Mapping Unconventional Resource Industry in the Cardium Play Region

Cardium Tight Oil Play Backgrounder Report

May 1, 2014

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Prepared For:

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Executive Summary

The Cardium oil fields of the Western Canada Sedimentary Basin represent one of the largest conventional light/medium oil deposits in the country. Pools found in this formation have been producing oil since the early 1950's mainly from the large Pembina Cardium oil pool surrounding Drayton Valley, Alberta. Other conventional Cardium oil pools are found in western Alberta, with similar characteristics to the Pembina Cardium, and have been producing almost as long.

Historically Cardium oil well drilling has occurred in the Alberta Counties of: Brazeau, Clearwater, Mountain View and Yellowhead, with much smaller amounts of development along the western edges of bordering municipalities, stretching from the M.D. of Greenview in the north to Red Deer in the south. The original oil production was mainly through vertical wells drilled into the 1-3 m thick Cardium formations, mainly in areas where there were extensive gravel beds, or "conglomerates", within the sandstone formation which allowed oil to drain to the producing wells. The location of these types of conventional oil reservoirs are generally found in the central portions of the formation, shown as bright orange in Figure 1 below. This oilfield development has been a major factor in the growth of a number of communities in the region, including Drayton Valley, Edson, and Sylvan Lake, and has been supported by local oilfield service firms and entrepreneurs, as well as other service providers located in Edmonton, Nisku, Red Deer and Calgary.

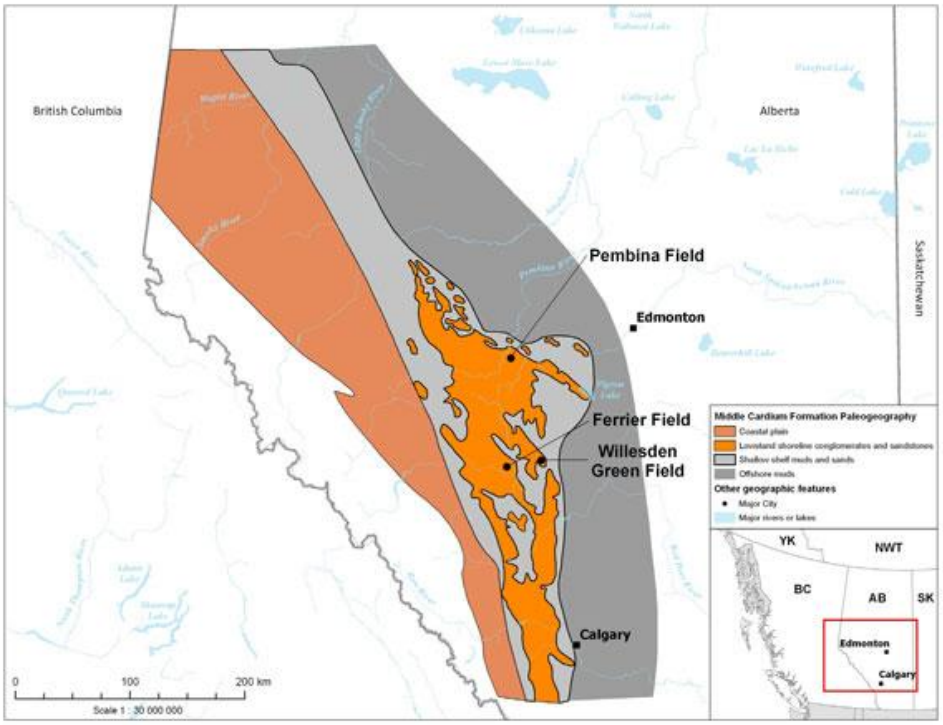


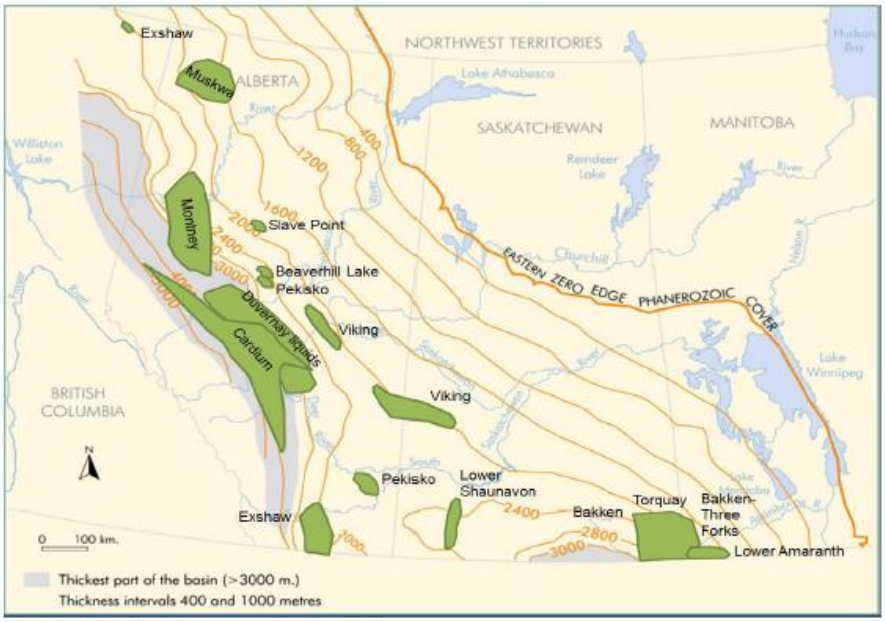
Figure 1 – The Cardium Formation in Western Alberta showing the Main Extent of Cardium Field Areas (Source: www.neb-one.gc.ca)

These pools have been in a general production decline for decades, even though the total recovery of the original conventional oil resource has been limited to about 18-20%, through primary production and extensive water flooding. The introduction of horizontal, multistage hydraulic fracturing technologies in 2009, has caused a major revival of activity in this region by facilitating the production of "unconventional", or "tight oil", resources found in lower quality portions of the Cardium formation surrounding the main conventional pools.

The purpose of this backgrounder report, is to map out the oil production history of the region, discuss potential business opportunities associated with the new technologies, and address how a focus on industry collaboration could enhance the benefits of these new developments for all stakeholders.

Historic Perspective of the Cardium Play Region

Geology – A number of tight oil formations are found in the Western Canada Sedimentary Basin, and most have seen production in the past at relatively low rates and low recoveries, while others are just recently attracting attention for potential development with horizontal multi-stage fracturing techniques. Generally these oil deposits were known to exist but large areas of the formations were considered to be uneconomic with conventional vertical wells.



Source: Modified from University of Regina map

Figure 2 – Map of Shale/Tight Oil Formations in Western Canada (from NEB Energy Briefing Note)

"Tight" Oil Formations - The oil industry uses this term for a wide range of formations which produce at very low oil rates. These formations were known to contain large volumes of oil but are generally termed "tight" denoting low "permeability", or a low ability for fluids to flow through the rock. Some formations, like the Cardium, may not have contained much organic matter when they were formed, but now contain hydrocarbons, which have migrated into them from deeper shale formations. As an example, "tight oil" formations can be sandstones originally formed as beaches or estuaries with relatively little organic matter but later sealed with caprock, and thus becoming low permeability traps, which captured hydrocarbons seeping upwards from lower source rocks.

Deposit Type – The Cardium formation consists of tight inter-bedded sandstone and shale layers and is found in much of west central Alberta. The formation depth is between 1,200 to 2,300 m and the average oil pay thickness is up to 1-3 m. Some higher quality parts of the formation in the Pembina Oil Field (one of Canada's largest oil fields) have higher porosity beds of sands and gravel conglomerates, which have already seen production. Poorer quality formations are the main tight formations.

Hydrocarbon Potential – Original conventional Cardium oil fields contained 1,700 million m^3 (10.6 billion bbls)[1] of light oil, or about 16% of all of the conventional oil resources found in Alberta, with 20% reported as reserves under primary and waterflood recovery. The lower quality fringes, or "halos" around the main pools, currently being developed, may contain an additional

[1] All volumes contained in this report are sources from Alberta Energy Regulator data or sources unless otherwise indicated.

160-480 million m^3 (1-3 billion bbls), although estimates vary and so far only 21 million m^3 (130 million bbls), or 5-10% of the original oil in place, have been claimed as proved and probable reserves which might be technically and economically produced. As of the end of 2013, over 12 million m^3 of these potential reserves had already been produced.

Geography – The area overlying these formations is mainly boreal forests although some agricultural development has occurred in the eastern portions. Some parts of the region are sensitive for caribou and grizzly bear. The deeper Duvernay shale formation underlies much of the Cardium, but much less is known about it, and the portions underlying the Cardium appear to be more prone to gas and are less attractive at current gas prices.

Drilling and Completions - Drilling for oil in the Cardium formations began a few years after the discovery of the Leduc oil field in 1947, with the first six oil producing wells being drilled in 1953. Over the next decade drilling in the Cardium boomed with over 2,700 wells drilled, peaking with almost 475 wells completed in 1956. Activity dropped until the mid-1980s when higher oil prices led to a mini-boom of infill vertical well drilling, and another mini-boom of directionally drilled infill wells, between 2002 and 2004, in the main Cardium pool areas. Starting in 2009, horizontal drilling combined with multi-stage hydraulic fracturing technology began to be applied in the Cardium formations. Most of these latest wells have been drilled in "halos" of wells, in "tighter" portions of the Cardium around the main conventional pools, with activity peaking at ~700 wells in 2011 and 2012. Many of the halos extended outside of the four main municipalities, which had previously seen most of the development. In 2013, new well drilling dropped off, likely due to a number of factors, which might include:

- **Infrastructure Limits** – Primarily limited oil pipeline capacity from the area as production hit the maximum production achieved in the 1950s and 1960s.
- **Lower Quality Reservoir** – As the halo expands from the conventional pools, reservoir quality drops off resulting in lower economic incentives, since well costs are still high.
- **Some Producers Over-extended** – Some producers were drilling wells quickly to grow production but became limited by cash flow and had to slow down.

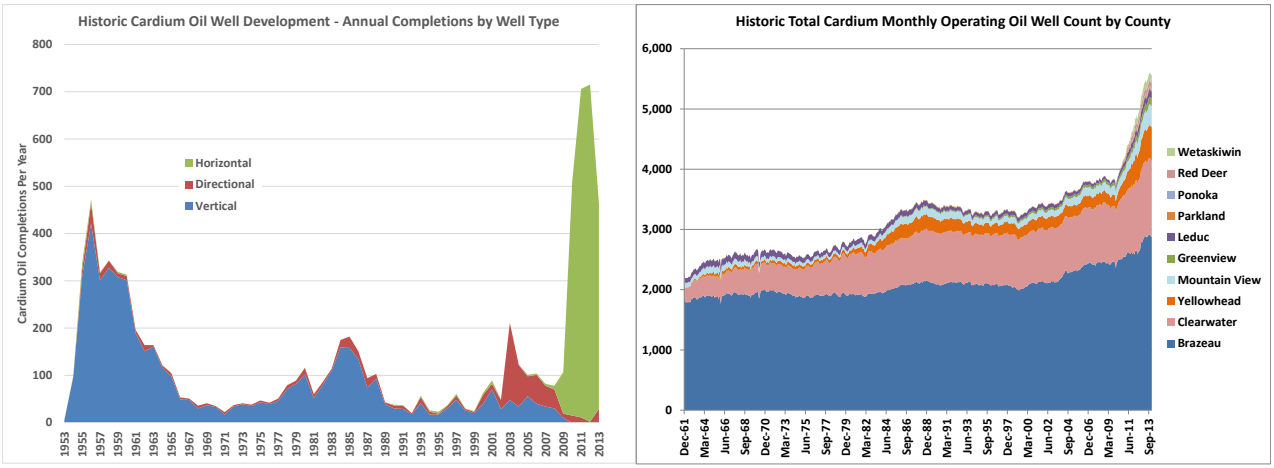


Figure 3 – a) Historic Cardium Oil Well Drilling Activity by Type of Well and b) Operating Cardium Wells by Municipality

Of the 8,500 Cardium oil well completions done between 1953 and 2013, almost 5,500 are still producing oil. Many of the wells that are no longer producing have been recompleted as water injection wells for water floods, and a number were re-entered and re-drilled in the 1990s to access undepleted portions of the main reservoir areas.

Conventional Oil Production from the Cardium and Other Formation – In most of the Cardium formations the oil is produced primary through "solution gas drive" followed very closely, by "water flooding". The solution gas drive mechanism relies on reducing the pressure in the formation so that natural gas can be released from the oil and displace the oil from the rock. Generally this type of process can achieve 5-10% recovery of the original oil in place, where there is no natural water flow into a formation. Much of the Cardium has no or very low water flow into the reservoir to take the place of the produced oil, so production was limited as the oil

cannot be pumped out if there is nothing to replace it. As a result, water injection was started in the main conventional Cardium pools and injected water began to displace the oil and to provide pressure to drive more oil to the producing wells, through the high permeability conglomerate channels. In the main Cardium pools most of the conventional reservoir areas have been subjected to water flooding, achieving overall oil recoveries in the range of 18-20% of the oil in place. These conventional production methods have been used in many oil fields around the world for many decades and are well understood. Water flooding continues to be economic in many of the older vertical wells even with very low production rates. Often water flooding is followed by some type of Enhanced Oil Recovery (EOR), where some type of gas or solvent, like methane, ethane/propane or carbon dioxide is injected to further assist oil flow from the formations. Piloting of CO_2 EOR was started in the Pembina Cardium in 2003-2007, and this type of EOR is anticipated to be capable of increase oil recovery by another 10-15%. However, the move to more economic "unconventional" horizontal, multi-stage fracturing, and a shortage of CO_2 supplies in the region, diverted producer efforts from EOR.

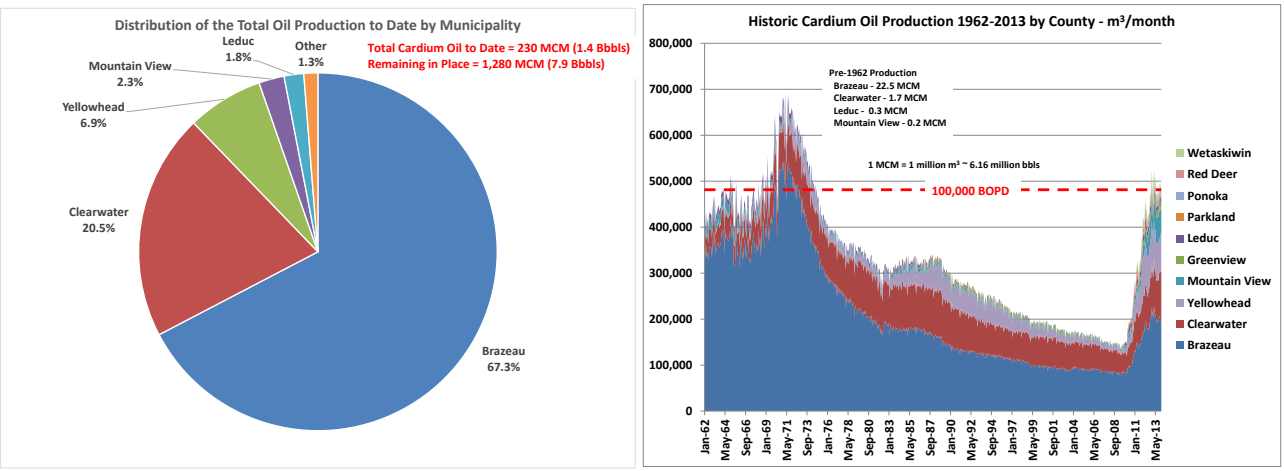


Figure 4 – a) Total Oil Production To Date from Cardium Wells by Municipality, and b) Historic Rate of Cardium Oil Production Showing an Initial Peak with Production from Vertical Wells and the Resurgence with Horizontal, Multi-stage Fractured Wells

Current Perspective on Cardium Oil Development

Unconventional Tight Oil Production from Cardium – Within the Cardium formation there are areas of the reservoir which lack the highly permeable conglomerate zones, or where there are tight zones above or below the conglomerates which are not connected to the flow system leading to a producing vertical well. While these zones contain considerable amounts of light oil, they did not allow for commercial rates of production with vertical wells, which only came in contact with about 3 m of oil producing rock. With 1-2 km long horizontal wells within the formation, and a series of fracture stages to connect the horizontal wells to various layers in the formation, the area of contact with the oil reservoir can be increased by 100,000s of times and result in economic oil production rates, even in relatively poor reservoir rock. While the horizontal wells and multi-stage fracture completions are more expensive than non-fractured vertical wells, they generate a higher initial rate of oil production than even the best vertical wells. In addition, eight or more horizontal wells can be drilled from the same surface location which simplifies tie-ins and minimizes the cost and environmental impact of having to build more roads, pipelines and well pads.

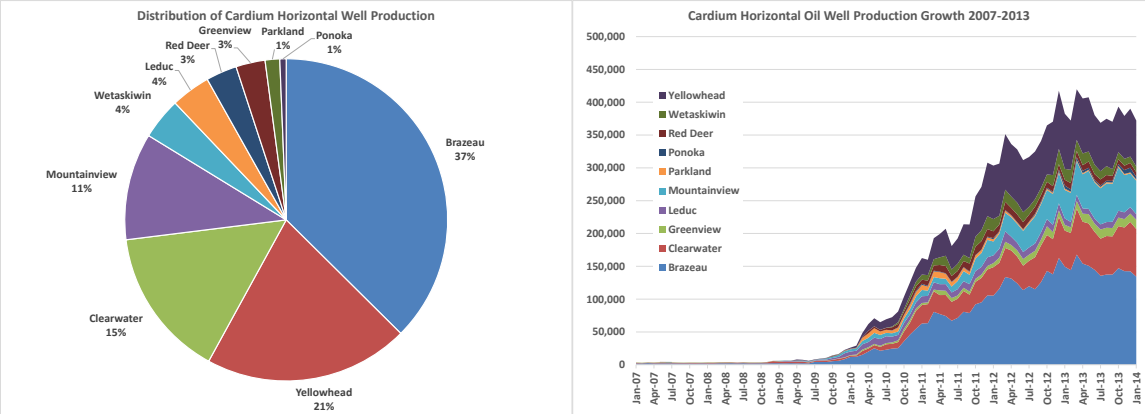


Figure 5 – a) Distribution of Cardium Horizontal Well Oil Production to Date by Municipality, and b) Monthly Horizontal Well Production by Municipality (m^3/month) 370,000 m3/month or 76,000 bopd

Unconventional Tight Oil Well Production Characteristics – While many of the original 1950s Cardium vertical wells are still producing, they initially produced at much higher rates when they were first drilled, and showed relatively rapid production declines until the conventional oil fields started receiving water injection to maintain the reservoir pressures and help to sweep oil from remote parts of the reservoir to the producing wells. The new horizontal and fractured wells produce at even higher initial production rates, but the flowrate also declines rapidly, as the initial reservoir pressure is depleted and as oil has to flow over longer distances through much smaller pores to reach the oil production wells. Since 2009, almost all wells drilled into the Cardium have been horizontal wells, but not all the wells have been drilled and completed exactly the same way and the reservoir characteristics vary over the formation, so every operator drilling wells goes through a "learning curve" to determine the best method of completing wells in different areas. The charts below show how the average well production has changed over time, with the main change being higher initial production rates. The cumulative production plots show that on average almost 75% of the primary well production is produced in the first 12 months, but it is too early to determine what the ultimate production will be from the various groups of wells as most continue to produce at lower rates for some time, and the more recent wells have only seen a few months of full production.

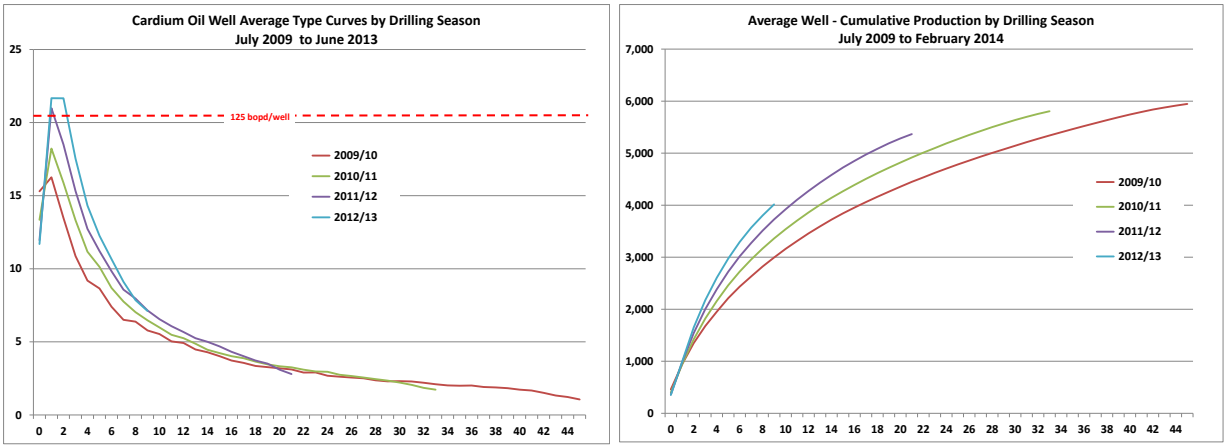


Figure 6 – a) Cardium Horizontal Fractured Well Type Curves, and b) Average Cumulative Horizontal Well Production by Drilling Season. (Includes data from all field areas and municipalities)

Solution Gas Production – Generally the natural gas produced from the Cardium formation is mainly solution gas that evolves from the oil as it is produced or as the reservoir is depressurized. But this natural gas still represents a significant resource which could be over 150 billion m^3 of gas in place. Generally, production of solution gas will be impacted by the oil reservoir conditions, and greatly impacted by the oil production drive mechanism, which affects the timing and extent of solution gas and associated gas production. In some cases, the percentage of raw solution gas produced will be greater than the percentage of oil production. With increased oil production through horizontal well additions and later potential enhanced

recovery there may be potential to produce another 10-15 billion m^3 of solution gas for sale. Currently, the horizontal Cardium oil wells are producing over 250 million m^3 of gas per month or about 300 million cubic feet per day with gas to oil ratios varying from as low as 150 m^3 of gas/m^3 of oil to as high as over 1,100 m^3/m^3 in the Clearwater and Greenview municipalities which are closer to the mountains and tend to be deeper. With production reported in barrels of oil equivalent these gas oil ratios add an average of about 0.56 boe to each bbl of oil production.

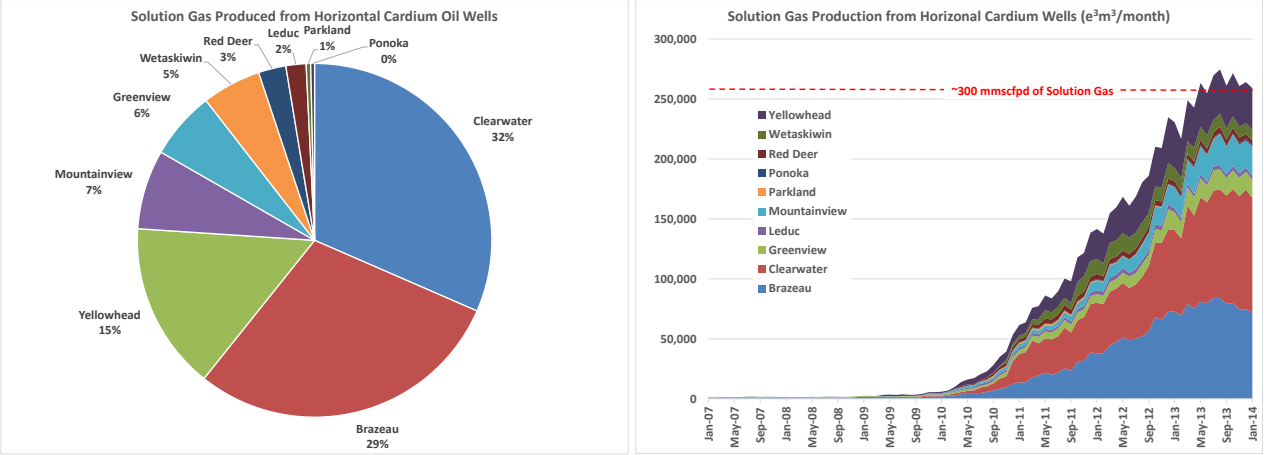


Figure 7 - a) Distribution of Cardium Horizontal Well Solution Gas Production to Date by Municipality, and b) Monthly Horizontal Well Production by Municipality (Thousands of m^3/month)

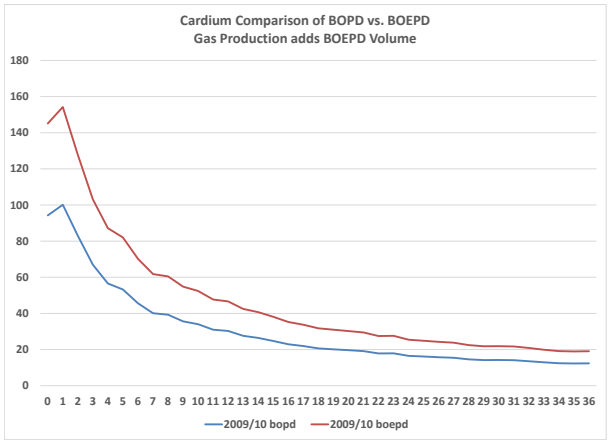
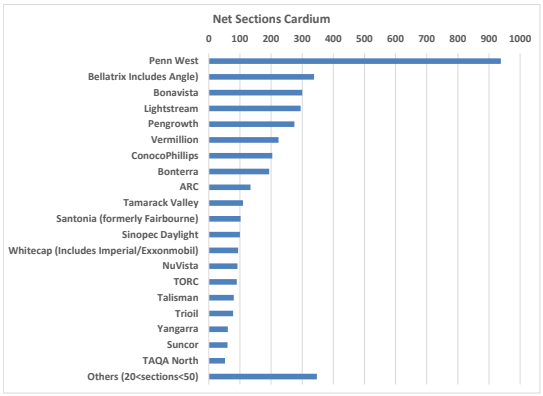
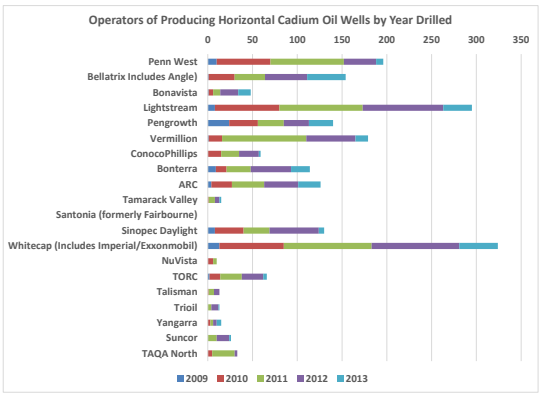


Figure 8 – Impact of Solution Gas on Oil Volumes Reported based on 2009/10 Type Curve

Current Operators – The largest two operators in the main conventional Pembina Cardium oil pool are Penn West and ARC Resources. However, the aerially more extensive tight oil formations, which form halos around the conventional pools, created opportunities for other oil and gas companies to obtain crown leases which were not suitable for conventional oil production. Penn West still holds the most sections of land in the Cardium area, but much of this is in the conventional portion of the formation. Others companies like Lightstream, Whitecap and Vermillion are more generally located in tight Cardium areas and have focused on drilling a large number of wells over the last five years. The lower number of wells drilled in the 2013 timeframe is due to both a reduction in drilling activity and also due to some of the drilled wells are still awaiting tie-in to allow production.





Figures 9 and 10– Status of All Wells and Current Operators

Hydraulic Fracturing in the Cardium – Hydraulic fracturing of horizontal wells has been utilized to open up many different types of formations in North America, and other parts of the world. These formations range from the relatively thin and shallow Viking formation found in east central Alberta, to deep and thick shale formations like the Duvernay. While the basic technology is the same, how it is applied and the resources required for each formation can be quite different, even if the same number of wells are drilled from a pad. For the Cardium formation, the producers have tried a variety of fracturing methods and carrier fluids with different impacts and results. Since January 2013, data on well completion methods, carrier fluids, and chemicals used by producers, have been required to be reported to the Alberta Energy Regulator, under Directive 059 *Well Drilling and Completions Data Filing Requirements*, with much of the basic information provided for public access through the website www.fracfocus.ca. Since these data are the most recent and complete available, they can provide information on what methods are currently being used by producers, as follows:

- The main components used are:
    - **Carrier Fluid –** In most Cardium completions water is used as the main fracturing fluid, although oil, diesel, nitrogen or other gases might be used. The water used varies with the number of fracture stages, the length of the well and the amount of other components (mainly nitrogen or sand) used.
    - **Energizing Fluid –** Often nitrogen or some other gas is used to generate a foam or to help clean out the fractures when they start production to encourage oil flow. The amount of nitrogen used can vary from none to nitrogen being be the main carrier fluid if it is in liquid form.
    - **Proppant –** It is needed to hold open the small fractures formed in the rock and, in the Cardium, the proppant is usually simply 20/40 or 40/70 mesh quartz sand.
    - **Other Chemicals –** Generally less than 0.5% of the fracture treatment mass is composed of a range of widely available chemicals, which are used to control bacteria, inhibit clay swelling in the formation, or change the properties of the carrier fluid to improve its performance.
- The main types of fracture treatments used in the Cardium are:
    - **Slickwater Fracture (<10% nitrogen) –** The majority (almost 75% of the 200 well sample analyzed) of the Cardium wells were completed using this method. Water use per well ranges from about 1,500-4,300 m^3/well, or about 50-250 m^3/fracture stage and an average water use per well of 2,600 m^3 water per well with an average of 4% nitrogen and 17% proppant. The average number of fracture stages per well was ~17. On a mass basis:
        - Water ~2,600 tonnes/well
        - Sand ~500 tonnes/well
        - Nitrogen ~120 tonnes/well

- **Nitrogen Energized (10 to 80% nitrogen) –** From the same analysis, approximately 25% of the 200 wells used larger volumes of nitrogen and required less water, with between 250-600 m^3 water used per well, or about 15-75 m^3/fracture stage and an average water use per well of 500 m^3 water per well with an average of 22% nitrogen and 31% proppant. The average number of fracture stages per well was ~18. On a mass basis;
    - Water ~500 tonnes/well
    - Sand ~350 tonnes/well
    - Nitrogen ~250 tonnes/well
- **Oil Carrier Fluid** – In the early years (2009-2011) many of the horizontal Cardium wells drilled were fractured with oil[2], in recent years the trend has shifted to slick water and nitrogen energized fracturing, with only a few wells being fractured with oil based carrier fluid.

- Distribution of hydraulic fracturing stages in the Cardium region is shown in the chart below:

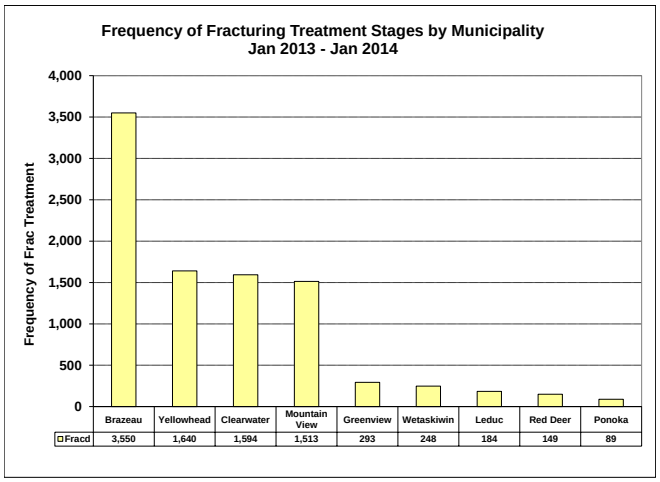


Figure 11 Distribution of Hydraulic Fracturing Treatment Stages by Municipality over the Last Year

Economics of Cardium Production – The economics of Cardium developments are extremely sensitive to the capital costs of drilling, completing and tie-in of the wells, and also to the volume of oil produced in the initial year of production. The table below shows a range of economic indicators extracted from 2014 corporate presentations of some of the main producers in the tight Cardium formations. Capital costs vary by the depth and length of the wells, and by the size and type of hydraulic fracturing treatment applied. They can also be impacted by the stage of development of Cardium resources in the area, as drilling wells from pads or near existing infrastructure will reduce the costs, compared to single wells in more remote or less developed areas of the formation. In most cases the well payout can change from being quite attractive, to very unattractive with a slight increase in capital costs or a slight decrease in first year oil and gas production. Note that producers prefer to report production in barrels of oil equivalent which includes the volume of gas, even though the gas is not worth as much as oil on an energy equivalent basis.

Table 1 – Examples of Cardium Single Well Economics

Producer and Area	Capital Cost ($MM/well)	Initial Year Production Rate (boe/d)	NPV@10% (MM$)	Rate of Return (%)	Payout (years)
ARC Pembina	2.6	104		66	

[2] Penn West reported in their June 2012 report "Reuse of Flowback & Produced Water for Hydraulic Fracturing in Tight Oil" for PTAC that in 2011 only 10 out of 100 wells completed in that year were fractured with water-based carrier fluids.

Bellatrix Cardium	3.6	~275	6.1	159	.8
Bonavista Lochend Cardium	3.4	194			.6
Bonterra Cardium	2.5	100		88	1.2
Lightstream West Pembina Cardium	4.1	~151			1.6
Pengrowth Garrington Cardium	3.5	77	2.1	35	2.3
Pengrowth Lochend Cardium	3.9	132	3.2	46	1.9
Penn West Cardium Crimson Lake	3.0				
Penn West Cardium Lodgepole	2.5				
Vermillion West Pembina Cardium	3.0	~165		85	2.0
Whitecap East Pembina Cardium	2.5	98	3.11	94	1.12
Whitecap Garrington Cardium (ERH)	3.6	169	5.5	164	.78
Whitecap Garrington Cardium (std)	3.0	114	3.46	79	1.28

Future Scenarios for the Cardium Region

To provide support for the development of further Cardium tight oil developments requires building on the historic production trends, and some consideration of other potential activities which are or may occur in the region that is currently under development for Cardium tight oil. For this background report, the initial scenarios will only briefly discuss a few potential futures for Cardium developments considering the combined potential contributions of the legacy conventional oil pools and the more recently developed tight oil portions of the formation. These preliminary scenarios are proposed for discussion with producers, mid-stream processors, pipeline companies and other stakeholders as a basis for projecting future Cardium development needs and impacts. The initial scenarios considered here are:

1) **Base Case** – Full development of the unconventional tight Cardium oil play based on continued drilling of already identified potential locations and limited by existing infrastructure. This case assumes that the rapid decline of horizontal Cardium oil wells would not motivate major expenditures on new gas plants or pipelines in the area. In this case, the main infrastructure constraint appears to be the Pembina Drayton Valley crude oil pipeline capacity from the area, which carries most of the production (Cardium and other formations) from this region to Edmonton.

2) **Water Flood Enhanced Base Case** - Would follow a similar development trajectory to the original conventional Cardium and trends being seen in the Saskatchewan Bakken and in early pilot tests by established Cardium oil producers. This would consist of a reduced rate of on-going drilling, supplemented with the use of water injection to increase recovery of oil from the horizontal Cardium oil wells. Infrastructure limits would continue to limit total oil production rates. While water for flooding would come from sources which have already been used for the conventional Cardium pool water floods.

3) **Formation Wide Gas or CO_2 EOR** – The conventional Cardium pools have been identified as potential targets for CO_2 EOR. Even though there currently are insufficient supplies of CO_2 available in the region to develop a formation wide EOR project, a few Mt/yr of CO_2 might be available from local gas plants within the region or imported from Ft. Saskatchewan or Northeastern B.C. If pure CO_2

is not available, natural gas or flue gas (N_2/CO_2) might be locally available if low gas prices continue, or from regional coal fired power plants or gas compression facilities.

4) **Co-development of Underlying Duvernay** – The Duvernay formation underlies much of the Cardium formation area, is much thicker and richer in hydrocarbons per section than the Cardium, and is estimated to contain considerable volumes of oil and natural gas liquids (NGLs). Future Duvernay development is relatively uncertain in this region but the potential should become clearer over the next few years as it is still at an exploration stage of development. If there is economic production from the Duvernay, this activity could radically change the development and service/support needs in the region and, if markets are available, would also provide an incentive to construct new pipelines and gas plants in the region to facilitate its development for oil and NGLs.

Base Case Inputs for Scenario Development – A basic set of inputs for the scenario development are to confirm information on the potential number of tight horizontal Cardium oil wells which might ultimately be drilled in the region and the current infrastructure limitations related to product pipelines and gas processing facility capacities which could limit production volumes.

- **Assumed Current Infrastructure Limitations** – The assumed infrastructure limitation on Cardium oil wells is assumed to be the capacity of Pembina Pipeline's Drayton Valley crude oil line which is seeing throughput close to the volumes it saw in the 1960's. Not all of the oil from the Cardium municipalities is Cardium sourced oil as the large Devonian pools such as Leduc, Bonnie Glen, Wizard Lake, and Golden Spike are in the M.D.s of Parkland, Leduc, Wetaskiwin, Ponoka, Lacombe and Red Deer, many of which were served by a different pipeline system. Greenview County also had large non-Cardium pools, but even the existing Cardium pools are serviced by a separate pipeline system from the Peace River area, so do not impact the capacity of the Drayton Valley system. In August 2012, the capacity of the mainline system (operating since the 1950s) was increased through pump additions to accommodate increased Cardium production, however, flow through some portions of the system may also be restricted. Other infrastructure restrictions could be related to available gas plant capacity to process solution gas in some areas.

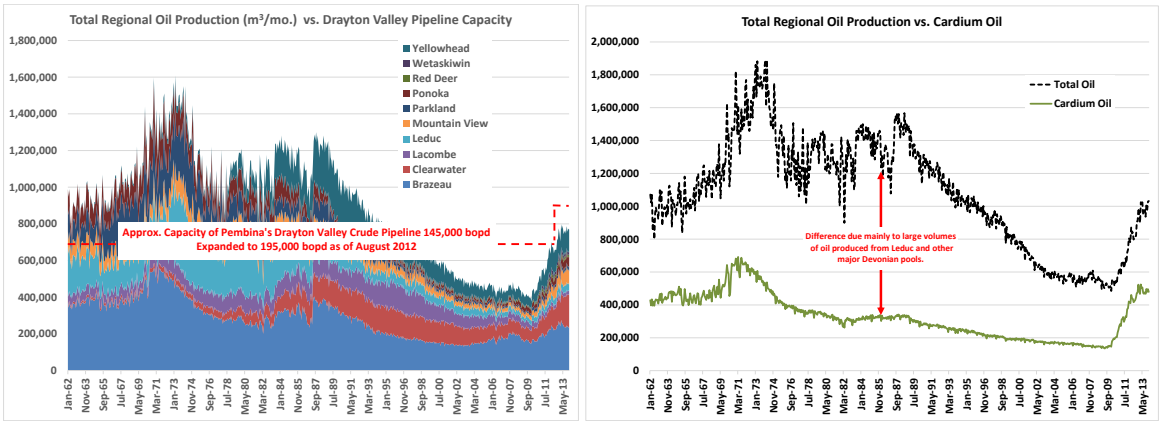


Figure 12 – Oil from Municipalities with Cardium Production vs. Nominal Mainline Capacity of the Drayton Valley Crude Pipeline and Comparison of Cardium vs. Total Oil Production

- **Potential Well Locations** – Companies in their 2013 or 2014 plans generally provide some indication of potential future locations for drilling unconventional wells. The numbers in Table 2 below were extracted from publically available information, but further clarification is required to ensure consistency between net and gross wells vs. operated wells for current, future and near-term plan drilling. Furthermore, some planned wells or locations may be in conventional areas for water flooding. Table 2 is intended to give a rough indication of potential well locations. (Note that not all companies involved in the Cardium provide this type of information.) Based on the information below, comparing the inventory of potential locations and assuming the number of wells drilled per year by the producers listed are similar to 2014 plans, the inventory would last 7-8 years of steady drilling to maintain production at current levels in the base case scenario.

Table 2 – Potential Well Inputs to Base Case for Existing Inventory, Potential Locations and Drilling Pace

Company	Current Horizontal Cardium Oil Wells (Incl. 2013)[3]	Inventory of Potential Future Locations[4]	Potential Near-term Drilling Activities
Penn West	248	~900	2014 – 67 new wells Water flood pilots and conversions
Bellatrix	177	742	2014 - 66 net wells
Bonavista	53	140	2014 – 20 wells
Lightstream	316	>530	2014 – 42 wells
Pengrowth	140	>160	2014 - ~87 wells
Bonterra	131	219	2014 – 56 wells
Vermillion	157	196	2014 – 36 wells
ARC	146		2014 – 43 wells 2012 started horizontal water injection pilot in
Whitecap	260	600	2014 – 32 wells
TORC	87	>260	2014 – 18 wells
Totals (excluding companies not listed here)	1,715	~3,750	467/yr

Initial Assessment of New Potential Opportunity Areas the Cardium Tight Oil Play Region

Since the Cardium tight oil play development is mainly focused on drilling new wells with minimal amounts of investment in facilities, most of the potential business opportunities and potential for collaborative development are associated with drilling and completions which have already been going on for decades in this region. The main impact is that the intensity and volumes of material and personnel will be higher than it was even during the initial Pembina Cardium pool development, as the new technologies take more time and materials for each well, larger crews for drilling and completions and more time spent by rigs and completion equipment at each well site or pad.

Basic Needs Intensified from Historic Operations

- **Drilling rigs and crews** – larger more complex rigs, but with fewer rig moves due to pad drilling.
- **Completion rigs and crews** – much larger and more complex operations to handle larger volumes of fluids, pumping equipment, sand, cryogenic gases, and on-site refueling.
- **Drilling camps** – Larger crews, spending longer times on specific locations leads to benefits in local drilling camps rather than hotels, or on-site accommodations.
- **Trucking** – Significantly larger demands for trucking for water, chemicals, sand, nitrogen, fuel and personnel.

[3] AER data extracted through geoSCOUT of oil wells with production and with company listed as current operator.
[4] Data generally extracted from 2014 or late 2013 corporate presentations to shareholders. Note these data are subject to disclaimers contained in the corporate presentations.

- **Drill pipe and cement** – Somewhat of an increase over traditional, but may be better supported out of yards in Nisku or Red Deer with potentially no need for intermediate staging of materials.
- **Road/Lease Construction and Materials** – Extensive road networks already exist in the area to service legacy wells and acreages or logging, and fewer roads and leases are needed for pads of horizontal wells.
- **Pipelines** – Shorter length additions to existing main network.
- **Water supply sources** – This is not a water constrained area of the province and there are large potential supplies of produced water, or saline groundwater in the area as well as facilities which would have been licensed for fresh water supply for water flooding. Total water demands for drilling and completing 500-600 wells per year will likely be less than historic water demand for waterfloods in the region. A reasonable assumption would be: 600 wells x 2,000 tonnes/well = 1,200,000 tonnes or m^3 of water per year. Over 9,600,000 m^3 of produced water are handled annually in the M.D. of Brazeau alone, and work by Penn West showed that utilizing this produced water for fracturing is a viable alternative. Data being collected for Directive 59 should be able to indicate how much of the water used for fracturing came from produced water sources. (The FracFocus website indicated that water was supplied by producers but did not indicate the type of water or volumes.) Water production in Brazeau has increased with oil production and much of the water used for fracturing is likely produced back or remains in the reservoir to displace oil.

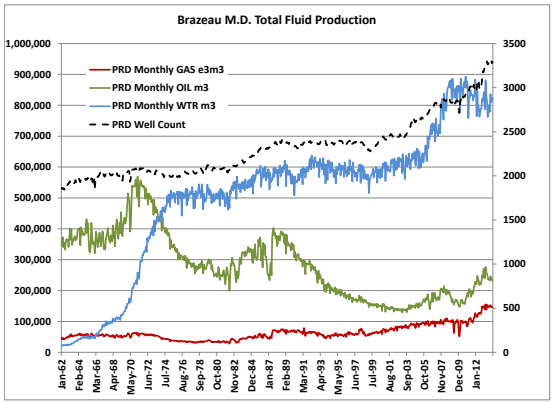


Figure 13 – Fluid and Gas Production in the MD of Brazeau Indicating Availability of Large Volumes of Produced Water.

New Needs Specific to Hydraulic Fracturing Activities

- **Large Volumes of Proppant** – Assume 500 tonnes/well x 600 wells/yr = 300,000 tonnes/year of sand which may be a sufficient volume to justify a quarry and screening, if there are suitable sand resources in the Cardium region or other locations in Alberta.
- **Large Volumes of Nitrogen** – Assume 200 tonnes/well x 600 wells/yr = 120,000 tonnes/year which may be sufficient demand for a small air separation plant or staging facility.
- **Chemical Storage** – May not be sufficient demand to have local storage of chemicals outside of Nisku or areas close to rail transport as most chemicals will be from outside of Alberta and moved by rail, then distributed by specialized trucks.

SWOT Analysis of Potential for New Opportunities

- **Strengths**
  - Region has a history of oil well drilling and completions and existing infrastructure.
  - Legacy oil pools in the region produce larger volumes of water than are needed for fracturing.

- Communities are generally supportive of oil operations and have already adapted to higher activity levels.

- **Weaknesses**
  - Producers in the region are generally smaller, potential take-over targets, or focused on short-term planning.
  - Most of work is done by larger contract suppliers like Schlumberger, Calfrac, Halliburton, Trican, Canyon and others for services, so likely have control of procurement.
  - Service companies may not want to collaborate in some areas for competitive reasons.
- **Opportunities**
  - Multiple formations in the region should create more stability over long-term for services of some types.
  - New activities drive new businesses and jobs, synergies with other regions.
- **Threats**
  - Environmental issues, infrastructure bottlenecks e.g. increasing truck traffic, competition for resources and people from other regions.