Oil Sands/Tar Sands Overview: Resource Development

Randy Mikula
Introduction:

- The oil sands geology
- The resource and reserve: Surface mining and in-situ
- Environmental Issues associated with oil sands development
  - Energy Balance
  - Water Use
  - Toxicity
A very detailed description of the geology is in the Alberta Geological Survey Bulletin 46
Natural Outcrops along the Athabasca River just North of Fort McMurray
Natural Outcrop along the Athabasca River, Tar Island, Just Upstream of the Suncor Mine
Canadian Reserves on the world stage: since 2002 Canada has been the biggest exporter of oil to the United States
### Reserves and Production Summary 2005 (billions of barrels) EUB NR2006-08

<table>
<thead>
<tr>
<th></th>
<th>EUB ST98-2007</th>
<th>Alberta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitumen Total</td>
<td>1,694</td>
<td></td>
</tr>
<tr>
<td>Reserve</td>
<td>179</td>
<td></td>
</tr>
<tr>
<td>Remaining Reserve</td>
<td>174</td>
<td></td>
</tr>
<tr>
<td>Annual production</td>
<td>0.388</td>
<td></td>
</tr>
<tr>
<td>Years of production</td>
<td>448</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Mineable</th>
<th>in situ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peace River</td>
<td>35</td>
<td>144</td>
</tr>
<tr>
<td>Fort McMurray</td>
<td>0.252</td>
<td>0.189</td>
</tr>
<tr>
<td>Edmonton</td>
<td>0.189</td>
<td></td>
</tr>
<tr>
<td>Calgary</td>
<td>760</td>
<td></td>
</tr>
<tr>
<td>Edmonton</td>
<td>140</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bitumen</td>
<td>Total</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>---------</td>
<td>----------</td>
</tr>
<tr>
<td>Resource</td>
<td>1,805</td>
<td>131</td>
</tr>
<tr>
<td>Reserve</td>
<td>176</td>
<td>38</td>
</tr>
<tr>
<td>Remaining Reserve</td>
<td>170</td>
<td>34</td>
</tr>
<tr>
<td>Annual Production</td>
<td>.544</td>
<td>.302</td>
</tr>
<tr>
<td>Years of Production</td>
<td>312</td>
<td>113</td>
</tr>
</tbody>
</table>

Approximately a 20% production increase in 2 years; 27 fewer years to reclaim
Western Canadian Oil Sands Potential

All of CERI’s research is publicly available at [Link for CERI's research].

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Oil Sand Composition

• Oil sand consists of Mineral (sand, fines, clays), Bitumen, and Water (with soluble salts).

“Typical Composition” is
Mineral 85%
Bitumen 10%
Water 5%

Heavy Oil

Definitions in terms of physical properties
(UNITAR—on heavy crude and tar sands 1998 No.1998.039)

<table>
<thead>
<tr>
<th>Crude</th>
<th>Maximum viscosity, mPa s</th>
<th>Gravities °API (S.G. = 141.5/(131.5-°API))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>1- 1000</td>
<td>20-40</td>
</tr>
<tr>
<td>Heavy</td>
<td>1000 - 10,000</td>
<td>10-20</td>
</tr>
<tr>
<td>Tars</td>
<td>10,000 –100,000</td>
<td>&lt;10</td>
</tr>
</tbody>
</table>
A lot of water is required to produce a barrel of bitumen!
In order to meet pipeline specifications, oil has to have a low viscosity (less than 350 centistokes) and a low water and solids contamination (less than 0.5% by volume).

The upgrading process removes carbon from the bitumen and adds hydrogen to create a synthetic crude oil that can meet pipeline specifications. Without an upgrading step, diluents must be added in order to reduce viscosity and pipeline the bitumen. These “diluents” can be paraffinic (C5-C6 natural gas condensates), Naphtha or gas oils, or conventional crude oils. Dil-bit can span a wide range of compositions.
PADD regions enable regional analysis of petroleum product supply and movements

Petroleum Administration for Defense Districts

PADD 1: East Coast
PADD 2: Midwest
PADD 3: Gulf Coast
PADD 4: Rocky Mountain
PADD 5: West Coast, AK, HI

Source: U.S. Energy Information Administration.
## 2011 Facts about Canadian Crude

### Production:
- Western Canada (AB, BC, SK, NWT) Conventional LIGHT Crude: 561,929 bbls/day
- Western Canada (AB, BC, SK, NWT) Upgraded Bitumen: 846,112 bbls/day
- Western Canada (AB, BC, SK, NWT) Condensate (C5+): 128,498 bbls/day
- Western Canada (AB, BC, SK, NWT) Conventional HEAVY Crude: 421,618 bbls/day
- Western Canada (AB, BC, SK, NWT) Non Upgraded Bitumen: 758,919 bbls/day
- Eastern Canada (NF/LAB, ON) Conventional LIGHT Crude: 271,778 bbls/day
- **Total 2011 Production of Crude Oil and Equivalent**: 2,988,854 bbls/day

### Exports:
- PADD I (74% Light, 26% Heavy): 171,182 bbls/day
- PADD II (21% Light, 79% Heavy): 1,439,447 bbls/day
- PADD III (12% Light, 78% Heavy): 111,358 bbls/day
- PADD IV (17% Light, 83% Heavy): 213,709 bbls/day
- PADD V (61% Light, 39% Heavy): 167,295 bbls/day
- Non-US (67% Light, 33% Heavy): 35,261 bbls/day
- **Total US (28% Light, 82% Heavy)**: 2,138,260 bbls/day

### Imports:
- Atlantic Canada Conventional Crude: 333,990 bbls/day (80%)
- Quebec Conventional Crude: 298,775 bbls/day (84%)
- Ontario Conventional Crude: 52,836 bbls/day (15%)
- **Total Canadian Imports**: 685,560 bbls/day

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All of CERI’s research is publicly available at [CERI](http://www.ceri.ca).
Options for Canadian Crude By Pipeline

Source: Canadian Association of Petroleum Producers, Crude Oil Forecast, Markets & Pipelines, June 2011

All of CERI’s research is publically available at KALIUM Research

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No nation can long be secure in this atomic age unless it be amply supplied with petroleum . . . It is the considered opinion of our group that if the North American continent is to produce the oil to meet its requirements in the years ahead, oil from the Athabasca area must of necessity play an important role.

J. Howard Pew (GCOS 1960’s)
Surface mining compared to in situ production: Energy Use, Water Use, Land disturbance
ENERGY BALANCE
Diagrammatic Representation of the Cold Lake Plant for Bitumen Extraction Using Cyclic Steam Stimulation (CSS)

Stage 1: Steam Injection
Stage 2: Soak Time
Stage 3: Melted Bitumen Production

Diagrammatic Representation of the Underground Test Facility for Bitumen Extraction Using the Steam Assisted Gravity Drainage (SAGD) Process

Cross Section Through a Steam Chamber

Courtesy Fran Hein, ERCB
1 m^3\text{OE} \sim 40 \text{ GJ}
So 10 \text{ GJ/m}^3\text{OE} \sim
Is about 25% of the input energy in the product
1 \text{ GJ/m}^3\text{OE} \sim 2.5\

Source: Clearstone et al - An Air Quality Impact Study of Canada’s Oil and Natural Gas Industry – October, 2008
LAND DISTURBANCE
The area occupied by the circle is approximately 400,000km², and the area of the oil sands resource (in white) is approximately 141,000km². Currently land disturbance due to oil sands development is about 600km², with tailings containment about 180km².
WATER USE
MINING → EXTRATION

tree clearing

truck & shovel

crusher & cyclofeeder

slurry

bitumen froth to treatment

tailings oil recovery

tailings settling basin

sand storage

MFT & CT containment

water recycling

TAILINGS MANAGEMENT

Courtesy Syncrude
Bitumen
Froth
Ore
Wet Sand
Recycle Water
Fluid Fine Tailings
The sand tailings are used to build the containment for the fine tailings.
Water used for extraction: Approximately 12 barrels per barrel of bitumen
Water Recycled: Approximately 70%
Water lost to tailings: Approximately 4 barrels per barrel of bitumen

(this is for a typical ore)
The tailings containment structures are some of the largest man made features on the planet.

Dry stackable tailings technology is one way to reduce the volume of the accumulated fluid fine tailings. Dry stackable tailings implementation will allow for reclamation of the boreal forest, and reduce the water requirement from the Athabasca river.

Photo courtesy of NASA, space shuttle program
Tailings research at CETC-Devon: Minimizing the Environmental Impact of Oil Sands Development
Aerial photo from approximately 1987 when the “best available technology” was water capping of the accumulated fluid fine tailings or sludge.

CT/NST technology promised to increase water re-use from 75% to over 80%, but now even this improvement on the “best available technology” proposes to have an end pit lake containing leftover fluid fine tailings or MFT.
Suncor Pond 1 September 2010 (Wapisiw Lookout)
Aerial view of tailings facilities - 170 km

Syncrude
Shell: JPM
Imperial Oil: Kearl Lake
CNRL: Horizon
Aurora North Shell: JPM

Slide courtesy Alan Fair IOSTC 2012, Edmonton
Storage volume limitations will drive new tailings technologies as much as water availability. Without the implementation of some other dry stackable tailings technology, long term storage volumes could become unsustainable.
A VARIETY OF DRY STACKABLE TAILINGS TECHNOLOGIES ARE BEING COMMERCIALLY IMPLEMENTED
Centrifuge 2010

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A new standard in fluid fine tailings dewatering: Syncrude Centrifuge Pilot cell #3
The arrow marks Mildred Lake, adjacent to Syncrude’s tailings pond; the Mildred Lake Settling Basin.

The Department of Fisheries and Oceans routinely harvests game fish from this lake to restock a sport fishing lake south of Fort McMurray (Lac La Biche)
With the correct recipe, CT or NST is pumpable, but rapidly releases recycle water, leaving a trafficable surface for reclamation of the boreal forest. Without the correct recipe, the mixture will segregate, leaving a fluid material unsuitable for reclamation.
SUMMARY

Several tailings management options are commercialized or have been demonstrated at close to commercial scale. Although progress has been slower than anyone would like, mined out areas are becoming available and are being utilized to implement a variety of stackable tailings technologies.

Water conservation by the use of “dry stackable tailings” management options will have significant implications for the recycle water chemistry, possibly offering the opportunity to improve water quality from an environmental perspective.

Water bugs and goldfish in composite tailings release water
Any Questions?