Summary

• Traditionally, light oil development of the Swan Hills Platform was limited to the conventional oil reservoirs - very thick reef buildups/aprons and to a lesser extent the reef margins

• Penn West, Pengrowth, Devon, ARC and Apache all have access to the low-risk conventional play on the reef and reef margins where enhanced oil recovery schemes will increase recovery factors

• With the advent of horizontal multi-stage fracture treatments, the potential in the porous but less permeable areas of the oil-charged platform can be unlocked

• Significant landsale activity has occurred over the last 18 months, securing these sought-after platform positions

• Coral Hill, Second Wave, Midway and Arcan have secured land positions and have successfully drilled horizontal wells with multi-stage fracs into the unconventional play

• There are more than 840 sections of undrilled lands on the oil-charged platform

• OOIP on these lands is conservatively estimated to be 2.5 billion barrels - “The Sleeping Giant”
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Introduction

As the industry continues in its quest to identify and exploit the next light oil resource play in the Western Canada Sedimentary Basin (WCSB), it has been drawn toward re-visiting established producing areas characterized by proven production and minimal hydrocarbon risk. The advent of new technology has been critical in the industry’s ability to unlock the remaining hydrocarbon endowment within tight reservoirs. In this report BMO Capital Markets has evaluated the available public well data and analyzed the recent drilling and landsale activity for the Middle to Upper Devonian Beaverhill Lake Swan Hills Platform area of west-central Alberta (Figures 1 and 3; Production Map and Stratigraphic Chart). The Swan Hills Platform appears to be evolving into a light tight oil (LTO) resource play with the advent of horizontal wells and multi-stage acid fracs unlocking the hydrocarbon reserves. However, detailed analysis of the geology integrated with the available production data indicates that there is a significant variation in reservoir play type, reservoir quality and reservoir continuity potentially affecting productivity and estimated ultimate recovery (EUR) across the Swan Hills Platform. This report subdivides the Swan Hills Platform into its component play types characterizing this variability across the Platform, and highlights activity and exposure of companies to each of these areas.

The Swan Hills Platform is characterized by production from reef buildups e.g. Swan Hills, Swan Hills South, Judy Creek, Carson Creek, Virginia Hills, Kaybob, Goose River and Snipe Lake and reef margins, e.g. Deer Mountain/House Mountain (Figure 1). The Swan Hills Platform in its entirety can be divided into two halves where the large embayment roughly delimits west from east. On the western, regionally down-dip platform, carbonates are water...
charged (supported by DST and production data), making reservoir structure critically important. On the east side of the embayment, and arguably south and including most of Virginia Hills, the entire gross carbonate package is oil charged. Liquid-rich gas produced from the carbonate bank (Carson Creek) will not be discussed within this oil-focussed paper. The main reef buildups were initially discovered in the 1950s and are in their exploitation stage of development with well-developed enhanced oil recovery schemes (EOR) and horizontal infill drilling. Figure 2 shows the eight largest Beaverhill Lake oil pools in the WCSB, all of which are displayed on the map in Figure 1. In total these eight pools have a remarkable 5.6 billion barrels of oil in place. As of March 31, 2011, the total reported production from all 3,143 Beaverhill Lake wells in the Swan Hills Platform is 2.39 Bbbl and 5.62 Tcf. There are currently 1,169 wells producing at a combined rate of 35.2 Mbbl/d and 93.9 MMcf/d. The vast majority of this production comes from the east side of the platform – which is highlighted in this report, and currently has 997 wells producing at a rate of 32.3 Mbbl/d and 42.0 MMcf/d accounting for 92% of the current production.

<table>
<thead>
<tr>
<th>No.</th>
<th>Field</th>
<th>Formation</th>
<th>Discovery Year</th>
<th>OOIP (MMbbl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Swan Hills</td>
<td>Swan Hills</td>
<td>1957</td>
<td>2,447.4</td>
</tr>
<tr>
<td>2</td>
<td>Judy Creek</td>
<td>Swan Hills</td>
<td>1959</td>
<td>1,065.5</td>
</tr>
<tr>
<td>3</td>
<td>Swan Hills S</td>
<td>Swan Hills</td>
<td>1959</td>
<td>847.9</td>
</tr>
<tr>
<td>4</td>
<td>Virginia Hills</td>
<td>Swan Hills</td>
<td>1956</td>
<td>292.5</td>
</tr>
<tr>
<td>5</td>
<td>Carson Creek N</td>
<td>Swan Hills</td>
<td>1958</td>
<td>378.6</td>
</tr>
<tr>
<td>6</td>
<td>Kaybob</td>
<td>Beaverhill Lake</td>
<td>1957</td>
<td>286.8</td>
</tr>
<tr>
<td>7</td>
<td>Snipe Lake</td>
<td>Beaverhill Lake</td>
<td>1962</td>
<td>196.2</td>
</tr>
<tr>
<td>8</td>
<td>Goose River</td>
<td>Beaverhill Lake</td>
<td>1963</td>
<td>133.3</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td></td>
<td>5,648.3</td>
</tr>
</tbody>
</table>

Source: BMO Capital Markets, Alberta Geological Survey

The reef margins are being produced by a combination of mature waterfloods and play extension to the south, along trend from House Mountain. In this trend, Arcan Resources was among the first to drill a horizontal well in the Swan Hills Platform - Deer Mountain Units of the Swan Hills Field - and complete it with multi-stage acid fracs. The Arcan well had an initial IP of ~600 bopd. The intra-reef buildup areas are now the focus of activity with 65 horizontal wells testing what was assumed to be lower (unconventional) quality reservoir. Horizontal drilling and multi-stage fracturing will allow for the exploitation of this large untapped resource.
Geologic Overview

Middle to Upper Devonian Beaverhill Lake Group, ranging in thickness from ~50 to 250 m, consists of shelf limestones, dolostones, anhydrites and associated basinal limestones and shales. The Beaverhill Lake Group is underlain by the Watt Mountain Formation and overlain by the Cooking Lake Formation (Figure 3, Stratigraphic Chart).

The Beaverhill Lake Group is divisible into three depositional domains (Figure 4, Beaverhill Lake Group depositional domains of central Alberta): the Eastern Shelf, the Central Alberta Basin and the Western Shelf which is the focus of this report.

The Western Shelf is a complex geological setting with examples of most carbonate depositional environments. It consists of a succession up to 150 m of shallow-marine limestones and dolostones of the Swan Hills Formation, which can be highly variable in characteristics. Overall the average porosity of Swan Hills oil pools varies from 3-20%, and the average water saturation ranges from 10-50%. Most Swan Hills reservoirs are dolomite with reported core permeabilities ranging up to 1 or 2 Darcies (Golden, Fox Creek). Limestone reservoirs show permeability ranging from 1 to 500 mD (Dawson).

These carbonates were deposited on regionally extensive carbonate banks, platforms, and geographically limited, isolated reefs.

Carbonate reefs and organic buildups form both in shallow normal marine waters where there is a break in slope on the sea floor, or landward of this break in slope within the slightly deeper water of platform interiors and wide shelf sea settings. There is normally a strong zonation in play types across a platform or carbonate bank due to changes in physical processes (waves and tides) that control the primary porosity and permeability of the carbonate deposition. Later diagenetic events may also affect (positively or negatively) the reservoir quality of the rock. The Swan Hills Platform formed seaward of the Swan Hills Bank, along the Western Shelf Domain, facing into a SW dominant wind direction. Multiple cycles of sea level change resulted in multiple prograding and retrograding stacking events of reservoir and non-reservoir facies. The later collapse of the Peace River Arch (PRA) to the north, and tectonic faulting
to the south, resulted in the formation of conduits for hydrothermal dolomitization, locally further enhancing the reservoir rock.

Together, these controls resulted in at least 10 identifiable facies types developing on the Swan Hills Platform. The next section will detail the location, attributes and productivity of each of these 10 play types/areas.
Beaverhill Lake Swan Hills Platform Play Types

The map in Figure 5 shows the play type/areas on the eastern Swan Hills Platform Complex, based on the inferred depositional environment. The boundaries between most play areas would be much more gradational than the fine lines shown, and the expectation would be that wells in these transition zones would exhibit characteristics from multiple groups. The play areas examined are: forereef debris apron (1), reef margin buildup (2), reef sand apron (3), interior platform north (4), reef debris apron (5), reef buildups (6), leeward platform (7), tidal banks (8), interior platform south (9) and back/patch reef buildups (10).

The platform complex first produced from the large reef buildups (6) in the late 1950s. Within a decade, much of the reef margin (2), sand apron (3), debris apron (5) and the buildups (6) were producing and unitized, and by 1970 waterflood schemes were well underway. It wasn’t until the last year that operators began unlocking the potential of the lower permeability platform play types with fractured horizontal wells.

The two cross sections shown on the map are detailed in Figures 6 through 9, and show schematically and using well control, the 10 play types.
Figure 6: Swan Hills Platform Model Play Types North

Source: BMO Capital Markets

Figure 7: Swan Hills Platform Model Play Types South

Source: BMO Capital Markets
Each of the areas are distinct in lithology, porosity, permeability and as a result deliverability. For the most part all 10 facies have been drilled both vertically and horizontally. The exception would be Play Areas 1 and 10, the Forereef Debris Apron and Black/Patch Reef Platform, which have yet to have modern wells drilled in to them. The two schematic sections shown on the previous page (Figures 6 and 7) show the play areas across the north and south ends of the platform. On this page, Figures 8 and 9 show real wells in the same lines of section. Whenever possible, the wells were chosen adjacent to operators actively drilling horizontally (tagged at base). What becomes most interesting is that outside of Play Area 6: (Swan Hills Reef Buildup), the porosity, permeability and net pay are very similar for each of the Play Areas. Each play type is presented in more detail in the Appendix.
Porosity, Permeability and Deliverability by Play Type

The average permeability, porosity and deliverability of course vary significantly in the previously described play types. Not surprisingly, when reviewing average porosity and permeability for each of the play types, two reservoir styles appear: conventional oil reservoirs (Swan Hills Buildup, Reef Margin and Sand Apron) and unconventional oil reservoirs (all other play types). When viewed in context of an oil charged system from the base of the platform to the top of the Swan Hills, significant untapped resource remains to be exploited - “The Sleeping Giant”.

Average porosities and permeabilities (Kmax) were calculated for each play type from core analysis. In total, analyses from 1,520 cored wells were used and subsequently allocated to play types as seen previously in Figure 5. The core data was then sorted to remove any porosities (and corresponding permeabilities) less than 3% - assuming this data could not be considered effective reservoir.

Figure 10 shows the average porosity and permeability by play type. Average porosity ranges from 5.2% in the Forereef Debris Apron to 8.2% in the Swan Hills Reef Buildups. Remarkably all the areas show significant storage but as is expected outside of the reef buildsups, permeability is reduced and hence deliverability when drilling vertical wells.

*Using core data where porosity is greater than 3%

Source: BMO Capital Markets
When using the play classification developed by R. Mann (Figure 11), the Swan Hills Platform provides both conventional and unconventional reservoirs. The Reef Margin, Reef Sand Apron and Reef Buildups all have porosity and permeability profiles that confirm them to be conventional reservoirs. These areas have seen horizontal development into unswept areas to increase overall recovery factors. As well these reservoirs may be excellent candidates for tertiary (solvent and miscible hydrocarbon) and quaternary (CO₂) recovery schemes to enhance overall recovery.

Conversely, the unconventional reservoir includes seven play types; Forereef Debris Apron, Interior Platform, Reef Debris Apron, Leeward Platform, Tidal Banks, Patch Reef Platform, Back/Patch Reef Buildup - all of which are prospective for horizontal, multi-stage fracture treatment wells.

Of course in situ permeability directly affects deliverability and Figure 12 shows the deliverability of horizontal wells both pre 2006 and post 2005 by play type. The horizontal wells were vintaged to isolate the more modern drilling and completion techniques from the earlier methodologies. As the histogram indicates, even in the most permeable play type – the Swan Hills Reef Buildups – the modern horizontal wells have outperformed those drilled prior to 2006. However improvements are seen across the board with average 3-month IPs (Swanson Mean) increasing significantly from the non-traditional reservoirs (Figure 13). The most significant of which is play type 3 (Reef Sand Apron) where the initial production (IP) increased from 65 bbl/d in the pre 2006 horizontal wells to 163 bbl/d in the post 2006 horizontal wells. Play type 7 (Leeward Platform) is somewhat of an anomaly showing the pre 2006 horizontal wells with an IP of 72 bbl/d decreasing to 27 bbl/d in the post 2006 horizontal wells. It should be noted that the post 2006 IP was a single data point and that the wells drilled into Leeward Platform do confirm oil saturation within that facies.

![Figure 11: Play Classification by Oil Properties and Reservoir Rock](Image)
With the review of core, log and production data, the nontraditional play types clearly contain significant storage with compromised permeability - an unconventional reservoir containing conventional oil (light oil). Overall drilling density to date will be discussed in the next section highlighting the scope of the potential development particularly in play types 4 and 9 – the Interior Platform and the Patch Reef Platform, which is most impressive and encompasses 11 or 12 townships of mostly contiguous lands. The untapped potential in the Swan Hills Platform has lead to significant landsale activity.

Source: BMO Capital Markets

---

**Figure 12: Initial Well Deliverability by Play Type**

3-Month IP (Swanson Mean) and Well Count

<table>
<thead>
<tr>
<th>Well Type</th>
<th>3-month IP Pre-2006 (bbl/d)</th>
<th>HZ 3-month IP Pre-2006 &amp; (bbl/d)</th>
<th>Well Count Pre-2006</th>
<th>Well Count 2006 &amp; Later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reef Margin</td>
<td>na</td>
<td>120</td>
<td>163</td>
<td>113</td>
</tr>
<tr>
<td>Reef Sand Apron</td>
<td>na</td>
<td>15</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>Interior Platform</td>
<td>na</td>
<td>28</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Reef Debris Apron</td>
<td>na</td>
<td>113</td>
<td>113</td>
<td>113</td>
</tr>
<tr>
<td>Swan Hills Reef Buildups</td>
<td>na</td>
<td>167</td>
<td>27</td>
<td>27</td>
</tr>
<tr>
<td>Leeward Platform</td>
<td>na</td>
<td>5</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tidal Banks</td>
<td>na</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Patch Reef Platform</td>
<td>na</td>
<td>35</td>
<td>na</td>
<td>na</td>
</tr>
</tbody>
</table>

There are no HZ wells drilled in the Tidal Banks after 2005

There are no HZ wells drilled in the Patch Reef Platform before 2006

Source: BMO Capital Markets

---

**Figure 13: Table of Well Counts, Initial Rates, Porosity and Permeability by Play Type**

<table>
<thead>
<tr>
<th>Play Type</th>
<th>Initial Rate</th>
<th>Well Count</th>
<th>Porosity (%)</th>
<th>Permeability (mD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Forereef Debris Apron</td>
<td>2006 &amp; Later: Hz, 3-month IP (bbl/d)</td>
<td>120</td>
<td>3.4%</td>
<td>1.46</td>
</tr>
<tr>
<td>2 Reef Margin</td>
<td>na</td>
<td>28</td>
<td>4.5%</td>
<td>1.58</td>
</tr>
<tr>
<td>3 Reef Sand Apron</td>
<td>65</td>
<td>33</td>
<td>4.8%</td>
<td>2.40</td>
</tr>
<tr>
<td>4 Interior Platform</td>
<td>86</td>
<td>37</td>
<td>4.2%</td>
<td>1.78</td>
</tr>
<tr>
<td>5 Reef Debris Apron</td>
<td>63</td>
<td>15</td>
<td>5.1%</td>
<td>1.66</td>
</tr>
<tr>
<td>6 Swan Hills Reef Buildups</td>
<td>147</td>
<td>15</td>
<td>6.8%</td>
<td>2.44</td>
</tr>
<tr>
<td>7 Leeward Platform</td>
<td>72</td>
<td>55</td>
<td>4.4%</td>
<td>1.18</td>
</tr>
<tr>
<td>8 Tidal Banks</td>
<td>72</td>
<td>6</td>
<td>4.6%</td>
<td>1.67</td>
</tr>
<tr>
<td>9 Patch Reef Platform**</td>
<td>na</td>
<td>19</td>
<td>3.6%</td>
<td>0.76</td>
</tr>
<tr>
<td>10 Back/Patch Reef Buildups</td>
<td>na</td>
<td>0</td>
<td>3.8%</td>
<td>0.60</td>
</tr>
</tbody>
</table>

* Swanson Mean-Calendar Day Value
** Rate and well count do not include Coral Hill 100132-20-064-09W5/00

Source: BMO Capital Markets
Landsale Results

Historically the Swan Hills reef complex was developed through unitization of the lands which was followed by secondary (waterflood) recovery schemes. Figure 14 shows all the unitized lands along the complex in blue. In total 300,000 acres of land have been unitized into 20 units, mostly in play types 2, 3, 5 and 6. Access to the unitized land occurs only if one of the unit holders chooses to sell their working interest in the unit. Most of the units are operated by large companies including Penn West, Pengrowth, Devon and Apache.

However, recent activity has begun to take place outside of the conventional reef play (play types, 2, 5, 6) and as a result there has been significant landsale movement in 2010 and in 2011. Landsale activity by quarter for 2010 and 2011 is shown in Figure 14. Note that most of the lands outside of the reef build ups were held prior to 2010 (shown in light grey).

As expected with the land inventory depleted, the peak price paid in 2010 rose to $5,415/ha ($2,191/acre) and in 2011 more than doubled to $13,842/ha ($5,602/acre) (Figure 15). Of interest is the activity surrounding the Forereef Debris Apron (play type 1) which has yet to be proven to contain commercial rate oil. Note that a significant amount of open crown remains between Judy Creek and Virgina Hills.
When reviewing the accumulated land positions (Figure 16), much of the land is held under brokers’ names; more than 187,000 net hectares (725 sections). For declared land ownership the top five include; Pengrowth (59,046 net hectares), Coral Hill (42,943 net hectares), Penn West (an estimated 40,469 net hectares), and Apache (20,410 net hectares).

It is clear based on land positions that new entrants such as Arcan, Coral Hill, Second Wave and Midway have been able to amass significant land positions. Note that Second Wave has recently announced the farmout of their Swan Hills rights.

**Figure 16: Top Beaverhill Lake Land Owners by Net Hectares**

**Source:** BMO Capital Markets, GeoScout

**Figure 15: Beaverhill Lake to Slave Point Petroleum and Natural Gas Crown Sales by Quarter since 2009**

Source: BMO Capital Markets, GeoScout
Drilling Activity by Company and by Play Type

Since January 2006 a total of 258 wells have been drilled into the Swan Hills area. The most active play types are the traditional targets of the Reef Buildups (73 wells) and the Sand Apron (49 wells) offsetting the Reef Margin. Surprisingly, the Interior Platform has seen almost as much activity with a total of 44 wells drilled to date. Recall that the deliverability for the unconventional Interior Platform wells was 115 bbl/d which rivaled the conventional Sand Apron at 163 bbl/d.

Activity by operator indicates that the most active operator is Arcan with a total of 70 drills since 2006 focusing on the Interior Platform and Sand Apron as well as the NE Margin and to a lesser extent the Patch Reef Platform and Reef Debris Apron. The second most active operator is Pengrowth, having drilled 57 wells focusing on the Reef Buildups, Sand Apron and Interior Platform. Penn West, Devon, Apache, Coral Hill, Second Wave, ARC, Midway, EOG and Sure are also involved in the play (Figure 18).

Source: BMO Capital Markets
The first well drilled into the Swan Hills – Beaverhill Lake Complex was a vertical producer in the Virginia Hills Reef Buildup (play type 6) in 1957. Immediate development continued on this reef and the other reef buildups in the complex (Swan Hills, Swan Hills South, Judy Creek, and Carson Creek). Drilling continued in most of the other play types throughout the remainder of the decade (play types 2 through 5) and then the 1960s saw the first locations drilled in the Leeward Platform (play type 7), Tidal Banks (play type 8), and Patch Reef Platform (play type 9). Figure 19 shows the locations of the first producing well and the first modern, horizontal well in each play type. Only the Forereef Debris Apron (play type 1) and Back/Patch Reef Buildups (play type 10) remain untested.

All of the initial development consisted of vertical wells that were cased to total depth, perforated and then stimulated with “Matrix Acidising Treatments”, also known as “acid squeeze” or “acid wash”. These are characterized by relatively low pump rates (e.g. 0.2 m³/min) at pressures well below the rock's fracture pressure. The purpose of this completion technique is to remove any damage or skin that has developed in the reservoir (near the wellbore) to help maximize deliverability and recovery. This drilling and completion methodology resulted in IPs in the range of 100 bbl/d.

Enhanced oil recovery with waterfloods was implemented in the early 1960s, primarily in the reef structures, helping to increase production rates and recovery factors.

In the early 1990s, horizontal development began in each of the conventional play types, either as stand-alone wells, or as re-entries into abandoned or low-volume vertical producers. They were completed as open-hole, and stimulated with an acid squeeze resulting in initial rates that were marginally better than the vertical wells. With IPs generally greater than 120 bbl/d, this has become an effective way of increasing capture in the conventional reservoirs. As an example, Apache has done this effectively in play type 3 (The Reef Sand Apron).

After 2006, new technologies allowed operators to begin completing horizontal wells with multi-stage, acid fracture stimulations. The horizontal legs are left open-hole, but a removable
A liner is used to isolate multiple intervals, and inject an acid solution at higher pump rates (i.e., 4 to 12 m³/min) with pressures above the reservoir’s fracture pressure. The effect of the fracture stimulation is to greatly enhance the reservoir’s permeability, leading to much higher deliverability and ultimate recovery. In one case study (Reef Sand Apron), the horizontal wells completed with acid washes show an average 3-month rate of 65 bbl/d compared to the horizontal wells with multi-stage acid fractures almost tripling their average 3-month rate to 163 bbl/d.

In addition, tertiary (solvent or miscible hydrocarbon) and quaternary (CO₂) flooding is being tried in the Reef Buildups (play type 6) and can be effective at rejuvenating production after waterflooding has been exhausted. The combination of waterflooding and solvent injection is expected to give recovery factors of approximately 40%. CO₂ flooding could increase recovery factors as high as 60%.

As Figure 19 indicates, horizontal wells have been drilled into all play types except 1 and 10 (Forereef Debris Apron and Back/Patch Reef Buildups).
The map in Figure 20 indicates areas with drilling opportunities on the Swan Hills Platform. The coloured quarter sections reflect oil drill spacing units (DSUs), by play type that have not yet produced oil. DSUs for new drills or newly licensed wells were not included in the estimate of undeveloped sections. In total we estimate an astounding 844 sections or 23 townships of undrilled lands into all play types on the platform. Much of the activity to date is occurring in the largest untapped opportunity which is 425 sections in the Interior Platform and Patch Reef Platform.

In the appendix you will find eight case studies which are representative sections of land, detailing the opportunity in each play type. For each case study an OOIP calculation was
made based on the log and core data for that section. These OOIP calculations were then used as a conservative case to extrapolate the potential OOIP left to be drilled. These numbers are reflected in Figure 21. In total we estimate there to be 2.5 billion barrels of oil on the undrilled lands. Note that this does not take into account the already drilled sections which may still have very low recovery factors and present an excellent opportunity for ongoing development.

The two unconventional play types with the most undrilled lands are the Interior Platform and the Patch Reef Platform and are highlighted in Figure 21. Here we see a number of operators actively pursuing these play types with early success.

Figure 22 indicates the most recently announced results from operators (Coral Hill, Second Wave, Midway, Arcan) who are developing The Sleeping Giant. In the unconventional play types, recent company reported IPs range from 300 to almost 4,000 bbl/d, with the Coral Hill well at 12-20-064-09W5 having produced more than 52 Mbbl by the end of April 2011 (4 months).

In the conventional play types both Penn West and Pengrowth expect deliverability ranging from 250 to 500 boed confirming the efficacy of continuing to maximize capture into the reefs, reef apron and the reef margin.
Conclusions

• The completely oil-charged eastern portion of the Swan Hills Reef Complex spans 100 km by 60 km or 2317 square miles

• Historically thought to be a conventional reef play which left vast areas of undeveloped land on the platform

• Recent landsale activity has seen undeveloped land positions sell for record amounts

• Core and log analysis suggest there is both a conventional oil play (well developed) and an unconventional oil play (which is early in its development)

• There are 3 well developed conventional oil reservoirs in the complex: the Swan Hills Reef Buildups, the Reef Sand Apron and the Reef Margin Buildup. These three areas have opportunities for low-risk horizontal infill drilling as well as enhanced oil recoveryEOR)) schemes to increase recovery factors as high as 50-60%

• Unconventional reservoir play types include the Reef Debris Apron, the Leeward Platform, the Interior Platform, the Tidal Banks and the Patch Reef Platform. The Back/Patch Reef Buildups and the Forereef Debris Apron may also hold promise

• Case studies into the unconventional play types show OOIPs to range from 1.6 MMbbl to 6.2 MMbbl per section. Overall the undeveloped lands are estimated to contain 2.5 billion barrels of oil in place

• Recent results into unconventional reservoirs show IPs as high as 3,958 bbl/d (Coral Hill – Tidal Banks) from long leg horizontal wells with multi-stage fracture treatments

Keep Your Eyes On

Unconventional

• Coral Hill’s drilling in the Tidal Banks and Patch Reef Platform as well as their development at Virginia Hills

• Midway’s development on the Leeward Platform

• Arcan’s drilling on the Reef Margin Buildup and the Reef Sand Apron – particularly towards the southern end (twp 066 and 067-08W5)

• Second Wave’s farmout of their lands in the Patch Reef Platform

• Evolution of general completion techniques - size (tonnage), number of fracs and use of proppant

• Landsale activity/posting on the unevaluated lands

Conventional

• Infill drilling by Devon, Pengrowth, Penn West and Apache into the Swan Hills Reef Buildups, the Reef Sand Apron and the Reef Margin Buildups

• The effectiveness of the EOR schemes (\(\text{CO}_2\), solvent, and miscible) by Penn West, Pengrowth, and Devon
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Play Area 1: Forereef Debris Apron

**Geologic Overview**

- Found in front of the windward margin of the reef deposits on the platform’s northeast edge
- Upper basin slope deposits consist of silt to boulder-sized debris derived from the reef frame and mixed with in situ forereef biota
- The lower basin slope (deeper water) lithologies includes marls and shales, and characteristically has a chaotic texture but may locally exhibit cross-bedding

**Core Analysis and Reservoir Characteristics**

- Very few wells penetrate the forereef debris apron, even fewer are cored
- Average core porosity of 3.4% and permeability of 1.5 mD in the sample set. Lithologies are exclusively limestone and typically are very-fine to fine grained with occasional anhydrite
- Reservoir may exist in areas where the reef itself is plugged by carbonate cement acting as updip seal
- There is minimal production from the forereef debris slope, and most of these wells are 50 years old with low volumes or only trivial production tests
Play Area 2: Reef Margin Buildup

Figure 24: Play Areas 2 & 3: Northeastern reef platform off the Majuro Atoll, Marshall Islands shows both reef margin and sand apron

Geologic Overview

• The northeast windward margin of the platform hosts a narrow belt of reef and mud-skeletal buildups which developed in a high energy environment
• Reef geometry is expressed as thick sheets which parallel depositional strike and whose thickness may be related to a particular change in sea level

Core Analysis and Reservoir Characteristics

• Average core porosity is 4.5% and permeability is 1.6 mD. Most of the porosity is primary; pin-point and vuggy. Average gross thickness is 36 m
• The occasional crystalline limestone indicates some plugging of the primary porosity, and some fracture (secondary) porosity is also observed
• Lower permeability and reasonable porosity suggest a much larger portion of the original resource still remains
• Horizontal drilling and multi-stage acid fracturing techniques are being used to increase recovery factor
• Proven waterflood success (e.g. Deer Mountain Unit 2) with three to four horizontal wells plus one or two vertical water injection wells per section
Play Area 3: Reef Sand Apron
(see Figure 24 for modern analogy)

**Geologic Overview**

- The narrow reef sand apron occurring immediately behind the reef margin buildup contains both skeletal debris transported from the reef crest and localized patch reefs
- The back reef sediments are frequently burrowed, widespread, and sheet-like and the patch reefs tend to be massive and lens-like
- The sediments are often cyclical as a product of frequent changes in base level
- Clean and well sorted, the primary lithologies are carbonate sands, muddy skeletal sands, and lime muds which often retain significant amounts of primary porosity, especially in reef-tracts where accumulation of skeletal rubble was rapid

**Core Analysis and Reservoir Characteristics**

- Average core porosity is 4.8% with relatively high permeabilities averaging 2.4 mD. Gross thickness ranges from 21 to 36 m
- The sediment varies in grain size from sand to mud, is predominantly carbonate and is often logged as broken, argillaceous or shaley
- The widespread, clean and sorted sheets of back-reef apron deposits naturally have higher permeabilities, second only to the main porous reef buildups
- Waterfloods easily, as proven in House Mountain Unit 1
Play Area 4: Interior Platform

Figure 25: Play Area 4: Extensive shallow water patch reefs/sand shoals/carbonate sands of the Great Barrier Reef, where, close to the horizon, a distant reef barrier stretches across the photo.

Geologic Overview

- The aerially extensive interior platform is characterized by continuous wide sheets of poorly-sorted sediments which are extensively burrowed.
- The depositional environment was a wide, shallow sea protected by reefs and mobile carbonate sand barriers; on the east by the reef margin complex and on the west by the Swan Hills buildups and the tidal banks rimming the embayment.
- Consists of a framework of patch reefs and sand shoals mixed with extensive sheets, belts and lobes of skeletal sands.
- Principal facies are clean carbonate sands, muddy skeletal sands, and lime muds.

Source: www.cosmomagazine.com
Core Analysis and Reservoir Characteristics

- Average core porosity is 4.2% and permeability is 1.8 mD. Lower permeability is reflective of the poorly-sorted deposits, yet porosity is very similar to other play areas discussed.
- Increased average grain density is supported by abundant core samples reporting dolomite and anhydrite.
- Primary porosity is dominantly pin-point. Secondary porosity includes leaching where sand shoals may have been aerially exposed shortly after deposition and fracture porosity where extensive fracturing may have introduced the dolomitizing fluids long after burial.
- Less permeable or “tighter” areas of the Swan Hills reef complex hold immense resources, but historically have yielded less productive wells that left most of the hydrocarbon in the rock.

Play Area 5: Reef Debris Apron

Geologic Overview

- The reef debris apron found in front of the northern Swan Hills buildups has characteristics similar to the forereef debris apron (play area 1) and the interior platform (play area 4) described earlier.
- Early Beaverhill Lake deposits consist of localized patch reefs intermixed with some skeletal debris shed from the buildups.
- In Late Beaverhill Lake time, the primary buildups continued to grow after the majority of the platform was drowned. On the northern end of the drowned platform, the shallow sea would have been partially protected in the northeast by the former reef margin complex (play areas 2 and 3).
• The windward facing foreslope deposits would reach farther into the protected shallow waters creating an apron of unsorted, chaotic reefal debris

• Where the reef fronts were less protected from direct winds, as in the Judy and Carson Creek North buildups, the reef debris apron would be significantly less aerially extensive leading to sharper definition of the cliff-like reef

**Core Analysis and Reservoir Characteristics**

• Average core porosity is 5% (good storage), and average permeability is 1.7 mD (lower permeabilities)

• Lithology descriptions often list anhydrite and occasionally broken or fractured, and the vast majority are limestones with pin-point porosity

• Gross thickness of the reef debris apron is second only to the large Swan Hills buildups, and ranges up to 50 m

• Horizontal drilling and multi-stage acid fracturing techniques are being used to increase recovery factors and are being completed even after waterflooding (Inverness and East Swan Hills units)
Play Area 6: Swan Hills Reef Buildups

Geologic Overview
- The Swan Hills Reef Buildups including Carson Creek North, Virginia Hills, Judy Creek, Swan Hills South and Swan Hills, developed as large atoll reef complexes off the carbonate bank. These grew through most of Beaverhill Lake time even after the majority of the carbonate platform had been drowned.
- Porosity development is associated with the high-energy reef margin (front) facies of each shallowing upward cycle, versus the lower relative porosities and permeabilities of the quiet-water carbonates of the interior lagoon environment.
- Original reservoir target discovered in the late 1950s.

Core Analysis and Reservoir Characteristics
- Extensively cored, the thick carbonates have average porosity of 6.8% and permeability of 2.4 mD. Fossiliferous limestone lithologies dominate the buildups.
- Gross thickness in these buildups can be 150 m or more (Virginia Hills), which is significantly thicker than any other play type.
- Primary porosity is common as vugs, interparticle and intraparticle pores. Fractured, leached and some dolomitized porosities add to the excellent reservoir quality.
- Primary production since late 1950s, and extensively waterflooded since 1960s.
- Recent infill horizontal wells and waterflood optimization continues to increase recovery factor.
Play Area 7: Leeward Platform

Geologic Overview

- This play area describes the leeward side of the interior platform that is behind the tidal banks rimming the embayment.
- Some deposits here can be similar to the reef debris apron (play area 5) in that there will be skeletal reef material shed off the back edges of the large Swan Hills buildups, increasing the gross carbonate thickness.
- Most deposits will be shallow water clean carbonate sands, muddy skeletal sands, and lime muds with localized patch reef development similar to play area 4.

Core Analysis and Reservoir Characteristics

- Average core porosity is 4.4% and permeability is 1.2 mD, which is very similar to the other parts of the interior platform.
- Lower permeability, but excellent storage again suggests this play area is ideally suited for horizontal wells with multi-stage acid fracs to increase the stimulated rock volume (SRV).
- Core descriptions commonly list shale and anhydrite, and little-to-no dolomitization has occurred.
- This area has not seen a lot of recent development.
Play Area 8: Tidal Banks
(see Figure 28 for modern analogy)

Geologic Overview

- The Swan Hills Platform in its entirety hosts a large embayment which roughly separates the downdip water-charged west platform (Snipe Lake, Goose River) from the updip oil-charged east platform examined here. Rimming the embayment is a wide belt of tidal and storm-generated mud banks and tidal bars.

- In contrast to the variety of sand bodies that form along windward margins, leeward open margins are dominated by off-bank sand transport. Here, wide sheets of non-skeletal sands form at the bank edge.

- The principal facies are clean carbonate sands, muddy skeletal sands, and carbonate muds.

Core Analysis and Reservoir Characteristics

- Average core porosity is 4.6% and permeability is 1.7 mD. The bulk of the core analysis shows less than 10 mD permeability and 9% porosity, and horizontal permeability is much better than vertical permeability.

- Crystalline, very-fine and fine-grained limestone dominate the lithology descriptions.

- Most of the production from this play area is older (1990s), but recent successful wells at the south end of the embayment substantiate the play.

- There are two modern horizontal wells into this play type but their production is not yet public.
Play Area 9: Patch Reef Platform

Geologic Overview

- The south end of the Swan Hills platform developed in a shallow water open-marine environment which was only indirectly protected by the reef margin complex to the north and was out of the direct force of the prevailing winds.

- Periodic changes in base-level would have influenced localized patch reef development, and the area mostly consists of sand shoals mixed with extensive sheets, belts and lobes of skeletal sands.

Core Analysis and Reservoir Characteristics

- There are relatively few wells cored within this area, showing average core porosity of 3.6% and permeability of 0.8 mD.

- The reservoir characteristics of the south platform are likely most similar to the north platform (play area 4) and several operators are having success accessing the oil-charged platform carbonates with long leg horizontals with multi-stage acid fracs.
Play Area 10: Back/Patch Reef Buildups

Geologic Overview

- This back reef area is found between the Judy Creek and Virginia Hills reef buildups, to the south of the tidal banks and flats of the embayment rim
- Deposits found in this play area are shallow water carbonates with abundant skeletal reef debris shed from the surrounding buildups and tidal banks

Core Analysis and Reservoir Characteristics

- Very few wells penetrate the backreef area, even fewer are cored
- Average core porosity is 3.8% and permeability is 0.6 mD in the five well sample set. Lithology descriptions include several accounts of oil
- There is no production from the back/patch reef area. There are a few wells in which both mud and water were recovered on DST
Case Study: Play Type 2 - Reef Margin Buildup - Conventional Reservoir

The Reef Margin Buildup case study focuses on an example section at 28-068-8W5 where a total of 10 wellbores have been drilled to date plus one modern horizontal well that transects sections 28 and 29. This play type is the least active with only two current drills and one licensed location—all belonging to Arcan. However this area holds significant opportunity particularly on the southern end where little development has occurred.

Historical Development (2005 & Earlier)

- The key vertical drilled into section 28 was 12-28-068-8W5 which since 1983 has produced 223 Mbbl of oil. The section has also seen 967 Mbbl of water injection on the southern end of the section primarily at 04-28-068-8W5 but to date doesn’t appear to have impacted production
- A number of other vertical wells have production to date ranging from 1 Mbbl to 47 Mbbl

Modern Development (2006 & Later)

- The wells drilled prior to 2006 confirmed the presence of oil in commercial volumes however deliverability was variable
- In 2008 Arcan drilled the 10-28-065-8W5 well and performed an acid frac treatment on the deviated well. Initial deliverability was 80 bbl/d and subsequently increased to 120 bbl/d
- Early in 2010 Arcan drilled the first long leg horizontal (05-28) with a multi-stage frac with an IP of 350 bbl/d or almost three times that observed at 10-28
- Production from the section is almost 400 Mbbl with an estimated OOIP of 4.3 MMbbl for a recovery factor of less than 10%
Play Type Opportunities

- The Reef Margin remains largely undrilled to the south from 66-8W5 to 68-8W5 where Arcan is focusing on their development at Ethel
- In the more well developed areas inside the units, Apache in particular has shown the effectiveness of drilling low-risk horizontals to increase recovery factors
- The application of secondary (waterfloods) and tertiary (CO₂) in localized areas will also increase recovery factors

Major Players

- Arcan, Apache and Pengrowth have all drilled horizontal wells into the Reef Margin
- Apache has drilled the most horizontals into the play (23) but all wells were drilled prior to 2006, as was the only Pengrowth horizontal well drilled in this play type
- Arcan was the first to drill a modern long leg horizontal well with multi-stage fracs into the play type and have drilled two more (not completed) and have another location licensed
Case Study: Play Type 3 - Reef Sand Apron - Conventional Reservoir

The Reef Sand Apron case study looks at an example section at 22-069-09W5. There have been six producing wellbores, including two horizontal wells and two converted to water injectors. The Reef Sand Apron is a very active play having a total of 29 modern horizontal wells and another 25 drilled prior to 2006 and another eight locations licensed.

Historical Development (2005 & Earlier)
- Initial production from section 22 began in 1963 from two vertical wells, one at 02-22-069-9W5 and one at 10-22-069-9W5. These two wells alone have produced more than 1.7 MMbbl of oil. However initial production was typical of the reservoir and ranged from 20-80 bbl/d
- Injection was begun in 1966 and more than 4 MMbbl of water have been injected into the reservoir in section 22

Modern Development (2006 & Later)
- The first horizontal well (14-22) was drilled in 2001 whip-stocked from the 10-22 well. This well was an openhole completion with a simple acid squeeze and had an IP of 113 bbl/d with production to date of 133 Mbbl
- Late in 2009 Apache drilled the 10-22 horizontal well but did not perform a multi-stage frac. Initial deliverability was 100 bbl/d – very similar to the vertical well’s initial deliverability. The 10-22 well has produced 18 Mbbl to date.
- Production from the section is about 358 Mbbl or less than a 7% recovery factor

Play Type Opportunities
- The Reef Sand Apron extends from the unitized lands at Deer Mountain and House Mountain south for six townships, where the units are operated by Apache
• Much of the land, particularly in the units, is operated by Apache

• Clearly the opportunity remains here to maximize deliverability and ultimately capture by using a multi-stage fracs on the horizontal wells

• A low-risk opportunity is to maximize recovery factors through infill drilling in the more densely drilled sections

• Continue to extend the play to the south where many sections remain undrilled

**Major Players**

• Arcan, Apache and Pengrowth have all drilled horizontal wells into the Reef Sand Apron having drilled 62 wells between the three operators – both pre 2006 and modern. Arcan has drilled the most modern horizontal wells into the play having drilled a total of 18 horizontal wells with some form of multi-stage fracture treatment and have an additional four licenses – Arcan reiterates in their corporate presentation the importance of their development at Ethel – which span both the Reef Sand Apron and Reef Sand Margin

• Apache has a further four wells licensed into the play
Case Study: Play Type 4 - Interior Platform - Unconventional Reservoir

The Interior Platform case study examines section 14-069-10W5 that has seen most of the exploitation techniques used to fully develop plays in the Swan Hills Complex. There have been four vertical wells and five horizontal wells drilled in the section, with current production from this section of 220 bbl/d.

**Figure 39: Play Type 4: Interior Platform Map**

**Figure 40: Interior Platform Type Log**

**Historical Development (2005 & Earlier)**

- First drilled with two vertical wells in 1973 and 1974, both were cased and stimulated with acid squeeze. Together they produced 451 Mbbl before being converted to injectors, which began in 1987 in the 06-14 well
- Two additional verticals drilled in the section in the mid 1980s were completed like the first two, and produced a further 353 Mbbl
- Pressure support from injection appears to have reduced the decline, particularly in the late 1980s
- In the 1990s the two remaining producers were whip-stocked to horizontal wells completed as open hole/acid squeeze resulting in initial rates > 100 bbl/d

**Modern Development (2006 & Later)**

- Two horizontal wells drilled in 2007 and 2009, both open hole/acid squeeze, had relatively poor initial rates (73 and 17 bbl/d 3-month IP)
- One of these was recompleted in 2010 with a fracture treatment which resulted in a production increase from 20 to 195 bbl/d
Play Type Opportunities

- The case study section clearly demonstrates that modern drilling and completion techniques can deliver tremendous results, even in areas that may initially appear to be depleted. After 50% recovery factor, the 2010 recompletion still yielded close to a 10-fold increase in rate.

- The northern parts of the interior platform are fairly well developed in ways similar to the case study section, and ample opportunities remain to further downspace and/or waterflood already producing sections.

- In the south, there are large extents of acreage with little or no development. Any of these undeveloped sections could have similar potential with significant OOIP.

Major Players

- Section 14-069-10W5 features ARC as the operator, who has a total of 13 horizontal wells in the Interior Platform play type. They are not currently drilling the play, nor do they mention the Swan Hills area in their 2011 corporate planning.

- Arcan, Pengrowth, Apache, and Penn West are all active in the Interior Platform with a total of 10 recently drilled locations and 11 licenses.
The Reef Debris Apron case study focuses on an example section at 36-065-10W5 where a total of five wellbores have been drilled, including two modern horizontal wells, with spectacular results. Most of the production from the section is thought to be primary, with little support from injection.

**Historical Development (2005 & Earlier)**

- The three wells drilled in 1964 and 1965 were originally stimulated by acid squeeze, with 3-month IPs between 24 and 53 bbl/d
- One of these, shut-in in 1972 at 17 bbl/d, was re-stimulated in 1978 with acid and brought back on at 42 bbl/d. A further acid fracture given in 2002 resulted in another production bump from 16 to 50 bbl/d. This well is still producing and has produced 274 Mbbl
- A second well, given the same acid and acid fracture re-works as the first, was suspended in 2007 after producing 117 Mbbl
- The third vertical well in the southwest corner of the section was converted to water injection in 1976 after producing 25 Mbbl. Because the injector is downdip from the other producers in the section, its impact on the section’s recovery factor appears to be minimal

**Modern Development (2006 & Later)**

- In 2010, two horizontal wells were drilled, one of which crosses into the adjacent section. The first, stimulated with only an acid squeeze, had an IP of 85 bbl/d
- The second horizontal was stimulated with multi-stage acid fracture leading to an IP of 300 bbl/d. This success
prompted the operator to re-stimulate the first well with a multi-stage frac, resulting in an increase from 22 to 45 bbl/d

- Both wells have shown outstanding results, and Penn West has very recently licensed at the end of April a third horizontal in the section

**Play Type Opportunities**

- There are 21 licenses issued in this play type, highlighting the interest in this low-risk infill drilling opportunity

- There are few undrilled sections in the play type, however drill density can be low. Most sections on the apron north of the Swan Hills reef produce from older wells, with only a few sections actively water flooded

- Abundant opportunities exist to infill these sections using modern techniques and to further enhance the recovery with efficient water flooding

### Major Players

- Penn West is the most active operator in the reef debris apron, with three recent drills and another 18 licensed locations
- Devon, Arcan and ARC also have exposure to the play type
Case Study: Play Type 6 - Swan Hills Reef Buildups - Conventional Reservoir

The Reef Buildups were the site of the first development in the Swan Hills complex, starting in 1957. The tremendous reserves are due to large net pay and high porosity (storage) with excellent deliverability. The Case Study focuses on section 14-064-11W5, at the north side of the Judy Creek buildup where a total of eight wellbores have been drilled producing 2.1 MMbbl to date.

Historical Development (2005 & Earlier)

- Four initial wells were drilled in 1960 and 1961. All were cased to total depth and completed with acid stimulations with estimated 3-month IPs of 80 bbl/d. Each was re-stimulated in the mid 1970s and produced between 228 and 821 Mbbl. Three were converted to injectors, the fourth was abandoned.

- On the north end of the section, a deviated well was drilled in 1985 and stimulated with an acid squeeze. It was re-stimulated in 1994, and then fracture stimulated in 2001 and 2010. All three work-overs resulted in production increases up to 75 bbl/d.

- The vertical well drilled in 2004 (06-14) was acid squeezed and generated a 3-month IP of 38 bbl/d. It was re-stimulated in 2008, resulting in a rate increase from 12 to 30 bbl/d.

- Injection began in one well (SW corner) in 1976 but it had little effect on the section’s decline. The second injector drilled in 1991 was successful in providing pressure support and stabilizing production. The four injectors on the section are still actively pumping into the top 55 m of carbonate.

Modern Development (2006 & Later)

- In 2007, a horizontal well was drilled up-dip from all the injectors, in the top 25 m of porous carbonate.

- It was completed open hole (acid squeeze) and had an IP of 205 bbl/d.
• An acid frac recompletion in 2009 increased the rate from 25 to 90 bbl/d, and the well has produced 68 Mbbl to date

Play Type Opportunities
• As this case study illustrates, the reservoir continues to be more than capable of delivering volumes, even after more than 50 years of production
• Work-overs with acid fracs are able to bump production rates and it appears often without accelerating the decline
• Secondary recovery from waterflood continues to be successful, and a few operators are conducting CO₂ pilots

Major Players
• Pengrowth is the most active company with four recent horizontals producing, six new locations drilled and seven licenses. In their latest investor presentation they have identified 2.3 Bbbl OOIP (net) over the Swan Hills Complex, including Carson Creek gas condensate (not dealt with in this report)

Devon and Penn West are also active in this play type with one and two licenses respectively
• Coral Hills recent horizontal well at Virginia Hills is awaiting completion
The Leeward Platform case study focuses on an example section at 02-069-11W5, where a total of eight wells have been drilled producing 2.6 MMbbl of oil. Current production from this section is 46 bbl/d. Many sections in the Leeward Platform remain sparsely drilled.

Historical Development (2005 & Earlier)

- Four vertical wells drilled between 1965 and 1966, with 3-month IPs ranging from 64 bbl/d to 88 bbl/d. These wells have combined production of 2.17 MMbbl
- One was converted to a water injector which was abandoned in 1978 and does appear to have supported production
- A horizontal well was drilled in 16-02 in 1995 with a 600 m horizontal leg, and had an IP of 151 bbl/d
- The production plot shown on the next page is the most recent drill on this section: a dual-leg horizontal at 06-02 in August, 2000. It was whip-stocked from one of the original vertical wells with two, 600 m horizontal legs, and had an IP of 124 bbl/d (producing day rate). It was re-stimulated in July, 2003 with another acid squeeze, resulting in an increase in production from 33 bbl/d to a peak rate of 85 bbl/d

Modern Development (2006 & Later)

- There has only been one horizontal well drilled in the Leeward Platform since 2006, and it is not in the case study section.
- In August, 2008, Sure Energy drilled 102/10-23-065-13W5/02 at Virginia Hills. The 1,000 m horizontal leg was completed open-hole with a multi-stage acid squeeze. The IP was 52 bbl (producing day rate) but the production rate has been flat for some time suggesting a poor fracture treatment of the well bore
### O2-069-11W5 Reservoir Parameters

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### Play Type Opportunities

- The Leeward Platform is one of the least developed play types with only six horizontal producing wells, leaving most of the play untouched.
- While the permeability is relatively low, the development to date has proven that commercial oil is present within this play type.
- It is reasonable to expect that application of multi-stage acid fracture stimulations will generate production rates that are significantly better than seen in the wells that have been stimulated with an acid squeeze only.
- Water injection has been shown to be effective and tertiary (CO₂) schemes may also increase recovery factors.

### Major Players

- Apache operates the five historical horizontal wells, and Sure Energy drilled the only modern horizontal well.
- Midway has three wells licensed in the Leeward Platform, and according to their corporate presentation they estimate more than 140 horizontal drilling locations on their Swan Hills lands.
Case Study: Play Type 8 - Tidal Banks - Unconventional Reservoir

The Tidal Banks case study is similar to the Leeward Platform in that it has been relatively underdeveloped. In fact, while there are a total of 13 horizontal producing wells in the play type, all of these were drilled prior to 2006. However, Coral Hill has two recently rig-released wells: one in December, 2010 that is confidential, and another in February, 2011 which does not yet have production available. The case study area for this play type is 640 acres that covers the east half of 22-069-11W5 and the west half of 23-069-11W5 and has six wells drilled into the play type.

Historical Development (2005 & Earlier)
- The first two wells were drilled in 1966. The second well was converted to a water injector after having produced 33 Mbbl, but the first well had a cumulative production of 527 Mbbl before being whip-stocked to a 500 m horizontal leg in 1994.
- This horizontal well at 02-22 had an IP of 200 bbl/d, and has produced a total of 189 Mbbl.
- A third vertical well drilled in 1977 produced 258 Mbbl and was then whip-stocked in 2001 to a dual-leg horizontal. It had an IP of 270 bbl/d with a simple acid squeeze.

Modern Development (2006 & Later)
- The only modern development in the Tidal Banks has been two recent drills by Coral Hill (05-27-066-13W5 and 16-21-066-13W5), which are not in this case study section.
- The first has a 1,500 m leg and was completed with a multi-stage acid frac but the production is not yet available. The second well’s results remain confidential.
Figure 57: Tidal Banks
15-22-069-11W5 Production Plot

Figure 28: Tidal Banks
Operator Table

### 22-069-11W5 Reservoir Parameters

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<td>Cumulative Oil to Date</td>
<td>1.1 MMbbl</td>
</tr>
<tr>
<td>Recovery Factor</td>
<td>33%</td>
</tr>
<tr>
<td>OOIP/ Section</td>
<td>3.5 MMbbl</td>
</tr>
</tbody>
</table>

Play Type Opportunities

- This example section has a recovery factor of 31%, but has yet to have any long horizontal wells (1,000 m or greater) or multi-stage acid fracture stimulations. Water injection has also proven to be effective, but has not been implemented beyond the one injector well.
- The southwest area has some very large producing vertical wells but to date the drilling density is very low.
- The north part of the Tidal Banks is more densely drilled and also has some excellent producing wells. Here there is still an opportunity to infill and apply secondary (waterflood) and tertiary (CO2) recovery schemes.

Major Players

- Apache and Penn West have drilled the only existing horizontal wells, however, they have not drilled any modern, long leg, horizontal wells with multi-stage fracs.
- Coral Hill is the only company with recent development, including two new drills that do not have production information yet, as well as two more licensed locations.
Case Study: Play Type 9 - Patch Reef Platform - Unconventional Reservoir

The Patch Reef Platform is the least developed play type in the Swan Hills Complex. The first well was drilled into the play in 1965, but there are a total of only 16 vertical wells and four horizontal wells – all four of which have been drilled since 2006. Due to the low number of producing wells, and the associated low drilling density in the Patch Reef Platform, this case study will examine each of the horizontal wells in addition to the three vertical wells that have accumulated more than 100 Mbbl.

Historical Development (2005 & Earlier)

- The first well drilled into this play type was a vertical at 04-18-064-09W5 which had an IP of 47 bbl/d and has produced 217 Mbbl. It was then whip-stocked in 2007 to a 1,000 m horizontal leg which had an IP of 123 bbl/d and has produced 22 Mbbl
- Two more vertical wells were drilled in the 1980s and have combined to produce more than 155 Mbbl

Modern Development (2006 & Later)

- Arcan has drilled two horizontal wells since 2006 into the play type. The first (02-27-065-08W5) was completed with only an acid squeeze and had an IP of 30 bbl/d. The second (06-36-065-09W5) had an IP of 208 bbl/d from a relatively short lateral of approximately 500 m
- This well was re-completed in 2011 and with a multi-stage acid fracture increasing production from less than 20 bbl/d to 102 bbl/d
- The most recent horizontal well in the public domain is the Coral Hill 13-20-064-09W5. While completion results and operating hours are unavailable since the well is confidential, the volumes produced for the first three months provide us with an initial calendar rate of 166 bbl/d with 452 bbl/d recorded in March 2011
- In addition, Second Wave has announced results from their recent horizontal well at 15-36-063-10W5 having a 15-day rate of 1,570 bbl/d
• It may be that deliverability can be further enhanced by drilling proximal to faulting

**Play Type Opportunities**

• The Patch Reef Platform provides the greatest amount of untapped resource in the Swan Hills Complex. It has a large aerial extent with a well density that is less than one well per section

• While the OOIP for section 25-063-10W5 is the lowest of the play types at 1.6 MMbbl per section, recent drilling results using modern completion techniques have proven to be excellent

• A drilling program targeting four wells per section to start could provide outstanding deliverability. While more time is needed to see how these wells perform, higher drilling density and the implementation of enhanced recovery techniques could support a 50% recovery factor

**Major Players**

• Each of Arcan, Coral Hill, Second Wave, and EOG have newly drilled wells into the Patch Reef Platform (waiting on completion). Coral Hill and Second Wave have licensed four additional locations, while Pengrowth has six licensed locations
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