/d
- TransCanada Keystone XL
  - New Phase 4 Hardisty to Steele City, Nebraska
  - New Phase 3 Cushing, Oklahoma to Houston, Texas
  - Total capacity 830,000 b/d
- TransCanada Energy East Pipeline Project
  - Conversion of a gas to oil: Saskatchewan to Quebec
  - New oil pipeline: Hardisty to Saskatchewan
  - New oil pipeline: Quebec, Montreal, Quebec City, Saint John, New Brunswick
  - Total capacity 500,000 to 850,000 b/d

- New Northbound
  - Alberta Oil Sands to Tuktoyaktuk, NWT (Beaufort Sea)

Outlook for Alberta Oil Sands Production

Dr. Malcolm Cairns



- By 2035 Alberta Oil Sands production estimated at 5.1 million b/d
- Majority of growth will be in the “in situ” category
- Over the longer term production may reach 8.3 million b/d
- Combining the 2012 figure of 2 million b/d with figures for conventional crude oil, suggests total production has run up against the existing transmission pipeline constraint

Discount Pricing

Dr. Malcolm Cairns

- Crude oil pricing in different markets is affected by several factors :
  - Product details – there is limited refinery capacity for bitumen
  - Supply – there is an increase in supply from US oil producers
  - Transportation – there are pipeline constraints between supply sources and refineries

		2012	YTD (Apr 25)	Apr 25 2013
Brent - North Sea	International Crude	$113	$110	$103
West Texas Intermediate (WTI) - Cushing, Oklahoma	North American Crude	$94	$94	$93
Western Canadian Select (WCS) - Hardisty	Heavy Crude	$72	$70	$78
Syncrude Sweet - Edmonton	SCO	$93		

Sources: TD Economics and Fisrt Energy Capital

- Heavy crude oil has a higher density, flows through pipelines more slowly and is typically more expensive to refine relative to lighter blends. As a result, the market price for heavier oil will generally be lower than lighter blends
- Recently: Brent = $16 + WTI ; WTI = $24 + WCS
  - Most recently the trend is for a reduction in the WTI-WCS spread to $15
  - With no signs of Canadian and U.S. production letting up significantly, and refinery additions limited, most analysts are looking to enhanced pipeline and other transportation to ultimately relieve the price pressure
  - If pipeline additions are stalled, there exists an opportunity for rail, providing the additional costs of rail are at or below the crude oil price discount

Recent Movements of Crude Oil by Canadian Railways

Dr. Malcolm Cairns

- Both CP and CN have begun to move significant volumes of crude oil since 2008 – but the volumes are NOT currently Alberta Oil Sands bitumen
- The recent growth in the movement of crude oil by rail is due to three factors:
  - The rapid development of Shale Oil – particularly the Bakken formation in North Dakota which has insufficient feeder pipelines
  - Associated transmission pipeline capacity constraints
  - The ability of rail to serve many markets across the continent, and to reach key underserved refineries
- Rail also has other advantages:
  - Transload facilities do not require very significant capital investment
  - Unlike new pipelines, existing rail does not require very long term contracts
  - There is synergy with related crude oil products: fracking sand, steel pipe, other oil field tubular products, aggregates, chemicals, condensate, construction materials, and dimensional loads
- Rail has proven its ability to handle crude oil successfully

Rail Service for the Alberta Oil Sands

Dr. Malcolm Cairns

- Short rail line build-ins may provide direct rail service:
  - CP lines into the Alberta Industrial Heartland northeast of Edmonton
  - CN into project sites along its existing line south of the Athabasca River
  - A 30 km CN line into Hardisty
- The construction of an Athabasca River bridge or an extensive new rail line network is unlikely:
  - Too expensive
  - Unnecessary, given the existing feeder pipeline network
  - A new railway to Alaska – as some have proposed – would require US government approval
  - An upgrade to the rail line to Churchill would see oil tankers for a short-season in the High Arctic
- Construction of Transload facilties is already underway:
  - CN at Fort McMurray
  - CP at Hardisty with Gibson Energy
- Bitumen can be handled in heated tank cars without the need of diluent

Potential Train Capacity and Equipment needed to move Alberta Oil Sands Crude Oil

Dr. Malcolm Cairns

- One tank car in practice handles 525-650 barrels depending upon the product
- Assume 1 train has 2 locomotives, 120 tank cars and average cycle time of 15 days
- With 10 train-starts per day:
  - Volume moved 630,000-780,000 b/d
  - Equipment requirements, 300 locomotives and 18,000 tank cars
- In 2011 CP and CN operated fleets of 2,400 locomotives and 65,000 freight cars
- 10 train starts – 5 each for CP and CN – would imply perhaps 2 westbound, 2 southbound and I eastbound each per day
- CP currently handles 30-35 trains per day to Vancouver

EXHIBIT 3: Potential Train Capacity and Equipment Requirements

One barrel of crude oil - gallons	42	
One tank car - gallons	30,000	
Number of barrels per tank car	714	525 - 650
Number of tank cars per unit train		120
Number of barrels per train		63,000 - 78,000
Average train cycle time - days		15
Number of train sets required for one train-start per day		15
Volume moved in one train-start per day - b/d		**63,000 - 78,000**
Number of locomotives required - 2 per train		30
Number of tank cars required		1,800
Number of barrels in 10 train-starts per day - b/d		**630,000 - 780,000**
Number of locomotives required - 2 per train		300
Number of tank cars required		18,000

- Handling the additional 3 million b/d solely by rail would likely be a stretch too far

Additional Cost of Moving Oil by Rail versus Pipeline

Dr. Malcolm Cairns

- Exhibit provides estimates of pipeline costs per barrel
- Rail costs and rates are confidential
- While rail is generally acknowledged to cost more than pipeline, one saving is the absence of diluent

EXHIBIT 4: Cost of moving Western Crude oil by Pipeline

Destination	Costs in $ per barrel
US Gulf Coast	$7.00
West Coast of British Columbia	$3.00
Montreal, Quebec	$3.00
Quebec City, Quebec	$6.50
Saint John, New Brunswick	$8.00

Source: TD Economics

- Crescent Point Energy Corp: "We see [the cost of rail versus pipeline] in the $2 per barrel range"
- Southern Pacific Resource Corp: Estimates the cost differential at $23 per barrel
- Overall, cost differentials in the range $2 to $20 per barrel depending upon the market appear likely – CN recently suggested $8
- With the oil price discounts, the advantage of not needing diluent, and the possibility of a diluent backhaul, the movement of Alberta Oil Sands bitumen appears economic

Conclusions

Dr. Malcolm Cairns

- The current feeder pipeline network serving the Alberta Oil Sands has the capacity to handle 2 million b/d:
  - This capacity can likely be expanded relatively easily since licensing is by provincial authority
  - The feeder network connects with the transmission network at Edmonton and Hardisty
  - Both Edmonton and Hardisty have direct rail connections and significant storage capacity
- The transmission pipeline network from these locations has the capacity to handle 3.5 million b/d:
  - This network handles conventional crude not just Alberta Oil Sands crude
  - Current expansion plans would see additional capacity of 2 million b/d
  - Official projections suggests production could increase to 5 million b/d by 2035 and possibly to 8 million b/d at a later date
- Pipeline capacity constraints are a factor in the current discounting of the price of Alberta Oil Sands crude :
  - The price discount fluctuates in the range $10 to $30 per barrel
  - The additional costs to move crude by rail over pipelines is likely in the range $2 to $20 per barrel depending upon the markets being served – CN recently suggested $8 per barrel
  - With the current discounting – as well as diluent advantages - crude oil by rail appears economic
- An estimate suggests rail could handle between 600,000 and 800,000 b/d

Postscript: Comparison of Rail and Pipeline – Spillage and Safety

Dr. Malcolm Cairns

- Recent reports misleading:
  - Products should be compatible
  - Frequency of incident an inappropriate metric
  - 75% or rail incidents less than 5 gallons
- Comparison metrics: spillage, fatalities, injury
  - Total transport in billion barrel-miles
  - Over the two decades, rail movement increased 40%, pipeline flat, but pipeline moves 30X the product
- Spillage – gross quantity released:
  - Rail and pipeline similar 1990-1999: 36 barrels released per billion barrel-miles
  - Both modes improved by 2000-2009 but rail made better progress
  - Rail versus Pipeline: 16.5 versus 23.9 barrels per billion barrel-miles
  - Both modes are safe
- Fatalities 1990-2009: Rail 3, Pipeline 42, but pipeline moves 30X the product
- Injuries 1990-2009: Rail 40, Pipeline 181 but again pipeline moves 30X the product

EXHIBIT 1: The Incidents in the US concerning the movement of Hazardous Liquid Pipeline Commodities by Rail and Pipeline 1990-2009

	RAIL				PIPELINE			
	Total Transport Barrel-miles Billions	Gross Quantity Released Barrels	Fatalities Number	Injuries Number	Total Transport Barrel-miles Billions	Gross Quantity Released Barrels	Fatalities Number	Injuries Number
1990	99.820	9,676	0	2	4,164.633	124,277	3	7
1991	98.394	2,805	0	2	4,124.705	200,567	0	9
1992	105.524	3,213	0	2	4,198.144	137,065	5	38
1993	108.376	1,505	0	0	4,227.377	116,802	0	10
1994	112.654	2,583	0	2	4,216.682	164,387	1	7
1995	119.071	2,676	0	0	4,285.843	110,237	3	11
1996	119.784	9,476	1	2	4,414.896	160,316	5	13
1997	119.071	1,610	0	0	4,395.645	195,549	0	5
1998	119.071	1,545	0	2	4,419.174	149,500	2	6
1999	133.331	6,736	0	1	4,404.201	167,230	4	20
Sub-Total: 1990-1999	1,135.096	41,825	1	13	42,851.300	1,525,930	23	126
Barrels Released per billion barrel-miles		36.8				35.6		
2000	144.739	4,103	0	0	4,116.149	108,652	1	4
2001	134.757	2,520	0	0	4,107.593	98,348	0	10
2002	144.026	6,773	1	0	4,179.606	97,255	1	0
2003	141.174	747	0	0	4,208.126	81,308	0	5
2004	154.008	2,007	0	4	4,275.148	89,311	5	16
2005	165.416	1,508	1	20	4,331.475	138,094	2	2
2006	183.954	333	0	2	4,144.669	137,693	0	2
2007	189.658	5,023	0	1	3,976.401	94,980	4	10
2008	163.990	2,624	0	0	4,491.187	102,076	2	2
2009	161.352	508	0	0	4,069.804	54,962	4	4
Sub-Total: 2000-2009	1,583.074	26,147	2	27	41,900.158	1,002,679	19	55
Barrels Released per billion barrel-miles		16.5				23.9		
Total: 1990-2009	2,718.170	67,972	3	40	84,751.458	2,528,609	42	181
Barrels Released per billion barrel-miles		25.0				29.8		

Source: AAR, 2013

Postscript: Comparison of Rail and Pipeline – GHG Emissions

Dr. Malcolm Cairns

- Comparison is made for the Keystone XL project
- Pipeline emissions: 3.2 million tonnes of GHG emissions per year:
  - Total movement of 730,000 b/d over 875 miles
  - Emissions result from use of electricity to power 100 6,500 HP pumps
- Rail-Truck emissions: 0.3 million tonnes of GHG emissions per year:
  - Total movement of 100,000 b/d over 1,347 miles
  - Loaded movement fuel use based upon loaded ton-miles and fuel efficiency of rail and truck in loaded ton-miles per gallon
  - Empty movement fuel use based upon empty miles and fuel efficiency of rail and truck in empty miles per gallon
  - GHG emissions based upon fuel consumption and GHG emission factors for rail and truck diesel
- After normalizing for differences in total movement, rail-truck versus pipeline: 3.17 versus 8.51 kg of GHG per 1000 barrel-km per year
- Rail-truck emissions are 2.7 times less than the Pipeline emissions

	RAIL			TRUCK			TOTAL	PIPELINE
	Loaded	Empty	Total	Loaded	Empty	Total	RAIL-TRUCK	
Crude volume - barrels per day	100,000			100,000				730,000
Weight of crude - tons per day	14,427			14,427				
Distance - miles	1,347	1,347		50	50			875
Distance - km: 1 mile = 1.609344 km	2,168			80				1,408
1000 Barrel-km per year	79,124,202			2,937,053			82,061,255	375,208,495
Ton-miles per day	19,433,169			721,350				
Number of trips per day		1.5			534			
Empty Miles per day		2,063			26,717			
Ton-miles per US gallon	480			154				
Empty Miles per US gallon		0.14			7.5			
US gallons per day	40,486	14,734		4,684	3,562			
Litres per year: 1 US gallon = 3.785383	55,937,761	20,357,844	76,295,605	6,471,844	4,921,797	11,393,641		
GHGs in kg per litre			3.00715			2.68963		
GHGs in tonnes per year			229,432			30,645	260,077	3,191,774
GHGs in kg per 1000 barrel-km							3.17	8.51

Source: Draft Supplementary Environmental Impact Statement, Keystone XL Project, Appendix Z, March 2013

Postscript: International Perspective

Dr. Malcolm Cairns

- From previous slide, total Keystone KL project GHG emissions per year would be some 3 million tonnes by pipeline or 2 million tonnes by rail-truck
- This covers transportation, but not production, refining, or end use
- However, the relative significance for Canada and internationally can be gauged from the Exhibit
- Extraordinary public attention to the Alberta Oil Sands and associated pipelines is out of all proportion
- China alone has increased its GHG emissions since 2005 by more than 3X the combined reductions of the US, Europe, Japan and Canada
- Canadian energy products could well reduce China's footprint by replacing coal

TOTAL ENERGY-RELATED EMISSIONS OF CO2

	2005	2011	Change	Proportional Change
	(millions of tonnes)			
China	5,463	8,715	3,252	59.5%
India	1,182	1,726	544	46.0%
Russia	1,587	1,788	201	12.7%
Japan	1,242	1,181	-61	-4.9%
Canada	624	553	-71	-11.4%
UK	583	497	-86	-14.8%
Germany	847	748	-99	-11.7%
Europe	4,675	4,305	-370	-7.9%
US	6,000	5,491	-509	-8.5%
Total	20,773	23,759	2,986	14.4%

Source: US Department of Energy