INOVA

TOGETHER, WE GET THE JOB DONE.

Formulating a Seismic Value Proposition for Oil Sands SAGD

A review of the continually evolving understanding and acceptance of the return on investment of seismic information

CSEG Lunchbox Geophysics

Vince P. Rodych, P.Eng.

November 22, 2016

Terms of Reference

This presentation is intended to:

- Focus on a geoscience “Value Proposition”
- Review the key elements and associated costs of a typical Steam Assisted Gravity Drainage (SAGD) project
  - and assess the areas where seismic can add value
- Use *broadly estimated dollar amounts* to assist in communicating the value of seismic and geophysics to a *diverse audience*
  - realistic & defendable in order to stimulate some lively discussions

This presentation is <u>not</u> intended to:

- Calculate a net present value or IRR for seismic investment
- Suggest operators do not have their own internal processes for assessing seismic investment
- Overly focus on the scientific details

Value Proposition

What is a “Value Proposition” ?

A business or marketing statement that a company uses to summarize why a consumer should buy a product or use a service.

The ideal value proposition is concise, and it appeals to a customer's strongest decision-making drivers.

Investopedia

What is a “Value Model” ?

A data-driven representation of the worth, in monetary terms, of what a company is doing or could do for its customers.

Wikipedia

Geoscientist Value Proposition

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What is a "Value Model" ?

A data-driven representation of the worth, in monetary terms, of what a geoscientist is doing or could do for its customers.

Wikipedia

CSEG VIG

The Value of Integrated Geophysics (VIG)

- Mandate
  - Facilitate an improved use of geophysics for business purposes

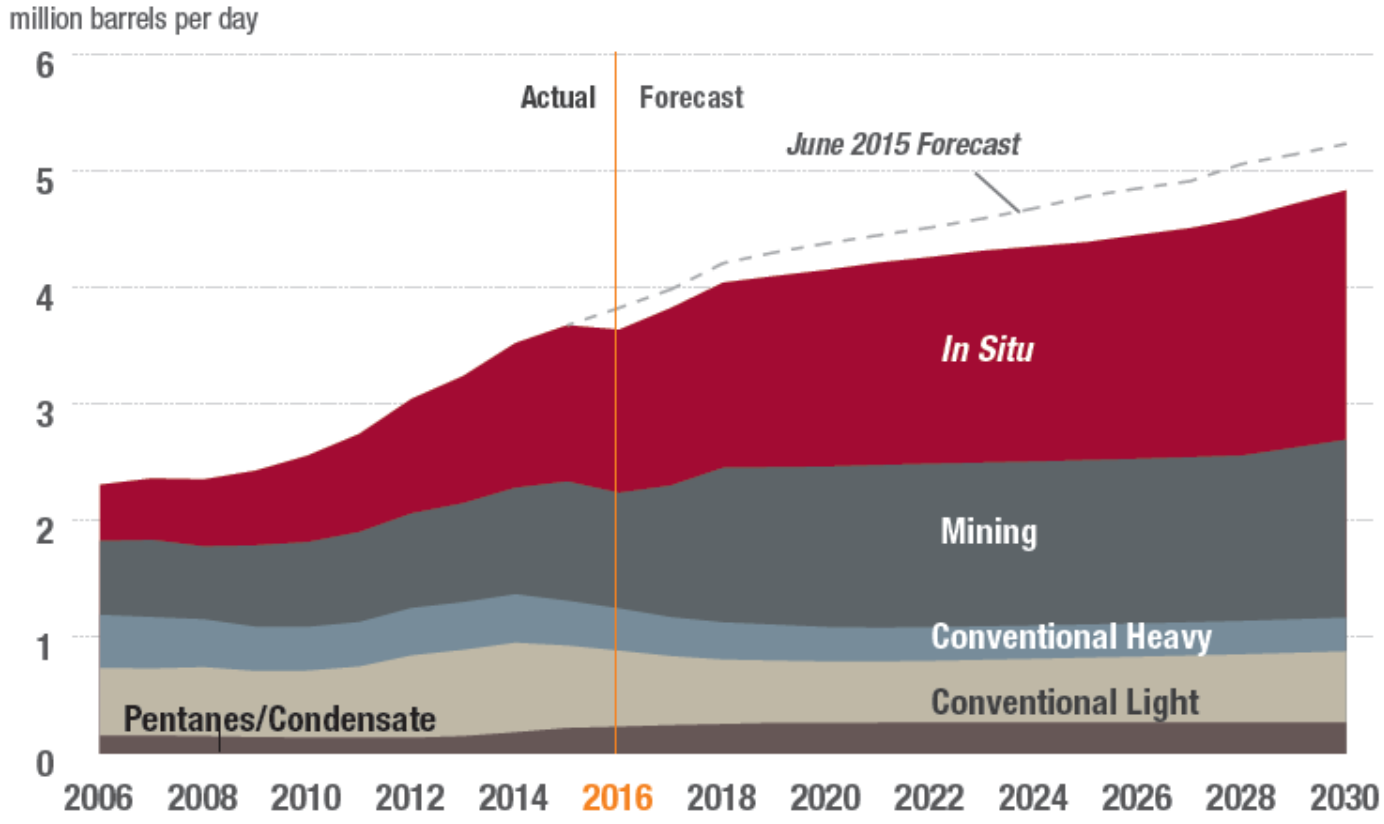
- Takeaways
  - Learn about how to illustrate the value of integrated geophysics in your presentations
  - Talk to your decision makers about encouraging decision analysis approaches to showing the value in applying geophysics
  - Promote to the earth science community the value of integrated geophysics

Background

- 1990's – Early 2000's
  Canadian Seismic Landscape Shifting
  - Attention towards oilsands in situ development
  - Rather than an exploration tool, seismic data increasingly being used for reservoir characterization
  - Seemed important to develop a detailed understanding of what was going on; identify opportunities for increased seismic acquisition expenditures
  - Often discovered a disconnect between engineers and geoscientists
    - Engineers were fixated on drilling and infrastructure
    - Turnaround of interpreted seismic data slow
    - Many individuals somewhat skeptical or ill-informed
    - Varying appreciation of value of seismic for SAGD
  - However, demonstrated value of seismic in a SAGD setting was evolving

Background

Figure 2.2 Western Canada Crude Oil Production



The Model

"Value Model"
to link components of SAGD to potential seismic value

Relied on various sources of information available in the public domain

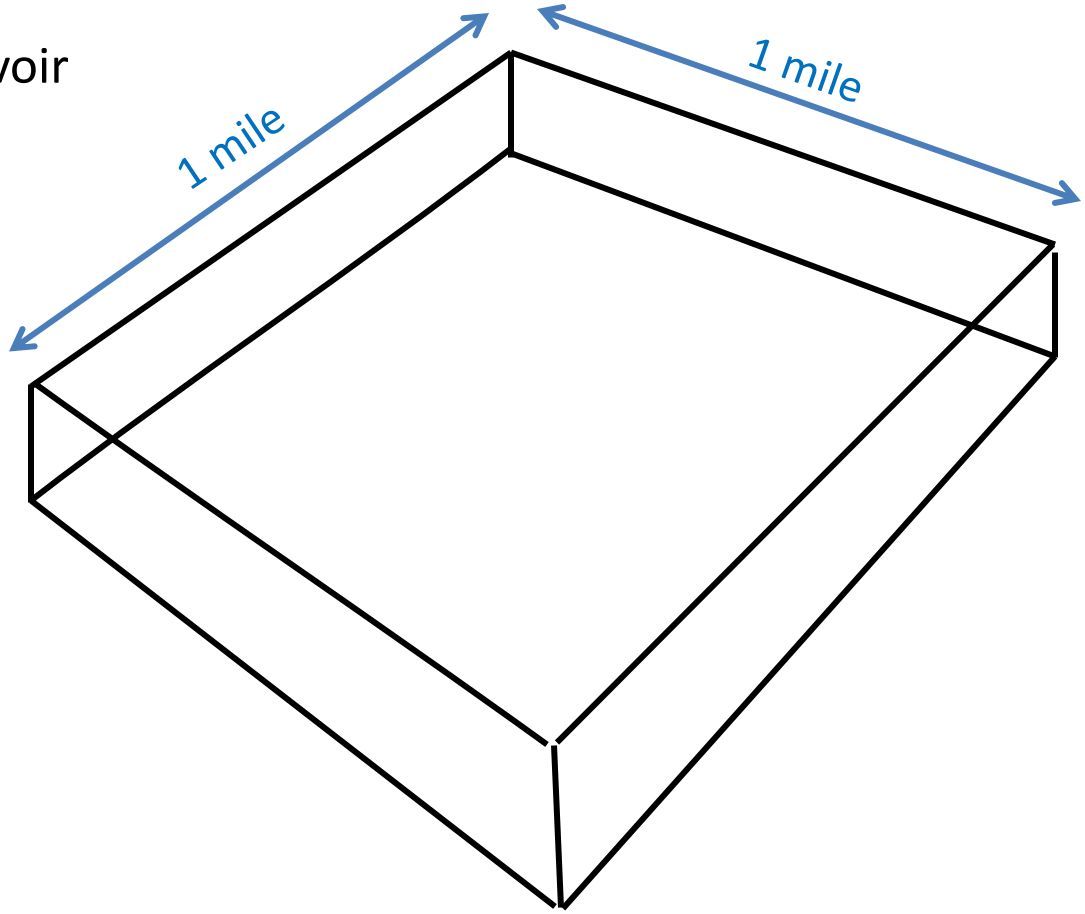
- regulatory applications
- company presentations
- technical papers
- conversations

Model proved to be an effective tool

- learning curve
- stimulate discussions with asset teams

One Square Mile of SAGD Reservoir

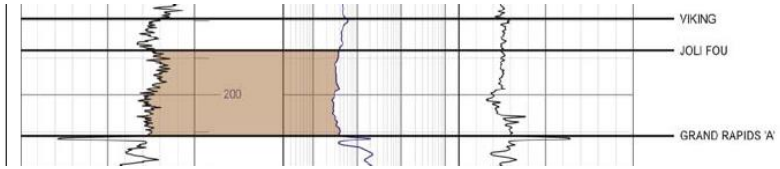
Basis of the model
1mile x 1mile
area of reservoir



SAGD Seismic Value Proposition

One Square Mile Model of Reservoir

25m thickness (suitably conservative) influenced by Devon's Jackfish application as primary info source



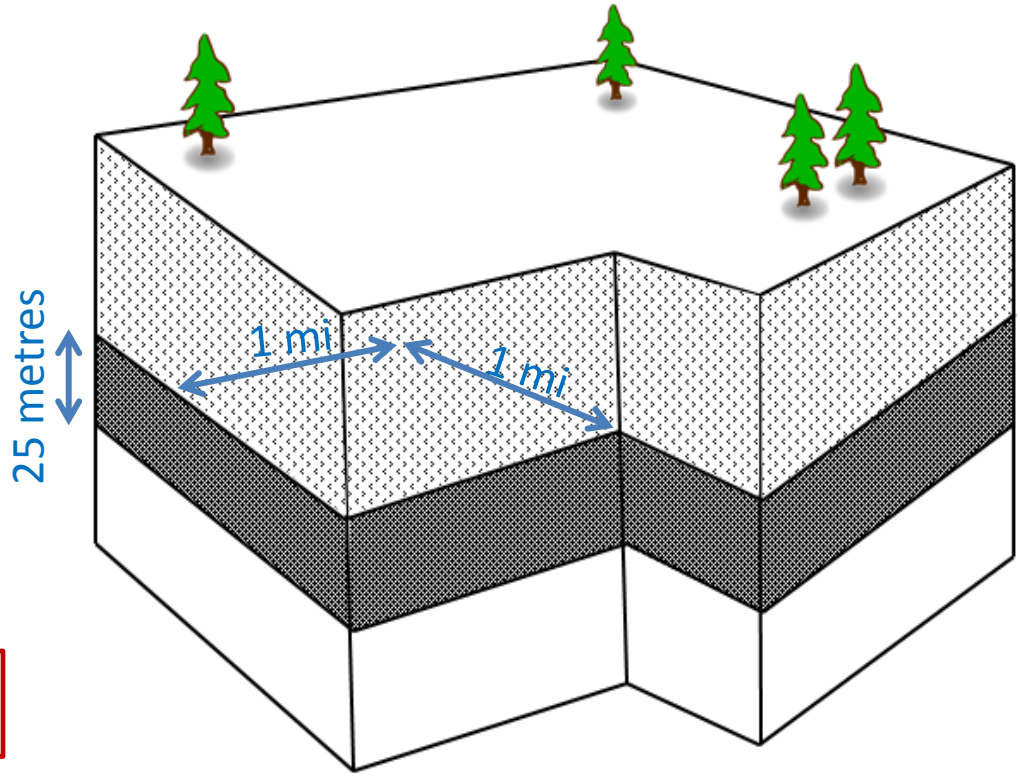
APPLICATION FOR APPROVAL OF THE DEVON JACKFISH PROJECT

VOLUME 2 – ENVIRONMENTAL IMPACT ASSESSMENT

November 2003

RESERVOIR PROPERTIES						
	Christina Lake.	Firebag	Foster Creek	Long Lake	MacKay	Surmont
Reservoir Depth (m)	350	250	435	200	95	330
Wt.% Bitumen	15	15	14	14	14	14
S_o (Calc.)	.85	.84	.8	.85	>.7	.8
S_w (Calc.)	.15	.16	.2	.15	<.3	.2
Porosity	.33	.32+	.33	.35	.32+	.35
Permeability (Darcies)	8	7	5+	8	High	4+
1st Development Thickness	46	65	30	36	30	58
Maximum Thickness	68	75	31	50	37	63
Top Gas	Yes	Minor	Minor	Occasional	No	Yes
Top Water	No	No	Minor	Yes	No	Widespread
Bottom Water	Yes	No	Yes (Flushed)	Minor	Rare	No
Flushed Zones	No	Minor	Yes	Yes	No	Minor

Table 1



A Geological Comparison of Six Projects in the Athabasca Oil Sands

Brian Rottenfusser*
Oil Sands Geological Associates
593 Silvergrove Drive N.W. Calgary, AB T3B 4R9
b.rottenfusser@shaw.ca
and
Mike Ranger
Consultant

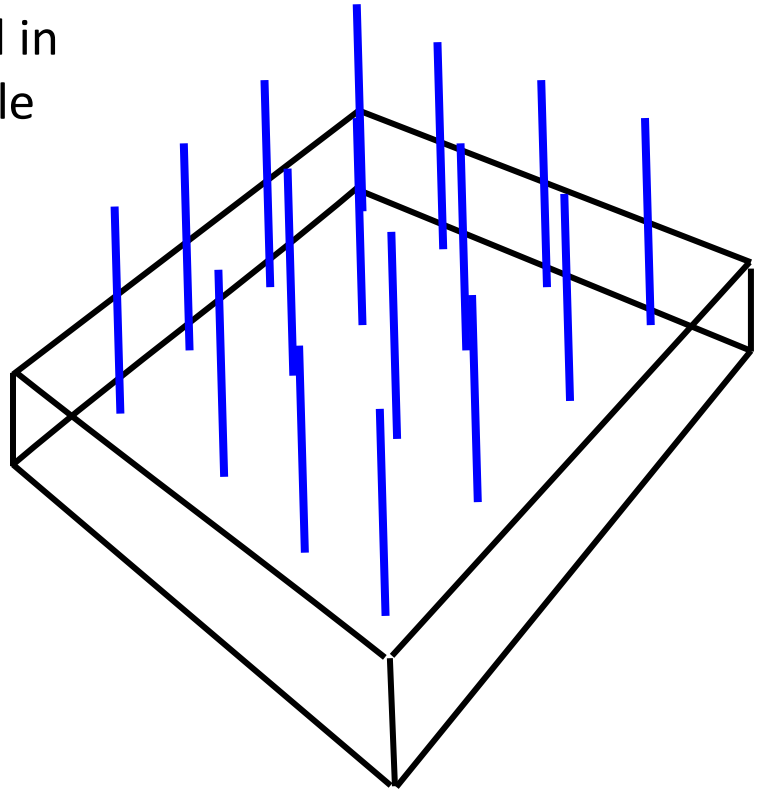
One Square Mile of SAGD Reservoir

Vertical Cored Stratigraphic Wells

Vertical Cored Stratigraphic Wells typically drilled in each legal subdivision, totalling 16 per square mile

A case can be made to substitute seismic for some of these wells

Eliminating any of these wells a hard sell to the asset team(?)



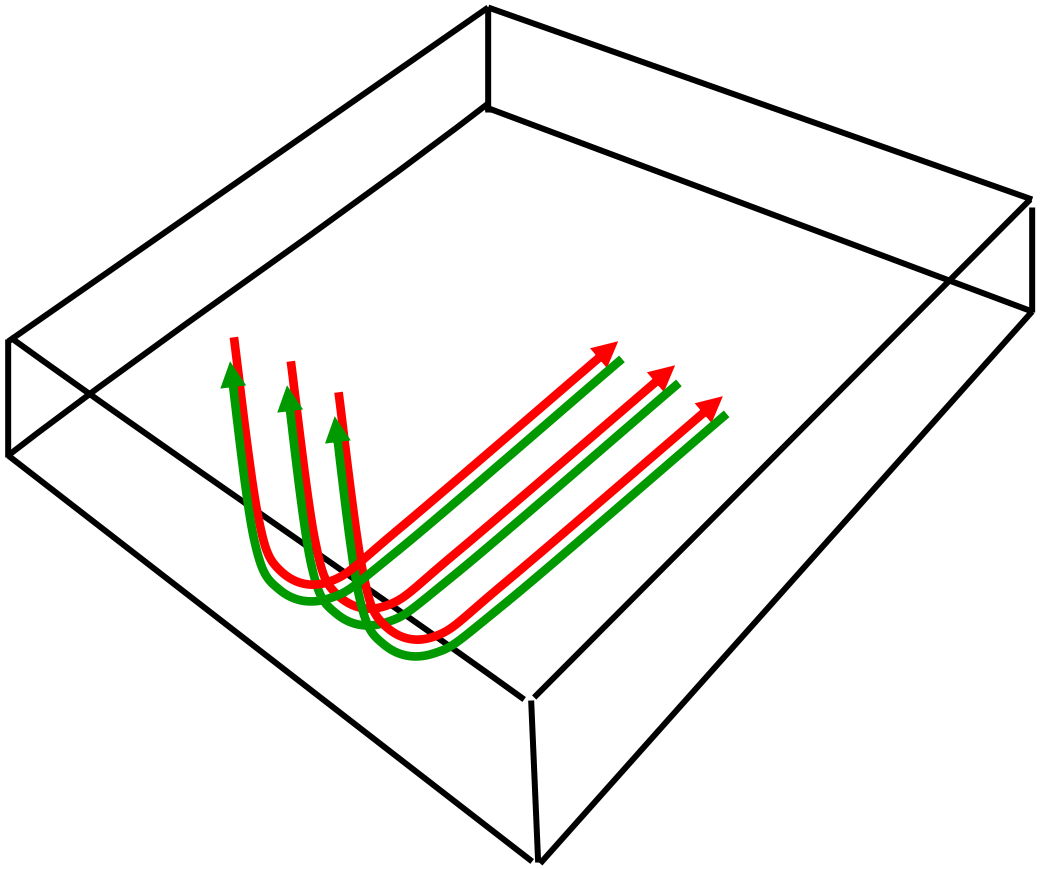
16 x Vertical Cored Stratigraphic Wells

~~@ $250k each = $4,000,000~~

@ $500k each = $8,000,000

One Square Mile of SAGD Reservoir

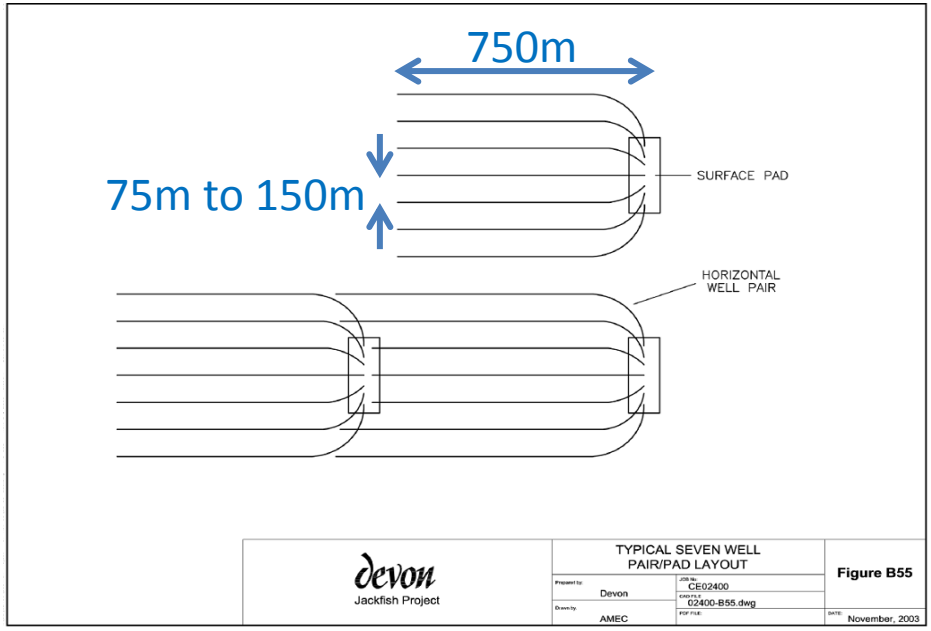
SAGD Well Pairs

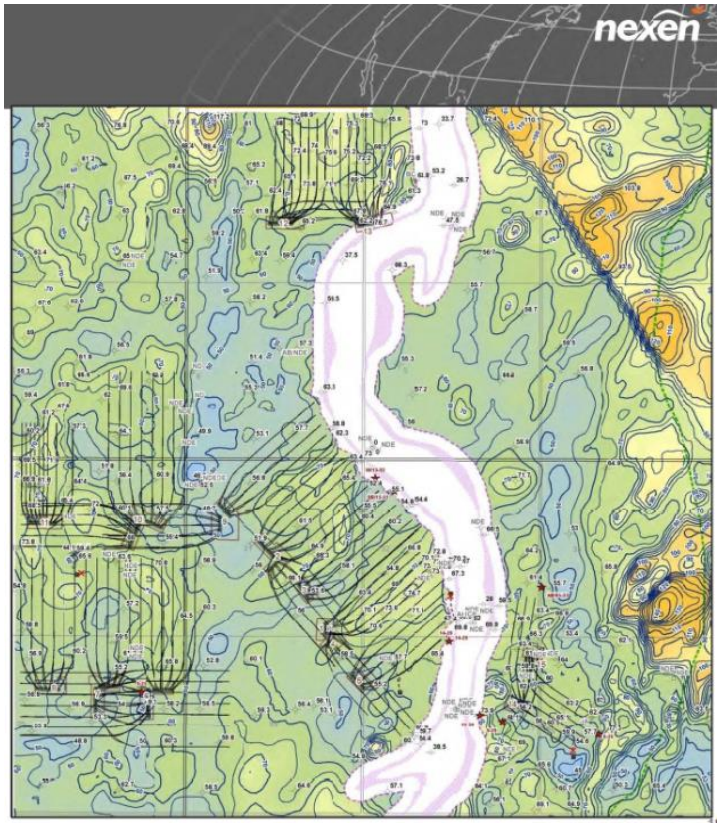


One Square Mile of SAGD Reservoir

SAGD Well Pairs

With optimal layout over 20 SAGD well pairs into a square mile.
Decided to conservatively use 15.





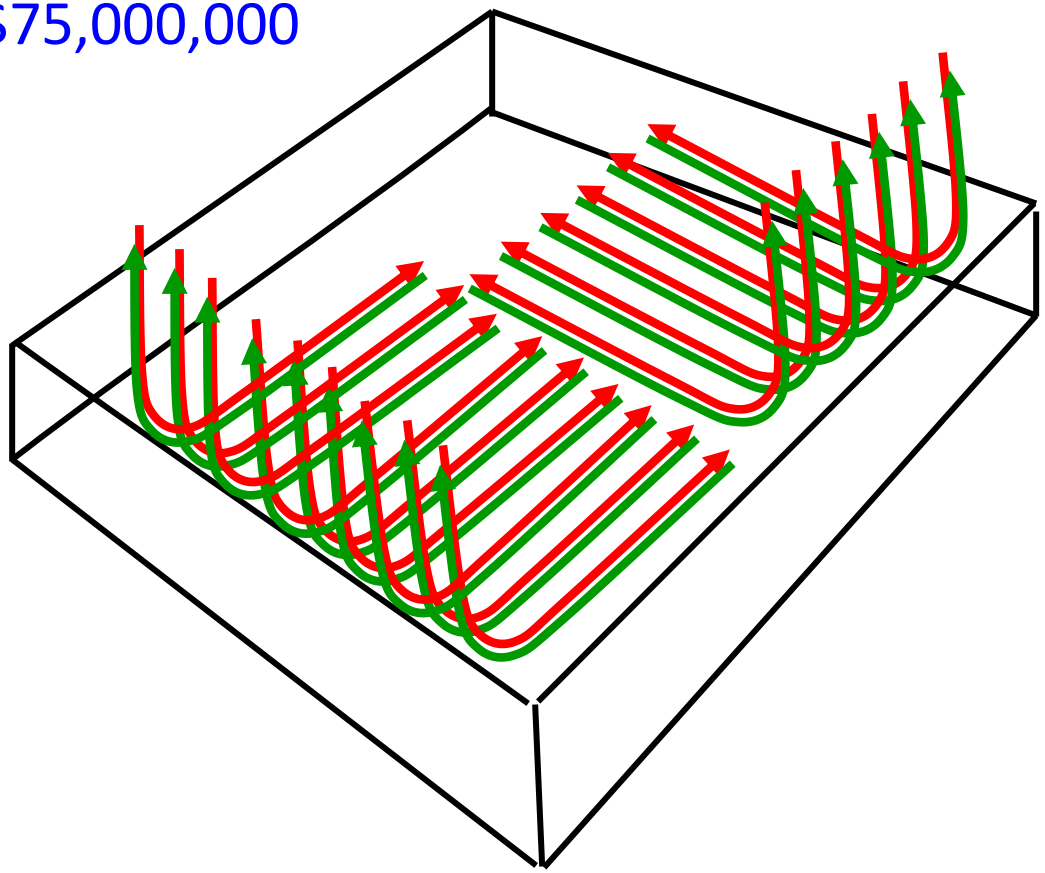
- 750m x (150m x7) = 787,500 m^2 per pad
- 1 mi^2 = 2,590,000 m^2
- Could fit 3.3 pads x7 = 23 well pairs

One Square Mile of SAGD Reservoir

SAGD Well Pairs

15 SAGD Well Pairs

@ $5 million each = $75,000,000



One Square Mile of SAGD Reservoir

Cost Tally So Far

One Square Mile	$ Cost
Vertical Strat Wells (x16)	8,000,000
SAGD Well Pairs (x15)	75,000,000
	83,000,000

High Density 3D Seismic for Reservoir Characterization

… However, demonstrated value of seismic in a SAGD setting was evolving…

I.D. shales for best SAGD pair placement

Continuous Improvements

Foster Creek & Christina Lake Areas

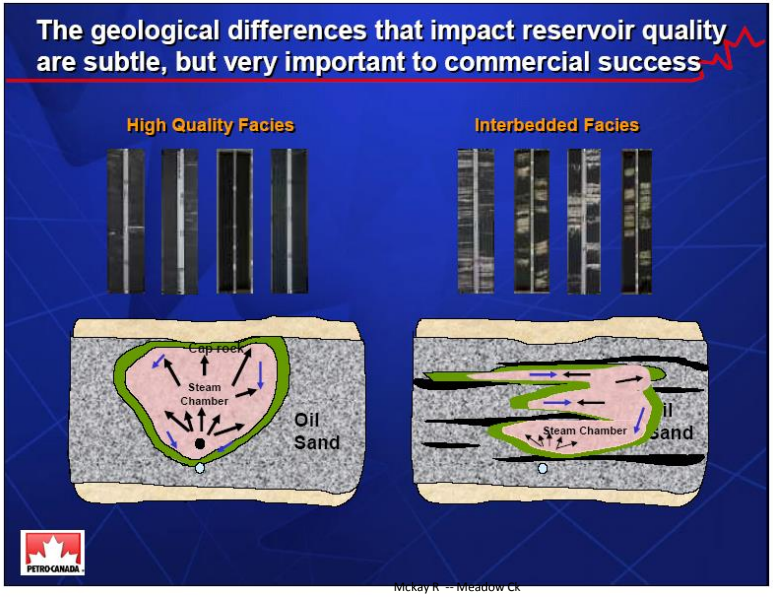
- Well performance
- Horizontal well trajectory control
- Steam injection distribution for improved well performance
- Increased seismic resolution for better well placement
- Environmental impact
- Sulphur recovery technology for low H_2S concentrations
- High salinity water usage for displacement for fresh water

TD Newcrest Oil Sands Forum 2004

ENCANA

Harbir Chhina
Vice-President, Oil Recovery Business Unit
July 7, 2004

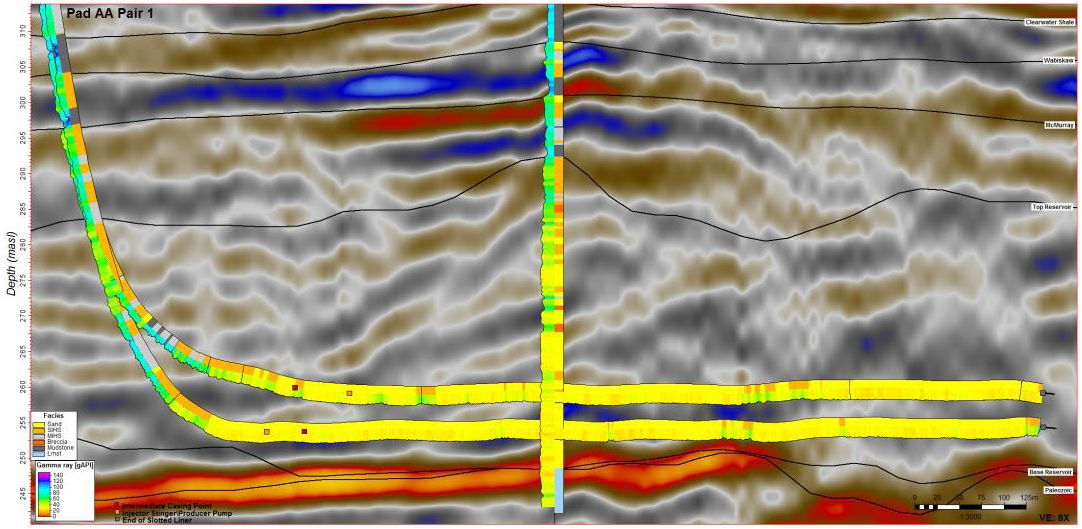
"Interbedded mudstone bits" prevent steam from efficiently steaming the entire chamber



T.D. Newcrest Oil Sands Forum 2004
Brant G. Sangster
Senior Vice President, Oil Sands
Calgary - July 7, 2004

High Density 3D Seismic for Reservoir Characterization

Regulator has expectations regarding how close the horizontal producer should be placed from the reservoir bottom.
Oil under the producer is unrecoverable (lost) oil.



- Map the reservoir bottom
  - lows, highs, water in the lows
  - place producer wells as close as possible above the base of the bitumen structure
- Avoid wet sections of reservoir

ATHABASCA OIL CORPORATION
PROJECT UPDATE FOR AER
December 2015

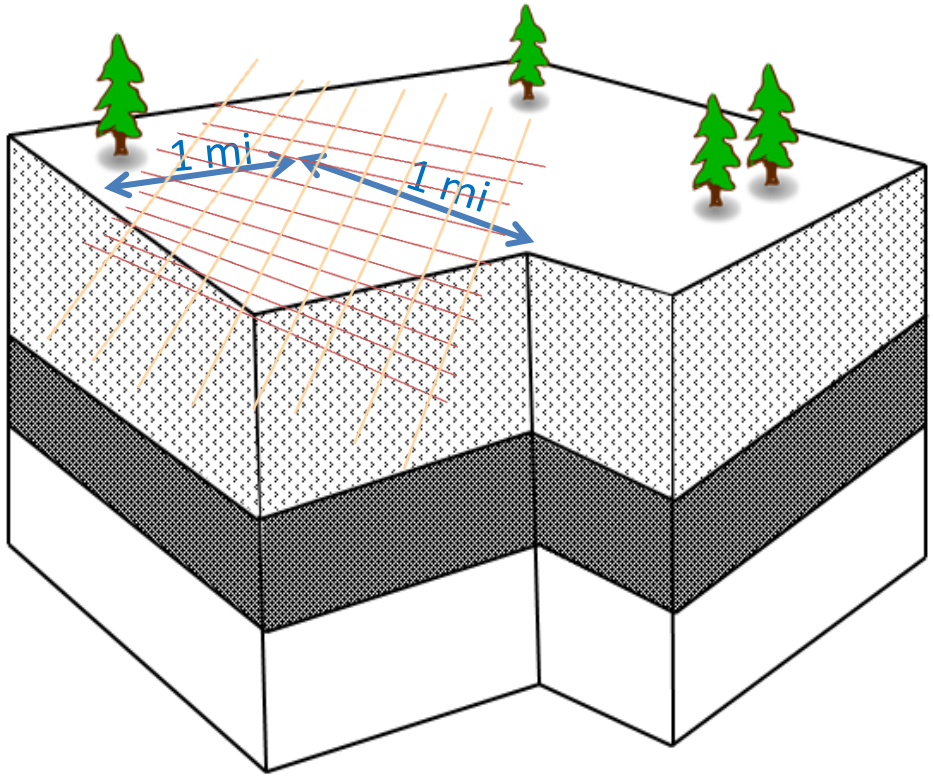
ATHABASCA OIL CORPORATION

High Density 3D Seismic for Reservoir Characterization

So now lets shoot some seismic!

- High density coverage
- Typical boreal forest
- Front-end planning, surveying, shot-hole drilling, recording, processing

One square mile of high density 3D Seismic = $1,000,000



Value Proposition #1

High Density 3D Seismic for Reservoir Characterization

One Square Mile	$ Cost
Vertical Strat Wells (x16)	8,000,000
SAGD Well Pairs (x15)	75,000,000
High Density 3D Seismic	1,000,000
Incremental Cost	**1,000,000**

One Square Mile of SAGD Reservoir
Well Production

B4.4 Production Forecast

A typical 750 m long Jackfish well production profile for a reservoir of 25 m thickness is shown in Table B3.

Table B3: Single Well Production Profile – Jackfish Project

Year	Oil Rate (m^3/d)	Oil Rate (bbls/d)	ISOR (m^3/m^3)	CSOR (m^3/m^3)	Cumulative Oil (Mbbl)	Cumulative Steam (Mbbl)
1	90	567	1.82	1.82	207	377
2	153	961	1.78	1.79	558	1 001
3	163	1 022	1.88	1.83	932	1 705
4	153	960	2.04	1.89	1 282	2 420
5	136	856	2.17	1.94	1 595	3 097
6	116	730	2.29	1.99	1 862	3 707
7	103	649	2.39	2.04	2 099	4 275
8	92	579	2.51	2.08	2 310	4 807
9	88	554	2.48	2.11	2 513	5 309
10	74	465	2.64	2.15	2 682	5 757
11	61	385	3.00	2.19	2 823	6 179
12	35	220	2.74	2.20	2 903	6 399
13	8	49	0.00	2.19	2 921	6 399

APPLICATION FOR APPROVAL OF THEDEVON JACKFISH PROJECT *VOLUME 1 – PROJECT DESCRIPTION*
Submitted to: **Alberta Energy and Utilities Board** *And* **Alberta Environment**
Submitted by: **Devon Canada Corporation, C**algary, Alberta November 2003

- Oil produced from a single well over its 13-year life: 2,921,000 Bbls
- For 15 producers over 13-year life: 43,815,000 Bbls
- At $50 per Bbl: $2,190,750,000

Value Proposition

High Density 3D Seismic for Reservoir Characterization

We can now begin to quantify our SAGD seismic value proposition

- Optimize the number of vertical stratigraphic wells
  - This will be minimal. Assume a reduction of 1 (from 16 wells to 15).
- Optimize SAGD well pair placement
  - into best pay
  - for most efficient steam chamber
  - avoid wet sections of reservoir
    - Assume the elimination of one SAGD pair out of the planned 15.
    - With better understanding of shale, mudstone, potential wet areas, etc. there is bound to be a specific location where a SAGD pair should be omitted.
- Place producer wells as close as possible above base of bitumen structure
  - Better imaging of the base of the structure & closer well steering to the base results in an estimated 0.1% increase in overall production
  - 0.1% x $2,190,750,000 = $2,190,750

Value Proposition #1

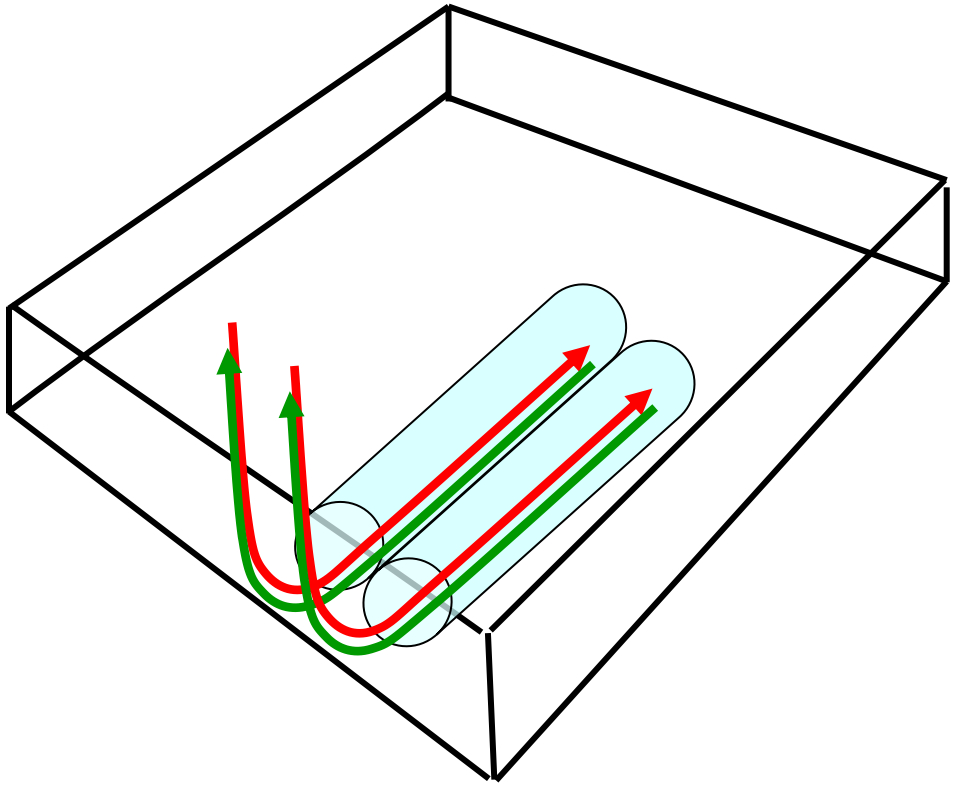
High Density 3D Seismic for Reservoir Characterization

One Square Mile	$ Cost	Benefit $	
Vertical Strat Wells (x16)	8,000,000	500,000	Reduce by 1 Strat Well
SAGD Well Pairs (x15)	75,000,000	5,000,000	Reduce by 1 Well Pair
Reserves below producer		2,191,000	Incremental Reserves
High Density 3D Seismic	1,000,000		
Incremental Cost	**1,000,000**	**7,691,000**	**Incremental Benefit**

One Square Mile of SAGD Reservoir
Steam Injection

Next Exercise

Estimate the cost of injecting steam over the life of this square mile of reservoir



One Square Mile of SAGD Reservoir
Steam Injection

A rule-of-thumb commonly used in the industry is that 1.0 Mcf of natural gas is required to produce a barrel of bitumen; however, gas requirements vary depending on the recovery technology, the quality of the reservoir, steam injection and bitumen production cycles, and the efficiency of the steam generation equipment. This rule-of-thumb is appropriate for most in situ recovery operations (i.e., dry steam-oil ratio or SOR of about 2.5), but is too low for less energy efficient operations. A typical SAGD project operates with an average SOR of about 2.5 dry (3.1 wet–wet is based upon 80 percent steam quality, which mean 20 percent of a barrel of steam is water the remaining 80 percent is steam) and would require 1.02 Mcf of natural gas per barrel of bitumen. A typical CSS project operates with an average SOR of about 3.5 wet (2.8 dry) and would require 1.14 Mcf per barrel. However, in situ projects typically use produced associated gas to meet part of the fuel requirements (15 percent is a common value for CSS while 1 percent is common for SAGD). Consequently, a value of 1.0 Mcf per barrel is an appropriate approximation of thermal recovery offsite natural gas requirements.

…purchased natural gas requirements are estimated at approximately 1 Mcf per barrel of bitumen produced

Canada's Oil Sands
Opportunities and Challenges to 2015:
An Update
An Energy Market Assessment
NEB JUNE 2006

Table 2.1
Natural Gas Requirements – 30,000 bbl / d Thermal In Situ Projects

Steam-Oil Ratio (SOR)		Fuel Requirements	
Wet (barrels per barrel)	Dry (barrels per barrel)	(MMcf/d)	(Mcf per barrel)
2.5	2.0	24.7	0.82
3.0	2.4	29.4	0.98
3.5	2.8	34.1	1.14
4.0	3.2	38.8	1.29
4.5	3.6	43.5	1.45
5.0	4.0	48.2	1.61
5.5	4.4	52.9	1.76
6.0	4.8	57.6	1.92

Table 2.1 is based on the following assumptions for a 30,000-barrel per day (4,800 m^3/d) thermal recovery in situ operation:

- steam generation using once through steam generators
- 175ºC boiler feed-water temperature

Canadian Energy Research Institute
Green Bitumen: The Role of Nuclear, Gasification, and CCS in Alberta's Oil Sands; Study No. 119, Part II - Oil Sands Supply Cost and Production
ISBN 1-896091-91-1
May 2008

One Square Mile of SAGD Reservoir

Steam Injection

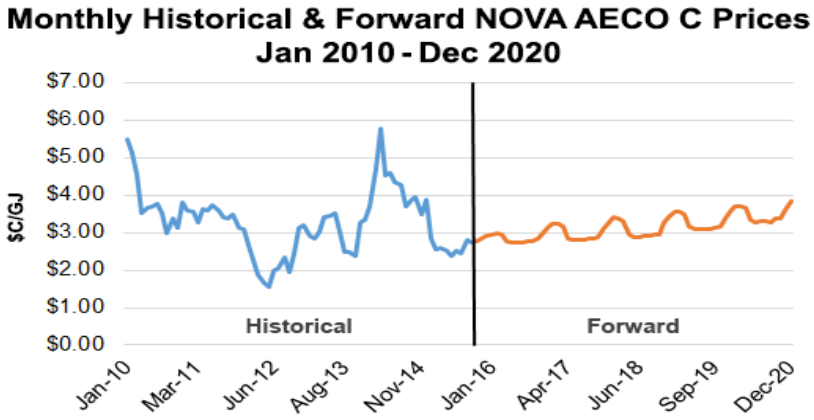
The pricing of natural gas in Alberta has been a wild ride.
Current average value of CAD$2.85/GJ.

$2.85/GJ x 1.05 GJ/mcf = $2.99/mcf

15 producers over 13-year life:
43,815,000 Bbls

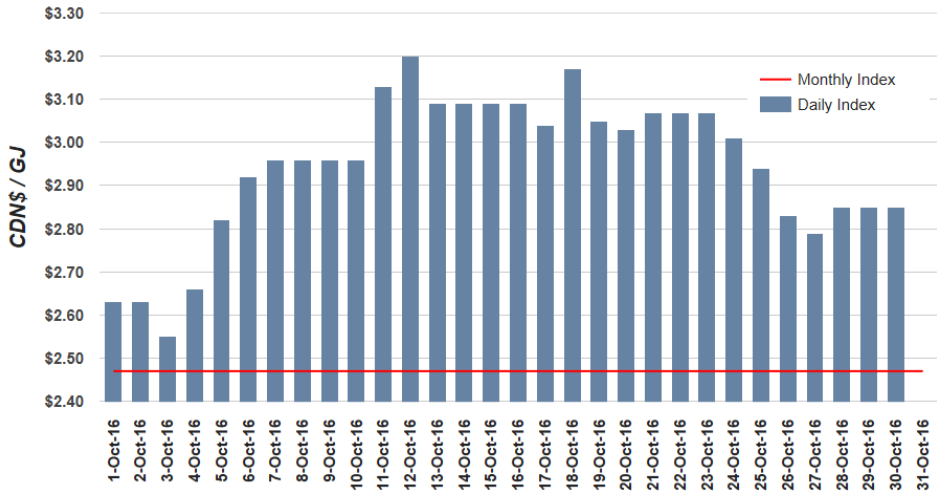
1 mcf per barrel of bitumen produced
= 43,815,000 mcf
x $2.99/mcf
= $131 million

It costs <u>$131m</u> to produce steam for <u>one sq. mile</u> for 13 years!



Note: Forward prices converted from $US/MMBtu to $C/GJ using a 1.055 MMBtu/GJ conversion factor and assuming a constant 1.3276 US/CAD exchange rate through 2020.

Source: NGI's Forward Look & Bidweek Survey, Natural Gas Intelligence calculations



Actual prices are based on a volume weighted average of transacted prices for all physically delivered natural gas at the Alberta AB-NIT market center (www.ngx.com).

One Square Mile of SAGD Reservoir

Steam Injection

Previous Slide:

It costs $131 million to produce steam for one sq. mile for 13 years!

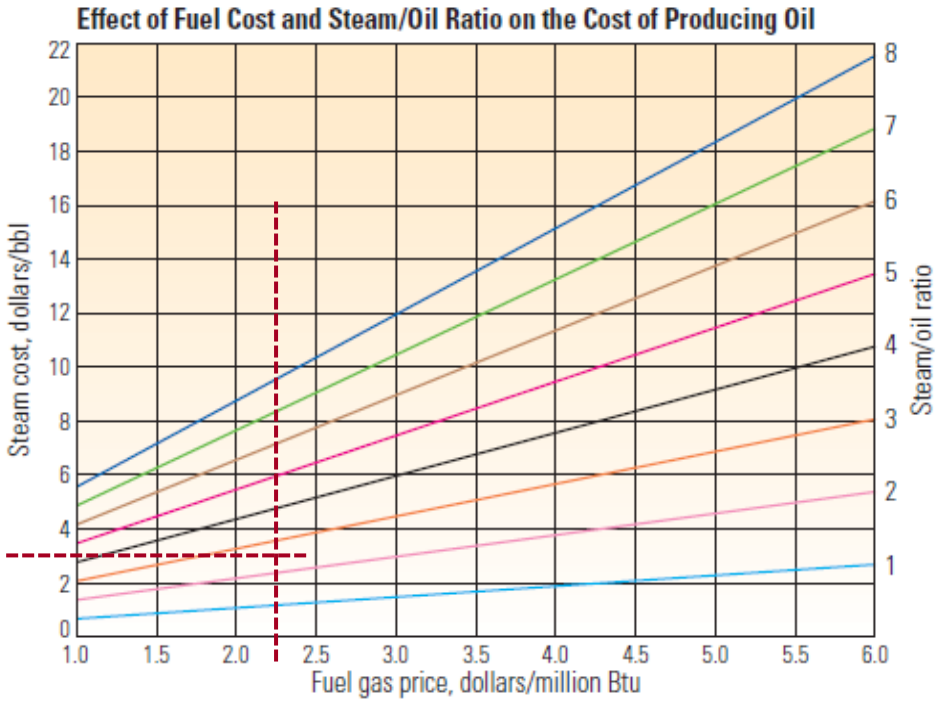
C$2.85 / GJ x GJ / 0.9478MMBtu x 0.75 USD / CAD

= USD$2.26/MMBtu

Steam Cost = USD$3.00/bbl

For 15 producers over 13-year life:
43,815,000 Bbls

= USD$131 million



^ How the cost of fuel and the steam/oil ratio (SOR) affect the cost of heavy-oil production. The SOR is defined as the number of cold-water-equivalent (CWE) barrels of steam required to produce one barrel of oil. Its value is determined by the reservoir and the efficiency of the steam-application process. The intersection of the fuel price (gas, in the case of California) and the SOR (colored lines) determines the cost of steam per barrel of oil produced. Operators can use this chart to determine the maximum fuel price for which production remains profitable.

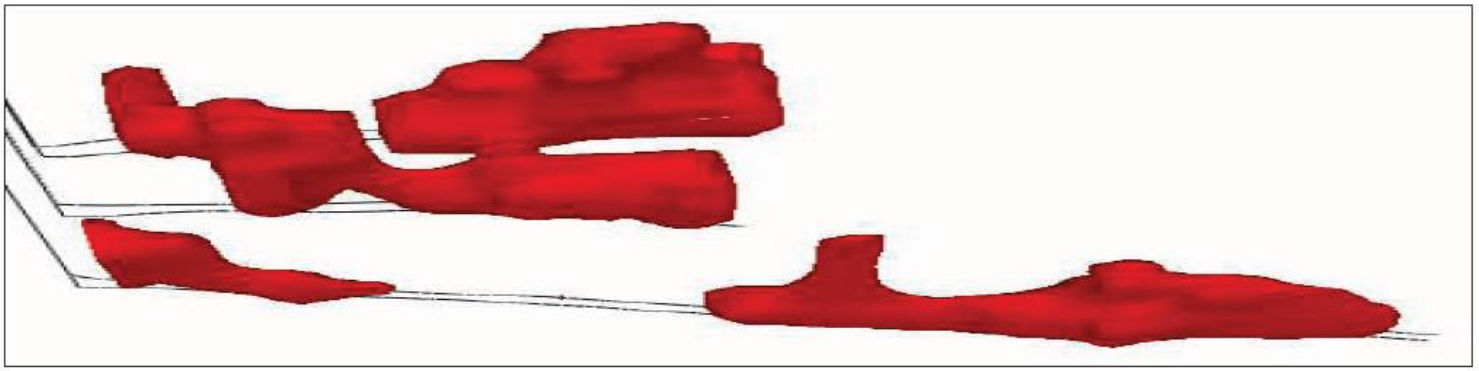
Oilfield Review Autumn 2002

Value Proposition #2

High Density 3D/4D Seismic for Steam Monitoring

INOVA

The Dog Bone Pattern



Statoil

Value Proposition #2

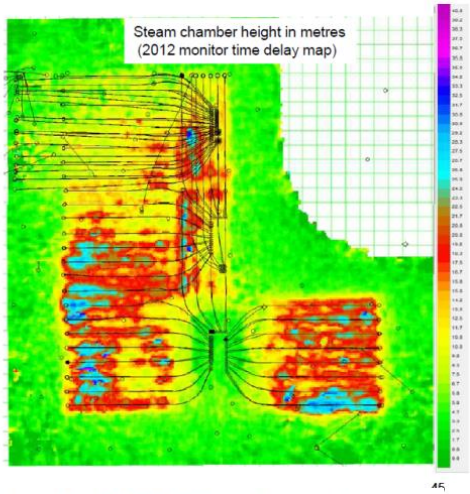
High Density 3D/4D Seismic for Steam Monitoring

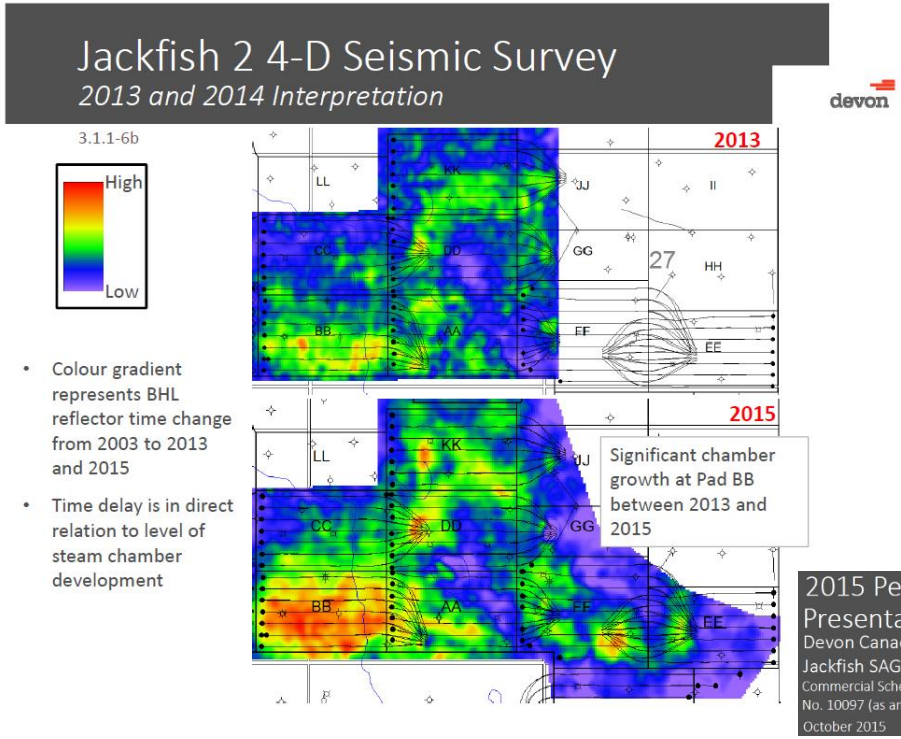
4D Seismic Data

Advancements in 4D

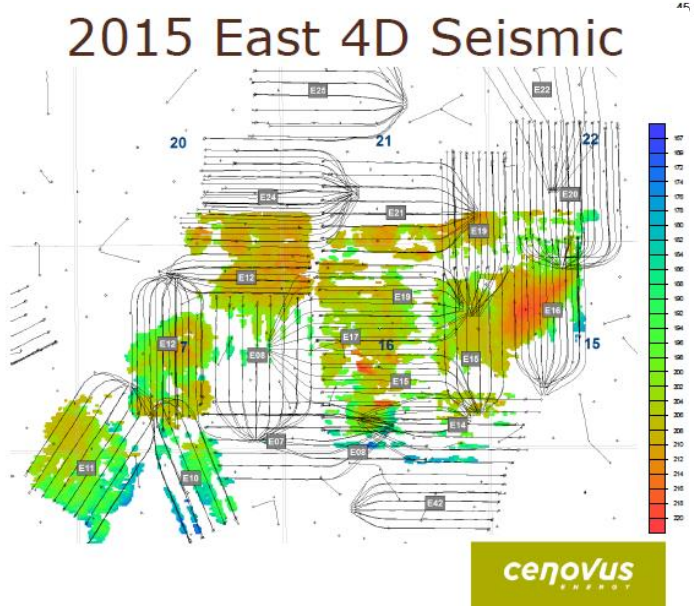
In Situ Performance Presentations on Alberta Energy Regulator's website (and read Directive 054)

- 4D seismic covers approximately an area of 8 km^2
- 2005/2007 3D surveys constitute the baseline to be compared with the 2010 and 2012 Monitors
- Steam conformance varies across the field
- The 2012 Monitor shows steam chamber height of 10-25m





- Colour gradient represents BHL reflector time change from 2003 to 2013 and 2015
- Time delay is in direct relation to level of steam chamber development



Value Proposition #2
High Density 3D/4D Seismic for Steam Monitoring

- 3D/4D Time Lapse Seismic
  - Assume a 4D recorded annually for 10 years
  - Assume $700,000 per sq. mile per year
    - Existing cut lines will be re-used, etc.
      - 4D Cost: $700,000 per sq. mile
        x10 years = $7,000,000
  - Assume steam injection design and operations will be altered based on this extra information
    - Resulting in efficiencies that optimize steam costs by 6%
      - Steam Cost: 6% Decrease
        $131 million of steam costs x 6% = $7,860,000
    - Resulting in efficiencies that enhance oil production by 3%
      - Oil Revenue: 3% Increase
        $2,191,000,000 x 3% = $65,730,000

Value Propositions #1 & #2

High Density 3D/4D Seismic for Steam Monitoring

One Square Mile	$ Cost	Benefit $	
Vertical Strat Wells (x16)	8,000,000	500,000	Reduce by 1 Strat Well
SAGD Well Pairs (x15)	75,000,000	5,000,000	Reduce by 1 Well Pair
Reserves below producer		2,191,000	Incremental Reserves
High Density 3D Seismic	1,000,000		
Value Prop #1 Incremental Cost	**1,000,000**	**7,691,000**	**Incremental Benefit**

One Square Mile	$ Cost	Benefit $	
3D/4D Seismic (8 years)	7,000,000		
Steam Injection (13 years)	131,000,000	7,860,000	Reduced Cost of Steam
Oil Revenue (13 years)		65,730,000	Incremental Recovery
Value Prop #2 Incremental Cost	**7,000,000**	**73,590,000**	**Incremental Benefit**
#1 & #2 Total Incremental Cost	**8,000,000**	**81,300,000**	**Incremental Benefit**

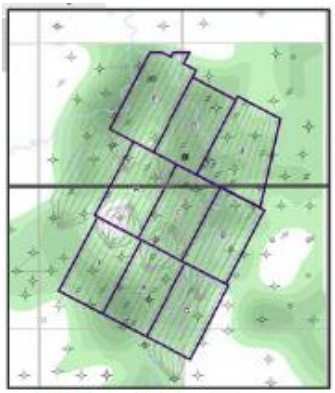
Value Proposition #1 & #2

Total Project Benefit

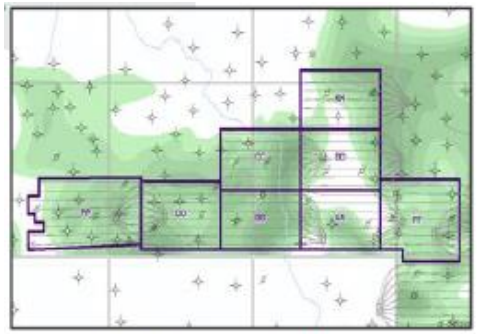
Estimated “project size” of 5 square miles, based on the net steamable pay areas >18m at Devon’s Jackfish 1,2 & 3 as shown below.

One Square Mile	$ Cost	Benefit $	
Total Incremental Cost	**8,000,000**	**81,300,000**	**Incremental Benefit**

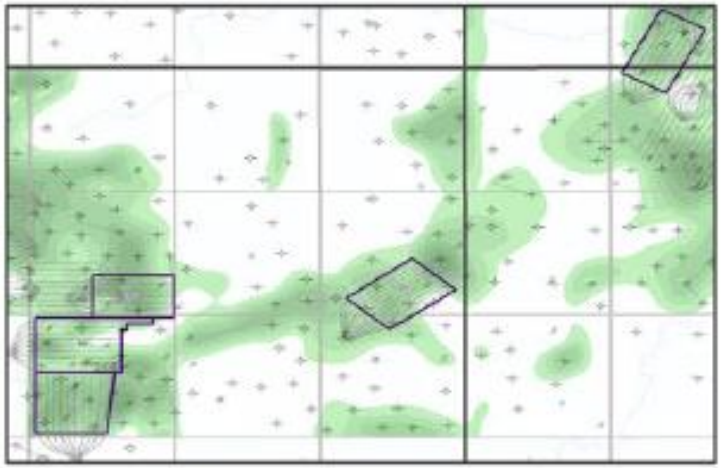
Project Area 5 Square Miles	$ Cost	Benefit $	
Total Incremental Cost	**40,000,000**	**406,000,000**	**Incremental Benefit**



Net Steamable Pay >18m



Net Steamable Pay >18m



Net Steamable Pay >18m

Net Steamable Pay

- Cumulative pay that exists within the steamable interval and contributes to OBIP
- Phi>25%; So>50%; Vsh <30%

SAGD Seismic Value Proposition
Conclusion

Project Area 4.6 Square Miles	$ Cost	Benefit $	
Total Incremental Cost	40,000,000	406,000,000	Incremental Benefit

Model and its results above do not take into account certain other areas of seismic value

Alberta Energy Regulator
Draft Directive – Reservoir Containment

DRAFT Directive : Reservoir Containment Requirements for Steam-Assisted Gravity Drainage Projects in the Shallow Thermal Area of the Athabasca Oil Sands Area
Released: Oct 13, 2015
Feedback accepted until Dec 31, 2015

8 Information Requirements

8) Applications for SAGD projects in the shallow thermal area must contain the information outlined in the rest of this section:

8.1 Geology
All isopach, structure, and depth maps must incorporate three-dimensional (3-D) seismic or other demonstrated equivalent imaging data…

Geoscientist Value Proposition

What is a "Value Proposition" ?

A business or marketing statement that a geoscientist uses to summarize why a customer should use a service.

The ideal value proposition is concise, and it appeals to a customer's strongest decision-making drivers.

Investopedia

What is a "Value Model" ?

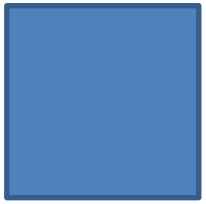
A data-driven representation of the worth, in monetary terms, of what a geoscientist is doing or could do for its customers.

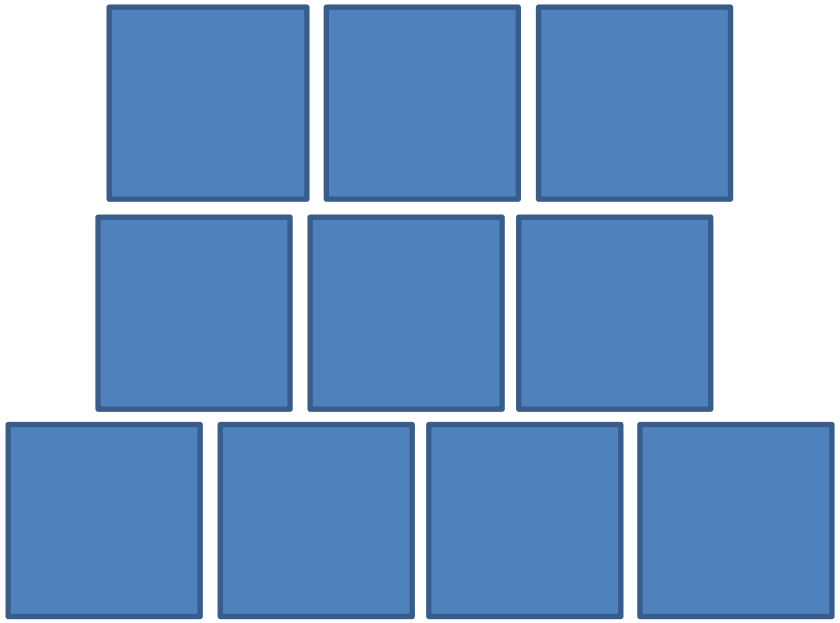
Wikipedia

SAGD Seismic Value Proposition
Conclusion

So, Mr. or Ms. Smarty-pants Geoscientist, what value can you bring to a heavy oil SAGD project?

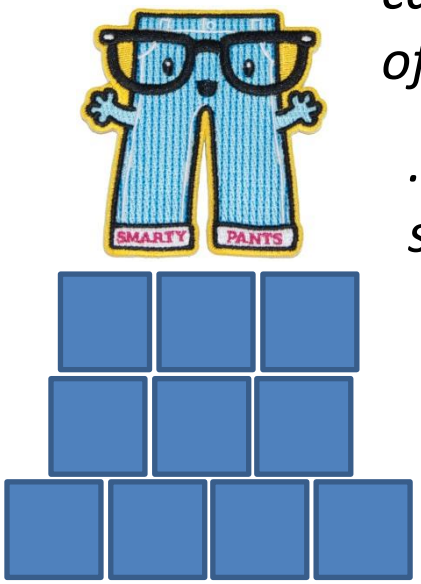
Well, our team estimates that, by reducing drilling costs, recovering incremental reserves, and optimizing steam costs, investing in seismic can produce a ten-fold return in revenue.





SAGD Seismic Value Proposition
Conclusion

And if you have another 30 seconds, let me give you some detail on that 10-fold return on seismic investment…



For a typical project, by investing $40 million in seismic, we can assist in operating decisions that will add $406 million of value. *(8 seconds)*

…We're going to inject over $650 million of steam, and our seismic is getting pretty damned good at monitoring it!

(7 seconds)

… And we're going to produce about 200 million barrels of bitumen. We believe we can enhance that by at least 3%. That's an additional 6 million barrels! *(9 seconds)*

…AND, not even included in that 10-fold return, did I mention how seismic is necessary to assess cap rock integrity? *(6 seconds)*

INOVA

TOGETHER, WE GET THE JOB DONE.

Thank you for your interest.

I invite you to use this information to stimulate some lively discussions.