Wainwright Area Drilling Data Analysis

April 5, 2018

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Cover Image

[1] Y. Hussain, "Some Canadian oil producers are shunning home basins for U.S. plays," Financial Post, 17 September 2015. [Online]. Available: http://business.financialpost.com/commodities/energy/some-canadian-oil-producers-are-shunning-home-basins-for-u-s-plays. [Accessed 19 March 2018].

Capstone Project Report

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5 April 2018

Mentor Acknowledgement

We would like to take this time to express our gratitude to Mr. Chris Gallant, for providing us with valuable insight into the world of petroleum engineering project developments and for warmly welcoming us into Enerplus. We would like to also thank him for allowing us to collaborate on a project that has increased our level of knowledge that pertains to the specific field of drilling operations.

We would like to thank Mr. Michael Wilton for providing us with useful criticism throughout the phases of the project and insight as to how things function on a day-to-day basis within the Enerplus workplace.

We would also like to thank Mr. Tom Mills for co-ordinating the project and for welcoming us into Enerplus.

Our thanks also go out to the whole Enerplus team that welcomed us and treated us as one of their own from the day we walked in to the Enerplus work environment.

The research put together over the past 12 weeks and the knowledge and guidance provided throughout the whole experience could not have been accomplished without these three individuals.

Sincerely,

Ali Mukyan, Yong Wook (David) Lee & Matthew McDonald

Executive Summary

The purpose of this report is based on Enerplus' recent interest in developing a region located in Wainwright, Alberta. This region was last developed by Enerplus in 2013 and has regained their attention as of recently. The company has chosen to collect publicly disclosed data from offset wells utilizing reputable sources such as the Alberta Energy Regulator and softwares such as GeoSCOUT and AccuMap. The information gathered was sorted through and analyzed in order to determine what can be beneficially put to use when developing Enerplus' proposed wells and what should be avoided/fixed in order to increase effectiveness and efficiency throughout the lifetime of the project.

Companies such as Devon Canada Corporation, Husky Oil Operations and Repsol Oil and Gas Canada Incorporation developed their own set of wells in the Lloydminster formation. All of the companies mentioned utilized well designs that are common to the Wainwright region and did not have to deal with significant issues that impacted costs associated or time requirements drastically.

Gear Energy Limited and Devon Canada Corporation are the two major competitors that developed wells that reached into the General Petroleum formation. Gear chose to develop all of their dual-leg lateral wells in the General Petroleum formation, while Devon decided to use a variety of horizontal well setups, ranging from a single-leg, dual-leg, three-leg, four-leg and even an eight-leg lateral well in order to make contact with the formation. Issues did not exist for both of Enerplus' Wainwright area competitors, but wells were developed in an untimely manner, which ultimately impacts the cost associated in developing the project, a parameter Enerplus seeks interest in reducing.

Baytex Energy Limited and Broadview Energy Limited were two competitors that had wells reaching into the Sparky formation. Significant wellbore issues did exist for both companies, such as a stuck pipe issue for Broadview and a lost circulation issue for Baytex. Drilling procedures may have been the potential factor for these issues, but an extensive look into what caused the issues to occur is required in order to develop a conclusive reason, which did not occur due to the timeline provided for the project, as well as the scope of the report.

Gear Energy Limited and Devon Canada Corporation have also developed wells that reach into the Cummings formation. Single-leg lateral wells was implemented by Gear Energy Limited, but there was an emphasis on the usage of multi-leg lateral wells for the particular formation. Wellbore issues did not exist, a factor that both companies benefitted from.

Other information regarding well development techniques, lithology, drilling fluid types, additives, depths and casing parameters were also discussed in order to understand the factors that play a vital role in the proper development of a well.

It was concluded that extensive research by the Enerplus team must be built on top of the report developed in order to determine whether the proposed project plan is viable or impracticable. The process of developing a conclusion for the project involves numerous other steps prior to making a final decision. The steps following the development of this report will require numerous months of extensive analysis of the fundamental information provided before deciding the fate of the proposed project.

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Introduction

The report will discuss and provide a complete understanding as to how Enerplus has approached the development of a drilling project, and how information gathered from surrounding wells through the utilization of public data sets and numerous other credible sources are used in order to curate a well that would compose of effective and efficient procedures.

Purpose

The report will thoroughly explore and educate readers about the development of the region of interest, as well as inform them with how the approach taken has assisted in developing a well plan that utilizes elements from numerous drilling procedures from competitors. This act would allow the company to develop their own set of drilling procedures in order to reduce the costs involved, as well as bring in effective results throughout the lifetime of the project.

Scope

The focal point of this report is on the development of a specific region in Wainwright, Alberta, where Enerplus has previously operated in the past. Enerplus is interested in returning to the area in order to develop a region where several competitors surround the planned operations. In the planning phase, Enerplus is utilizing key data provided by competitors in the surrounding region in order to analyze and discuss specific methods used throughout the drilling processes that are deemed to be successful, while also speaking about the issues encountered throughout the development of the well and how Enerplus can avoid these issues. Using all the information collected from the competitors, Enerplus will curate their own well development plan in order to reduce the costs associated with the development of the project, while providing effective results throughout the development and operational phases of the project.

Method

The technical report will utilize a variety of resources, specifically being reputable online articles, data collected from programs such as GeoSCOUT and AccuMap, information provided by companies such as the Alberta Energy Regulator (AER) and the experience and information provided by the mentors of the project.

Preview

The report will go into detailed depths about the Project Development Background, the formations of interest, and all of the operators that specifically operated in each of the formations that Enerplus is currently looking into for development purposes. Other information that is integral to the development of the well, such as drilling fluid and drilling techniques will also be discussed. The conclusion will tie up all of the analysis and research made by stating what the information developed has assisted in achieving and the appendix will provide additional support and conclusive evidence of all of the data collected, alongside comparisons made utilizing various types of charts in order to convey a point.

Project Development Background

Enerplus has chosen to revisit a region that was previously explored to search for a region in the subsurface that may contain valuable natural resources, located in Wainwright, Alberta. This region contains numerous operators in the region who are also developing and operating wells in search for valuable resources.

While in the planning phase, Enerplus has chosen to take an innovative approach to the development of the drilling plan by utilizing public information provided by the operators and the Alberta Energy Regulator (AER) in order to come up with information that the company can use to their advantage. Enerplus will compile the information provided from offset wells and make key decisions that will assist in the planning of the drilling procedure. The information that Enerplus will look at will revolve around how some companies utilized specific methods in order to reach a target zone effectively, and why the operator may have utilized the method. On the other hand, Enerplus will also investigate unsuccessful procedures committed throughout the drilling phase in order to understand why that specific method was not beneficial to that region in the subsurface, and how Enerplus can make changes to the unsuccessful acts in order to mitigate the impacts of any unwanted errors.

The subsurface formations that Enerplus is currently looking into include the Lloydminster Sand, Sparky Sand, Cummings Sand and General Petroleum Sand formations, which make up a part of the Mannville group. Enerplus’ previous experience in the region, alongside other operators specifically have proven to be successful. The region’s proven production capability is one of the primary motives for Enerplus’ reason for re-visiting the Wainwright, Alberta region.

Enerplus has decided to utilize a ±50-kilometer radius search criteria from their point of interest in order to allow the drilling department to come up with relevant and useful information that can be utilized to develop their own well program. The ability to increase the size of the radius allows Enerplus to furtherly investigate wells in regions outside of the original search, due to a lack of wells in the original surrounding region. On the other hand, Enerplus may choose to reduce the radius due to an overload of wells and information that pertains to those wells. Once the data has been collected, it would be sorted through and analyzed to ensure that the procedures utilized by other operators are relevant, effective and efficient for Enerplus’ own drilling program procedure.

As previously stated, Enerplus has operated within the Wainwright region, but has not drilled the region within the last two years. Information collected in the past can be utilized as sources of reference, but the data that exists in programs such as GeoSCOUT and AccuMap, as well as newly collected paperwork that relates to offset well data in the region will be highly beneficial to the development of the drilling program. The technology currently used by competitors in the region also play a vital role in effectively reducing costs and time required in order to reach the final stages of the development of the project.

Enerplus has been provided a project timeframe and budget that does not have much room for errors, meaning that the utilization of offset data information will mitigate the delays that may exist with a project that does not utilize competitors offset well data.

Methods of Data Acquisition

GeoSCOUT

Before the analyzing stage, the search criteria had to be selected. Since Enerplus wanted a more recent depiction of what was occurring in an area they had not drilled into in the past few years, a spud date cut-off was set at January 1st, 2017. There were enough wells drilled from the set date forward, making the project viable.

Understanding the need for not only recent data but also data specifically from the Wainwright region (the company's area of interest), it was decided to incorporate a 50-kilometer radius search area from one of their pre-existing wells. The Enerplus well at 6-13-47-5W4 became the point of reference for the area of concern. Another notable criterion entered in the GeoSCOUT software was that each of the wells to be used had to be horizontal and located within the Alberta border (as shown in figure one[1], with the 50-kilometer radius search area shown in red) [2].

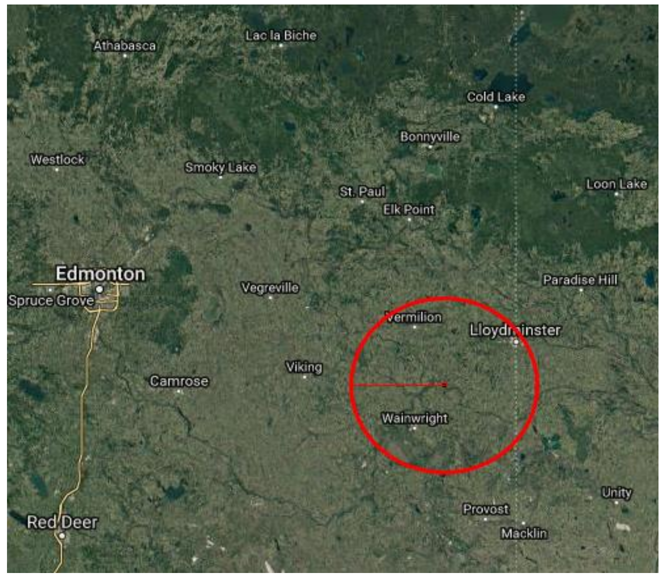

Figure 1: Highlighted 50-Kilometer Radius Search

Inputting the previously stated search criteria resulted in a list of 115 horizontal wells, ranging from single-leg laterals to dual and multi-leg laterals, as well as injectors that were not considered within the scope of the project [3].

Alberta Energy Regulator (AER) Tour Reports

Among the resulting wells there were specific well paths and designs that were of significance when comparing current operations to well designs previously developed by Enerplus. As they were considered a preference for Enerplus, single-leg lateral wells were of highest priority when it came to requesting tour sheets. Within the region of interest, many notable dual and multi-leg lateral wells were encountered. It was collectively decided that a few tour sheets that pertain to dual and multi-leg lateral wells should be analyzed, specifically from the operators Gear Energy Limited and Devon Canada Corporation. If Enerplus were to reconsider their current strategy to drill and produce the region, these specific designs from the previously mentioned operators would bring significant insight to future operations.

As all operators are required to provide tour reports to the Alberta Energy Regulator, there was much more and far more precise data than what could be found using GeoSCOUT's database [3].

[1] Google, "Google Maps," Google, 2018. [Online]. Available: https://www.google.ca/maps/. [Accessed 13 March 2018].

Formations of Interest

Mannville Group Background

The Mannville group within the Lloydminster area has been previously proven to contain an original oil in place (OOIP) value that ranges within 40 to 60 million barrels [4]. Tour reports from offset wells go back to 1988 display that companies have explored the region long ago and to this day still seek interest in initiating developments within the area [3].

Lithology

The formations that pertain to the scope of the project belong to the Mannville group [4]. Within the Mannville group are nine formations, with Enerplus seeking interest in potentially developing four of the nine formations. Enerplus' formations of interest are the Sparky Sand, General Petroleum Sand, Lloydminster Sand and the Cummings Member, as seen in figure two[2] [4].

The Sparky formation, the youngest formation of interest, is primarily composed of sand and shale. This specific formation has a maximum thickness of approximately 12 meters [5]. Up to 60 per cent of the original oil in place accumulated within the Mannville group exists within the Sparky formation [6].

The second formation of interest, the General Petroleum formation, contains very fine to fine grain sized quartzose sand. This formation has a maximum span of 15 meters [6].

The Lloydminster formation has a composition that includes unconsolidated quartz sand with silt. This composition has the ability to span a maximum of 30 meters, the largest thickness of all of the formations and members that Enerplus seeks interest in developing [6].

Lastly, the Cummings member, also known as the oldest formation of interest, contains shale with beds of lithic sandstone [6]. The Cummings member has a maximum thickness that spans 27 meters [6].

Collectively, operators see value in the region because of the compositions of each formation and how each formation has the capability to collect valuable natural resources over an expansive geological timeline.

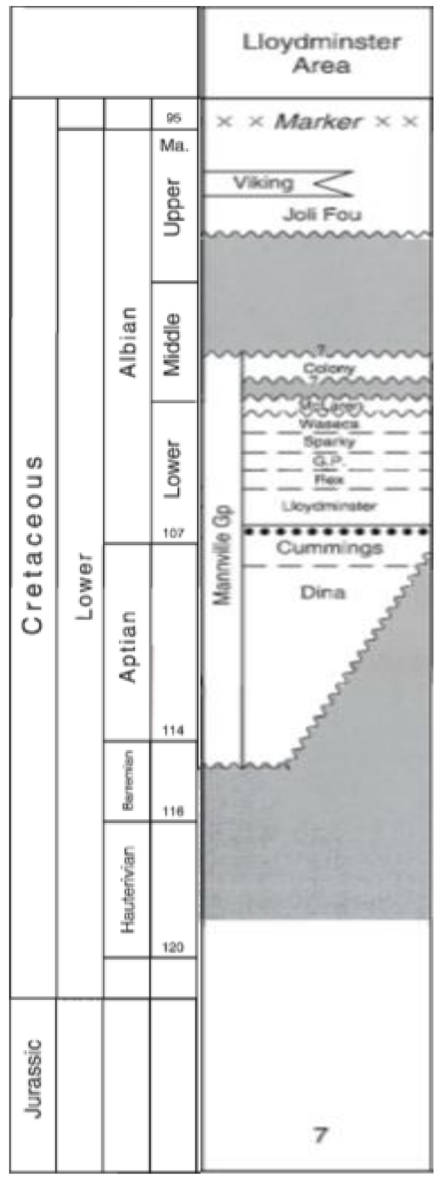

Figure 2: Mannville Group Geological Timeline

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[2] B. J. Hayes, J. E. Christopher, L. Rosenthal, G. Los, B. McKercher, D. Minken, Y. M. Tremblay and J. Fennell, "Chapter 19 - Cretaceous Mannville Group of the Western Canada Sedimentary Basin," Canadian Society of Petroleum Geologists, [Online]. Available: http://www.cspg.org/documents/Publications/Atlas/geological/atlas_19_cretaceous_mannville_group.pdf. [Accessed 26 February 2018].

Lloydminster Formation

Devon Canada Corporation

With six dual leg lateral wells (twelve laterals total) drilled into the Lloydminster formation, Devon Canada Corporation's wells should be a major consideration prior to drilling in the area [3]. Unique to the area, a dual build well is utilized to reach the proper true vertical depth and lateral leg length of their wells [7]. Unlike other operators with wells draining from the Lloydminster formation, that kickoff between roughly three and four-hundred meters deep, Devon' Lloydminster formation wells kickoff at two separate depths with a straight portion in between [7]. The straight portion is commonly known as a tangent section and can be very beneficial in controlling the build rate of a well while also providing a suitable place to land a pump. The first kickoff is at around 200 meters in measured depth, building until they reach an inclination of roughly 50 degrees, where they begin to rotate and drill a straight section, kicking off once again at around 700 meters in measured depth, building to their horizontal (around 90 degrees inclination) [7].

Another important thing to note is the casing string sizes within the wellbore; Devon uses a similar casing string in terms of diameters to that of Husky (as shown in the Devon's Lloydminster formation Stick Diagram in Appendix F and Table one) [8]. Although Husky Oil and Devon Canada's casings are of similar outside diameter, Devon Canada utilizes a heavier intermediate for their wells, thus having a higher burst and collapse rating to counteract the pressure exerted by the walls of the hole [7]. Their first two casing strings also seem to be set at similar depths, while the last liner is much shorter in Devon's wells than in Husky's [7] [9].

Devon Canada Corp. Lloydminster Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 167±9m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 992.75±145.75m	219.1	270	41.67	J-55	LT&C
Liner	978.1±148.2m - 1655.7±225.5m	139.7	200	23.07	J-55	LT&C

Table 1: Devon Canada Corp. Lloydminster Casing Parameters

Aside from the dual kickoff, major differentiation between Devon's wells and those of others within the Lloydminster formation is the fact that they utilize dual leg laterals rather than singles [3]. This allows them to produce from a wider area than with just a single horizontal, reducing the handicap of the shorter laterals and lack of water injection that others have.

Generally considered to be very challenging and rather expensive, Devon has also installed slotted liners in their dual leg laterals [7]. Typically, liners are only placed in single-leg lateral wells due to the complexity of hanging more than one string in a single intermediate. The added liners allow them to both reduce the amount of sand being produced, as well as ensure greater wellbore integrity. To sidetrack for the second lateral, the company decided to use a whipstock, a tool that would prove to increase the time to finish operations on the well [7].

Overall, Devon's design and method of drilling into the Lloydminster formation is rather unorthodox. Study of the well over the near future will allow Enerplus to confirm whether or not the production associated with such a design is enough to counteract the relatively long time on-site and associated capital expenditure.

Husky Oil Operations Limited

Husky Oil Operations Limited's data regarding the development of their wells are taken into consideration due to the amount of existing information that can assist in proving the viability of their project. Husky has a variety type of wells being developed, specifically being two single-leg lateral wells, one single-leg lateral injection well and two dual-leg lateral wells [9].

For the stick diagram developed, Enerplus has decided to base it off of the single-leg laterals wells formed by Husky. The operator's kickoff point initiates at a measured depth of approximately 300 meters, located just above the top of the Colorado formation (Appendix G) [9]. Husky's kickoff point exists much closer to the Colorado formation when being compared to Devon's dual-leg lateral wells, which have a kickoff point that initiates at a measured depth of just over 200 meters, roughly 110 meters shallower than the Colorado formation. The variance in kickoff points is due to the distinct types of well each operator in the Lloydminster formation is willing to utilize, such as the single-leg lateral wells and the dual-leg lateral wells, as well as the depth that the surface casings are set at, as seen in table two [8]. Another factor that plays into the varying kickoff points is the method in which each operator would like to approach the formation of interest. Each operator may have a distinct technique in which they believe can assist in maximizing the exposure they can achieve in the lateral zone of the well.

Husky Oil Operations Ltd. Lloydminster Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 193.5±2.5m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 956.75±108.25m	219.1	270	35.72	J-55	ST&C
Liner	949.8±97.1m - 2184±11m	177.8	200	23.07	J-55	LT&C

Table 2: Husky Oil Operations Ltd. Lloydminster Casing Parameters

Repsol, Devon and Husky all utilize the same grade of surface casing, intermediate casing and production liner, a factor that may prove that the casings that all three operators utilize are effective for the purpose of reaching the Lloydminster formation. Husky utilizes an intermediate casing with a lower burst and collapse rating and has successfully operated with the specific ratings ever since [9]. Repsol allows for a little more room for leniency by having the highest burst and collapse ratings for both the surface and intermediate casings, when being compared to Husky's casings [10]. Although a larger burst and collapse rating may be beneficial, higher costs are associated with the specific parameter. Based on Husky's success utilizing casings with a lower burst and collapse rating throughout their well development, it would be beneficial and cost-effective to utilize their specific types of casings.

The deepest total measured depth out of the three operators is set by Husky, with an average of 2212 meters [9]. This may potentially be due to allowing the operator to reach an extended region in the lateral portion of the well, where hydrocarbons may be stored. The length of the lateral portion of the well also allows for the proper placement of the liners that are to be utilized, and to allow room for an open hole region, which each operator develops as they see fit.

The overall design of Husky's single-leg lateral well seems to be a typical application for the Lloydminster formation and the Wainwright region, in which Husky has chosen to develop.

Repsol Oil and Gas Canada Incorporation

Repsol Oil and Gas Canada Incorporation, formerly Talisman Energy Inc., has developed four single-leg lateral wells that extend into the Lloydminster formation within the Wainwright region of Alberta. Enerplus has chosen to consider Repsol and their operations within the Wainwright region because of the amount of information available, in which comparisons can be made to, as well as Repsol's choice for developing wells that are all single-leg laterals and why the chosen method may have results that may be deemed effective.

On average, Repsol's casing depth is also set at lower depths when compared to Devon's and Husky's drilling stick diagram as well as table three [8] [10]. Reasons for placing surface casings at certain depths may play a role with the protection of groundwater. In past operations, companies have chosen to set surface casings at lower depths in order to ensure that all safety measures are taken when it comes to protecting aquifers that exist within the regions of operation.

Repsol's single-leg lateral wells require the shortest depth in order to complete the development of the well [10]. As previously explained, the total depth at which each operator chooses to stop at may be relating to the potential storage of hydrocarbons at that specific depth, since not all hydrocarbons that exist in the formation require extensive lateral portions.

Repsol Oil and Gas Canada Inc. Lloydminster Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 275±3m	244.5	311	48.07	H-40	ST&C
Intermediate	0m - 880±10m	177.8	222	34.23	J-55	LT&C
Liner	858±10m - 1175±15m	114.3	159	14.14	J-55	ST&C

Table 3: Repsol Oil and Gas Canada Inc. Lloydminster Casing Parameters

When comparing the average operation times of Devon and Husky to Repsol, Repsol has a slower process when it comes to drilling the surface hole [10]. Devon and Husky require an average of nearly four hours, while Repsol requires 14 hours [7] [9] [10]. Repsol also requires just over 29 hours to run the surface casing into the well and cement it, while Devon requires nearly 23.5 hours and Husky needing approximately 17 hours [7] [9] [10]. Lastly, another region in the well in which Repsol may require more time to develop is the intermediate casing and cementing portion, requiring just over 46 hours to complete the tasks associated [10]. Devon requires just under 28 hours to do the same task, while Husky requires just over 37 hours [7] [9]. Information regarding the average operational times can be found in Appendices A & B.

On the other hand, Repsol has also had efficient average operating times throughout the development of a well. Repsol only requires an average of nearly 21 hours to drill the intermediate portion of the well, while Husky requires over 33 hours to accomplish the same portion of the drilling program [9] [10]. Depths and execution techniques play a large role in the time required to develop specific sections of the well, as well as many other minor factors such as non-productive time (NPT) and downhole problems, even though none of the companies that have drilled in the Lloydminster formation encountered any downhole issues.

Overall, Repsol utilizes a technique quite similar to what Husky uses in the region, except for the fact that the majority of the well development processes revolved around the excess amount of time Repsol required in order to accomplish similar tasks.

General Petroleum Formation

Gear Energy Limited

Gear Energy Limited is one the largest operators that exist within Enerplus' ± 50-kilometer radius region of interest [3]. The company has 11 wells that utilize a diverse number of legs in order to potentially attain hydrocarbons that may exist in the proximity of the wells developed [3]. Of the 11 wells mentioned, Gear Energy has six two-leg lateral wells, one three-leg lateral well and four four-leg lateral wells [3]. The General petroleum formation utilizes all six of the two-leg lateral wells, which totals out to 12 lateral sections [3].

Gear's plan revolves around the idea of utilizing dual-leg laterals in the General Petroleum formation in order to maximize the amount of production that exists in the subsurface region, while minimizing the sand intake that each liner will encounter, which in turn will reduce the damaging effects that the sand has on the wellbore system.

Based on the averages involved across all six dual-leg lateral wells, Gear sets their surface casings at a measured depth of nearly 130 meters, as seen in Appendix I and table four [8] [11]. The depth of the surface casing is quite different when compared to Devon's operation in the General Petroleum formation. Devon sets their surface casing at a measured depth of approximately 175 meters, a 40-meter difference in depths (Appendix J) [7]. However, the kickoff point for Gear Energy is well below the measured depth that Devon chooses to initiate a kickoff point [7] [11]. Gear Energy starts off the kickoff point at nearly 315 meters in measured depth, while Devon Canada initiates a kickoff point at approximately 230 meters in measured depth (Appendix I & J) [7] [11]. This goes back to the method in which operators decide on how to approach a lateral region, as well as the technology utilized at that time that would assist them in achieving the deviations required to reach the lateral portion of the well and the development of the lateral section of the well.

Gear Energy Ltd. General Petroleum Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 133.25±3.45m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 869.75±46.75m	219.1	270	41.67	J-55	LT&C

Table 4: Gear Energy Ltd. General Petroleum Casing Parameters

Gear's dual-leg lateral wells have an intermediate casing set relatively close to the depths that Devon has chosen to set their intermediate strings at [7] [11]. Both operators also utilize an open hole lateral section, with Gear having the larger lateral distance when compared to Devon Canada's lateral portion of the well [7] [11]. The reason for utilizing an open hole lateral section may be due to costs associated with implementing multiple liners. Using multiple liners do bring benefits when it comes to wellbore stability and filtration of sand, although the costs and time associated with implementing such a complex process can begin to outweigh the benefits.

As previously mentioned, implementing slotted liners in each of the dual-leg lateral wells may increase the complexity involved in the development program. Costs of the liners also increase the amount of money required to develop a project, impacting the viability of the project drastically. Instead, Gear Energy has chosen to utilize an open hole lateral section in order to extract the hydrocarbons that may exist in the formation.

Devon Canada Corporation

Devon Canada is also known to utilize wells that vary in the amount of lateral sections that exist in one well. In the General Petroleum formation, Devon Canada has one single-leg lateral well, five dual-leg lateral wells, one three-leg lateral well, one four-leg lateral well, and one eight-leg lateral well [7]. The five two-leg lateral wells were chosen in order to develop a stick diagram and provide a comparison to the six dual-leg lateral wells that Gear Energy has developed.

The well developed utilized surface and intermediate casing that varied in sizes when compared to Gear's casings utilized. First, Devon required a smaller hole size in order to develop their well from the surface to the lateral section [7]. Devon started off with a 311 millimeters surface hole size, as seen in table five, while Gear developed a hole that was 375 millimeters in diameter [7] [8] [11]. Devon chose to implement a surface casing that has a grade rating of J-55, a grade that is higher than the H-40 Gear utilizes for their wells (Appendix I). The higher grade infers that the burst and collapse rating is also larger in value, allowing more room for leniency when dealing with well and formation pressures. The same case applies for the intermediate casing, with Devon utilizing a L-80 grade intermediate casing, while Gear chose an intermediate casing with a grading of J-55 (As shown in Table four & five, as well as Appendix I & J) [7] [8] [11]. Although a higher grade of surface and intermediate casing may be beneficial, Gear's utilization of a lower grade casing for both sections of the well did not encounter any form of wellbore issue in regards to pressures. This would mean that the lower grade of casing would also be suitable for the job, assisting Enerplus in reducing the costs associated with the project.

Devon Canada Corp. General Petroleum Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 176.25±16.75m	244.5	311	53.58	J-55	ST&C
Intermediate	0m - 875±56m	177.8	222	34.23	L-80	LT&C

Table 5: Devon Canada Corp. General Petroleum Casing Parameters

The bits utilized in order to drill the surface hole, main hole and lateral section of the wells varied in bit type. Gear and Devon decided to use a tooth bit type in the surface hole, but in the intermediate hole Gear Energy chose to use a Polycrystalline Diamond Compact (PDC) bit, while Devon proceeded with the use of a tooth bit (Appendix I & J) [7] [11]. The composition and geological structures that exist in the subsurface are not uniform, therefore meaning that the type of bit used has to fit the criteria of the formation that is being drilled.

When comparing the average operational times involved in the development of the wells, Devon proves to be efficient in certain sections, while in other sections, improvements can be made in order to ensure that jobs are done effectively and efficiently. Devon requires nearly 10 hours less than what Gear requires in order to drill the intermediate portion of the well (Appendices A & C) [7] [11]. The depths at which intermediate casings end at play a large factor, but in this case the depth for both operators are very similar. Devon proves to be efficient in the lateral drilling portion of the well plan, requiring only 15 hours on average to complete the task [7]. Gear requires nearly 43 hours to accomplish the same task [11]. This may be due to the depth that Gear has chosen to set their dual-leg lateral wells at. Devon is known to be a little slower when it comes to placing and cementing the intermediate portion of the well, six hours in time difference to be exact [7].

For this case, Devon's practices seem to be the best when developing a well that extends in to the General Petroleum formation, since the levels of efficiency and effectiveness are evident.

Sparky Formation

Baytex Energy Limited

Baytex Energy Limited is also one of the larger operators to exist within the Wainwright region. The company operates all of their 13 wells in the Sparky formation, with one of the wells being a dual leg lateral and 12 of the wells being a single leg-lateral, making up 14 lateral sections in total [12]. The stick diagrams developed for Baytex focus on the 12 single-leg lateral wells and the parameters that coincide with each well's data.

Beginning with the kickoff point, Baytex decided to initiate the deviation of the well at a depth that was significantly different when compared to Broadview Energy Limited's well data. Baytex decided to place their surface casing at an average measured depth of approximately 125 meters, as seen in table six, while Broadview decided to set their surface casing at an average measured depth of 218 meters (Appendix K & L) [8] [12] [13]. Both operators decided to utilize slotted liners in the lateral section of the well in order to ensure that the integrity of the wellbore is not compromised during operational phases.

The type of casing and liners used to develop the wellbore had parameters that varied. Baytex developed a larger average hole size, meaning that the surface casing, intermediate casing and liner size would be larger in size when compared to the likeness of Broadview's casing parameters (Appendix K & L). Baytex and Broadview have the same surface casing grades, but Baytex's surface casing had a larger unit mass per length (kg/m), while Broadview's surface casing had a larger burst and collapse rating [12] [13]. Both operators decided to utilize a J-55 casing grade throughout the intermediate hole [12] [13]. For the liners implemented in the lateral portion of the well, Baytex decided to utilize a J-55 grade liner, while Broadview utilized an L-80 grade liner [12] [13]. Both liners proved to be effective, since no wellbore integrity issues were mentioned throughout the tour sheets provided [12] [13].

Downhole problems did exist within the well for both operators. An incidence that involved lost circulation in the surface hole was evident in one of Baytex's wells [12]. This issue may be due to the drilling procedures involved in the program.

Baytex Energy Ltd. Sparky Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 127.5±4.5m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 818.5±79.5m	219.1	270	47.62	J-55	ST&C
Liner	796.2±75.3m - 2188.5±61.5m	139.7	200	25.3	J-55	LT&C

Table 6: Baytex Energy Ltd. Sparky Casing Parameters

Baytex's implementation of single-leg lateral wells throughout the majority of their operations in the Wainwright region of Alberta have proven to be successful, since all wells have been developed with minimal issue occurrences. The average operation time comparison between the two operators will be discussed in the following section and will go into an in-depth analysis of how Baytex was able to effectively reduce the time required to develop certain portions of the wells, an issue that Broadview encountered throughout some of their processes.

Broadview Energy Limited

In comparison to the operators that exist within the Wainwright area, Broadview Energy Limited is considered one of the smallest companies. The operator utilizes two single-leg lateral wells within Enerplus' ± 50-kilometer radius region of interest [13].

The bits that were utilized, alongside the drilling fluids used in the surface hole, intermediate hole and the lateral hole vary. Broadview chose to use a water-based drilling fluid in order to drill all three sections of the well (Appendix L) [13]. Baytex used a variety of drilling fluids throughout the drilling program, beginning with a water-based drilling fluid in the surface hole, a Gel-Chem Water type drilling fluid in the intermediate hole and a Polymer-water type drilling fluid in the lateral portion of the well [12]. The lost circulation that Baytex encountered may have ties to the type of drilling fluid utilized in that portion and the procedures involved in order to attempt to stop lost circulation from occurring.

Broadview also encountered issues in their well development process. After completing the drilling processes that occurred in the lateral portion of the well, Broadview had a stuck pipe occurrence [13]. This issue may play a factor in increasing costs in order to deal with the issue, as well as increasing the time required to complete the development of the well. Enerplus' purpose of the report is to understand and mitigate or prevent the effects of having issues that pertain to the drilling processes of each well, therefore Enerplus must investigate other methods that can mitigate occurrences from happening where the cost and timeline of the project require changes that are non-beneficial overall.

Broadview Energy Ltd. Sparky Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 218±2m	244.5	349	48.07	H-40	ST&C
Intermediate	0m - 812±5m	177.8	222	34.23	J-55	LT&C
Liner	798±13m - 2228±194m	114.3	159	17.26	L-80	LT&C

Table 7:Broadview Energy Ltd. Sparky Casing Parameters

Broadview's comparisons of average operation times required to develop a well seemed to be an issue. When comparing the time Baytex and Broadview required to drill the surface hole, Baytex only required just under half of the time Broadview needed. The depths at which the surface casing vary by approximately 90 meters, as seen in table six and seven, but should not require Broadview an extra 7.5 hours to complete the task [8] [12] [13]. Broadview required on average 12 hours less to place the surface casing and cement it when compared to Baytex's times (Appendix A & D) [12] [13]. Broadview was also efficient in placing the intermediate casing in the wellbore and cementing it, requiring approximately eight hours less than what Baytex required [12] [13]. The major issue in time required pertains to the drilling of the lateral portion of the well, as well as the time required in order to conclude operations. Baytex required approximately 31 hours to drill the lateral section, while Broadview required an additional 46 hours to accomplish the same task [12] [13]. Broadview also required an additional 48 hours to conclude operations on the well [12] [13]. Both scenarios that require Broadview additional time play a crucial role in costs and efficiency associated with the project.

Broadview's utilization of two single-leg lateral wells make sense when it comes to developing in the Wainwright region, however the issues that Broadview has with the time required to develop certain portions of the wellbore may potentially drive up factors that Enerplus is looking to reduce.

Cummings Formation

Gear Energy Limited

In the Cummings member, Gear Energy Limited decides to utilize a three-leg lateral well and five four-leg lateral wells [11]. This totals out to 19 lateral sections that exist in the Cummings member under the operations of Gear Energy Limited [11].

The approach that Gear has utilized in the Cummings member is quite unique, however it can be considered to be a non-cost-effective method to utilize when developing each well. Large-scale volumes of hydrocarbons and sands would have to exist in the Cummings member in order to have wells that have three to four lateral sections each. Wellbore integrity may be an issue in the formation, however Gear chose to utilize an open hole setup instead of utilizing slotted liners (Appendix M). The open hole setup would also reduce the complexities that would be added if liners were to be utilized in each lateral section of the well.

Devon Canada Corporation, Gear's competitor in the Cummings member, developed wells that varied in sizes as well (Appendix N). A difference that exists between the two operators is that Devon chose to focus on developing more single-leg lateral wells in the Cummings member, with a slight focus on multi-leg lateral wells. Gear chose to develop all of their wells utilizing a multi-leg lateral setup only (Appendix M).

Gear Energy Ltd. Cummings Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 131.5±4.5m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 911.25±43.75m	219.1	270	41.67	J-55	LT&C

Table 8: Gear Energy Ltd. Cummings Casing Parameters

In the lateral section of the well, Gear decided to leave them as open holes instead of implementing liners in each of their lateral sections. This act would reduce time required to develop the wells and costs associated but may eventually lead to wellbore integrity issues that can exist in future production related tasks [11]. Devon implemented liners in their wellbores to ensure that sand production does not occur in large volumes, while simultaneously reducing the potential chances of having wellbore integrity issues occurring in the future [7].

Gear also decided to place the surface casings of their wells much closer to the surface when compared to Devon's plans, as seen in table eight and nine, but decided to initiate a kickoff point at a deeper depth, sitting well above the top of the Colorado formation (Appendix M & N) [7] [11]. This factor may be due to Gear's interest in developing multi-leg lateral wells only, while Devon puts an emphasis on developing single-leg lateral wells.

The utilization of multi-leg lateral wells would only become beneficial for Gear if they are able to prove that there is a significant amount of natural resources stored in the Cummings member, otherwise the viability of the project would tarnish due to ineffective spending of capital resources that have been allocated for this project.

Devon Canada Corporation

Devon Canada Corporation has chosen to develop two single leg-lateral wells, alongside one four-leg lateral well in the Cummings member [7]. Devon has also participated in developing wells that reach into the Lloydminster and General Petroleum formations, displaying that the Wainwright region of Alberta is of significance to the company overall [7]. The company has also utilized a variety of well setups, ranging from single leg-lateral wells to multi-leg lateral wells, which is also evident in the Cummings member (Appendix E) [7].

Instead of developing numerous dual-leg and multi-leg lateral wells, Devon chose to implement more single-leg lateral wells in the Cummings member [7]. The single-leg setup that they have chosen to utilize in the formation allows the operator to implement liners within the wellbore (as seen in table nine and Appendix N), since the Cummings member is the deepest formation of interest that Enerplus seeks interest in potentially developing [8]. The lithology of the formation, primarily being shale and beds of lithic sandstone also play factor in the stability of the wellbore. Devon's

Devon Canada Corp.Cummings Casing Design						
Casing String	**Depth (m)**	**OD (mm)**	**Hole Size (mm)**	**Weight (kg/m)**	**Grade**	**Coupling**
Surface	0m - 191±1m	298.5	375	62.5	H-40	ST&C
Intermediate	0m - 853.5±10.5m	219.1	270	41.67	J-55	LT&C
Liner	846.55±11.85m - 1755±100m	139.7	200	23.07	J-55	LT&C

Table 9: Devon Canada Corp. Cummings Casing Parameters

intermediate portion of the well required a single phase to complete, while Gear's intermediate portion required two phases. The two phases are due to the deviated and non-deviated portions of the intermediate hole. Instead, Devon chose to deviate the well shortly after implementing the surface casing, while Gear reached a depth further down in the subsurface prior to initiating a kickoff point (Appendix M & N) [7] [11]. None of the companies encountered issues that related to the intermediate or any other portion of the well, displaying that both methods utilized were effective in that particular aspect.

The average operation times required to develop each portion of the well for each company seemed fitting for the well plans that they decided to execute. Since Gear was choosing to develop multi-leg lateral wells, they required more time to properly drill the intermediate portion [11]. Gear also required more time to drill the horizontal sections of each well, since they required numerous lateral sections instead of a single lateral section, something that Devon chose to do (Appendix E) [11]. Devon required more time to place and cement their intermediate casing, which should have not been the case since their plan was not as complex as Gear's [7]. Issues such as cement blends for the specific portion of the well may have played a role in the additional time required. All other average operation times between the two companies, such as surface drilling, surface casing and cementing were very similar (Appendix E).

Overall, Devon's operations in the Cummings member seemed to be suitable, since the implementation of single-leg lateral wells utilized liners in order to deal with potential wellbore integrity issues and did not have any major issues that required excess capital in order to deal with the matter.

Exclusions

Based on the scope of the project, specific operators and their well designs were left out. The reasons pertaining to the exclusion of certain operators and their well designs were very similar. The following sections will go into an in-depth analysis as to why specific operators and well designs were treated as outliers.

West Lake Energy Corporation (Lloydminster Formation)

West Lake Energy Corporation utilized a unique three-leg and four-leg lateral well design in the Lloydminster formation [3]. The mentioned well designs would have been of significance to this report if West Lake utilized more three-leg and four-leg laterals or utilized single-leg or dual-leg laterals in order to allow the research team to be able to compare West Lake's designs to themselves or to other operators exploiting the Lloydminster formation. Devon, Husky and Repsol all utilized single-leg or dual-leg lateral wells, which assisted the research team in concluding that there is insufficient data on West Lake's end in order to develop comparisons for the report.

Spur Petroleum Limited (Sparky Formation)

Spur Petroleum Limited encountered a similar issue in the Sparky formation. The company is one of the smallest operators in the region, utilizing one four-leg lateral well that extends into the Sparky formation. Other than Spur, none of the companies that are developing in the Sparky formation utilize a four-leg lateral well, which proves as to why the company and their developed well in the Sparky formation was not utilized for comparison purposes in the report.

Unit 18 Corporation (Sparky Formation)

Unit 18 Corporation utilized a single-leg well that also reached into the Sparky formation. The company's lack of developing a larger amount of single-leg lateral wells, in which data can be utilized for comparison purposes prevented the Capstone research team from developing a section in the report that pertained to the findings of Unit 18.

Surge Energy Corporation (Sparky Formation)

Lastly, Surge Energy Corporation encountered the identical issue that Unit 18 Corporation faced. The company decided to develop a single-leg lateral well that also extended into the Sparky formation, but was left out of the report due to a lack of single-leg wells the company has decided to develop that reached into the Sparky formation.

Several reasons exist for the companies that decided to develop specific wells in the Lloydminster and Sparky formation. A motive for West Lake Energy Corporation and their reasoning for developing a three-leg and four-leg lateral was to potentially increase the size of the drainage area, alongside the production across all legs of the wells. The same reasoning applies to Spur Petroleum Limited and their development of a four-leg lateral well in the Sparky formation.

The companies that developed one single-leg lateral wells in the Sparky formation may not have had sufficient funding for the project and decided to utilize the limited monetary resources they had access to in order to extract resources that exist in the Sparky formation.

Special Cases

Full Legal Sub-Division (LSD) Drainage Well

Devon Canada Corporation has drilled quite a unique well in township forty-eight, range five. Their well, DEVON BH 5C-20 MAIN HZ WILDMERE 5-20-48-5, has eight separate horizontal legs spanning out from a single intermediate and surface portion [7]. After the original lateral was drilled to total depth, they pulled back to the start point of the next lateral, sidetracking off the first. Ranging from the high four-hundreds to low seven-hundreds of meters in length, spaced roughly forty-five to fifty meters apart, the eight open-hole completed laterals were designed to drain the entirety of LSD five in section twenty [3] [7]. Based on the characteristics of the General Petroleum formation's tight sandstone and the relatively small casing strings in the well (as shown in the Devon General Petroleum stick diagram in Appendix J), the application of such a well design seems to be an option for areas with relatively low production capability. Gear Energy Limited also designed their General Petroleum wells with multiple legs, proving that designs similar to this could be considered for future use within the formation in the Wainwright area.

Hydraulically Fractured Well

Although only two of the wells within the set radius for this report were planned by Broadview Energy Limited, they have a feature to them that makes them stand out from all the rest, a liner string with integral fractured ports installed in the lateral portion of the wellbore. Although Baytex Energy Limited also had Sparky formation wells in the region, they did not seem to see the possibility of fracturing the formation prior to production, similar to the depiction in figure three[3] [14]. The Broadview example that we used data from (Appendix L) incorporated twenty-nine fracture ports, each ten centimeters in length. The time required to case a well of this variety was much greater than that of other casing scenarios.

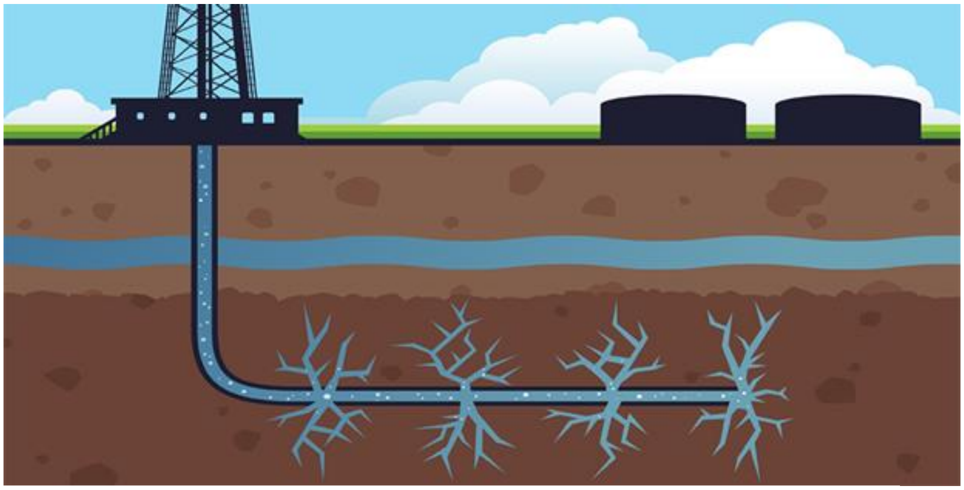

Figure 3: Hydraulically Fractured Well

The Sparky formation, as with many other formations in the area, is considered a tight deposit. Though it is an option to attempt to produce mid-grade oil through a typical slotted liner casing with no other stimulation, it may be a better option to fracture the formation prior to production. The Broadview wells and their associated production should be considered as a point of insight if Enerplus decides to drill a Sparky well in the future.

[3] Allspeeds Ltd., "Getting ready for UK Shale Gas," Allspeeds Ltd., 2018. [Online]. Available: http://www.allspeeds.co.uk/getting-ready-for-uk-shale-gas/. [Accessed 17 March 2018].

Water Based Drilling Mud

When compared to an oil-based mud, water-based muds are much cheaper, easier to dispose of, and generally easier to handle and maintain [15]. Water-based muds are drilling fluids composed primarily of water with additives used to flocculate, increase density (mud weight), increase gel-strength and viscosity among many other factors. For the purpose of this report, the main two types of drilling fluid used were water-based gel-chemical and polymer muds.

Gel-Chemical

For the region discussed throughout this project (the Wainwright area), the most common drilling fluid used to drill the surface hole was gel-chemical (Gel-Chem) water-based mud, displayed in figure four[4] [16].

Relatively cheap and easy to manage, a Gel-Chem drilling mud is composed mainly of water and bentonite [15]. The bentonite added to the water system enables the mud to easily flow while circulating, but gel when circulation is suspended. The "gelling" effect allows cuttings to be suspended when circulation is halted. Sufficient pumping force must be used to break the gel when circulation resumes [17]. Viscosity and gel strength of a Gel-Chem mud is mainly based upon the quantity of bentonite added [17]. It must also be noted that bentonite used in Gel-Chem drilling fluids is incompatible with shale inhibitors discussed later in the polymer section.


Figure 4: Drilling Fluid

The most common surface hole drilling fluid throughout Western Canada, Gel-Chem drilling fluids are typically of low density (1010-1050kg/m^3), though in some instances can be up to 1100kg/m^3 (as can be seen in the Devon Lloydminster stick diagram in Appendix H) [7]. A common surface hole problem is lost circulation, mainly due to a formation pressure lower than the hydrostatic pressure of the mud column. Considering a typical pore pressure gradient of roughly 10kPa/m and the common lost circulation issues found in surface hole drilling, Gel-Chem mud densities are generally kept as low as possible (while still maintaining an overbalance of course).

Overall, a Gel-Chem drilling fluid is very popular for surface hole drilling due to its easy to maintain and manage nature, as well as its relatively low cost and ease of disposal (more environmentally friendly than many other drilling fluids) [15].

[4] DrillSafe, "Drilling Fluids Series," DrillSafe, 22 January 2018. [Online]. Available: http://www.drillsafe.co.za/drilling-fluids-oils-and-greases/. [Accessed 28 March 2018].

Polymer

The most common main hole drilling fluid used by operators in the region is water-based polymer drilling mud. Polymers are additives used to manipulate the characteristics of the fluid, similarly to how bentonite is added in Gel-Chem drilling fluids.

A common reason to add polymers in the main hole portion of wells in the Wainwright area is shale inhibition [18]. While the composition of the formations being drilled through are primarily sandstone, there are small portions that are entirely shale [6]; clays can also be found within the pore spaces of sandstone formations [6]. When freshwater, with no additives, comes into contact with clays, sloughing (clay swelling) can be a major problem [18]. Swelling of clays can lead to both problems in the drilling process (e.g. stuck pipe) and the production of oil rich reservoirs (through the loss of porosity). Shale inhibition is the primary reason for using an oil-based mud over a water-based mud.

The typical density (mud weight) of water-based polymer drilling fluids used in the formations covered throughout this report (Lloydminster, Cummings, General Petroleum and Sparky) ranges from 1020 – 1080 kg/m^3.

Figure 5: Sacks of Bentonite on Wellsite Location

Common Additives Used

Common additives used in the horizontally drilled wells found in the Lloydminster, General Petroleum, Sparky, and Cummings formations are typically either used to decrease the risk of lost circulation, increase density, viscosity, or gel-strength of the fluid, or to inhibit swelling of clays encountered in the drilling process. Common additives (found using tour sheets) in the Wainwright region and their uses are as follows:

- Bentonite/Gel (increased gel strength, viscosifier) (found in figure five[5]) [17] [19] [20]
- Sawdust (prevention of lost circulation) [19] [20]
- Crushed walnut shells (prevention of lost circulation) [19] [20]
- Calcium Nitrate (shale inhibition/prevention of clay swelling/sloughing) [19] [20]
- Gypsum (shale inhibition/prevention of clay swelling/sloughing) [19] [20]
- Humalite (thinner, secondary filtration control) [19] [20]
- Calcium Chloride (shale inhibition/prevention of clay swelling/sloughing) [19] [20]
- Lignite (fluid loss control, shale deflocculant) [19] [20]
- Ash or Potash (increase pH/alkalinity, shale inhibition) [19] [20]
- Flocculants (e.g. Enerclear 1102, Hyperdrill 204, Hyperdrill 247) [19] [20]
- Viscosifiers (e.g. EnerPAC Lo Vis, Hyperdrill 204, Secure Vis) [19] [20]

[5] AES Drilling Fluids, "Drilling Fluids," AES Drilling Fluids, 2017. [Online]. Available: http://www.aesfluids.com/operations/about-drilling-fluids/. [Accessed 13 March 2018].

Methods of Reaching Desired Wellbore Deviation

Through in-depth analysis of tour sheet data from fourteen wells in the Wainwright region, there were two main means of reaching the desired well path and inclination, the use of mud motors and whipstocks.

Mud Motors

Composed of a bit box, bearing assembly, bend section, and power section, mud motors are the most common tool used to reach the proper well path in this day and age. Within the motor section there is a rotor and a stator designed similar to a progressing cavity pump (PCP), but work in the opposite way; where a PCP lifts fluids though power provided at surface, a mud motor is powered by the circulation of drilling fluid through the motor section, adding rpm (revolutions per minute) to the rotary rpm already provided by the Kelly or top drive [21].

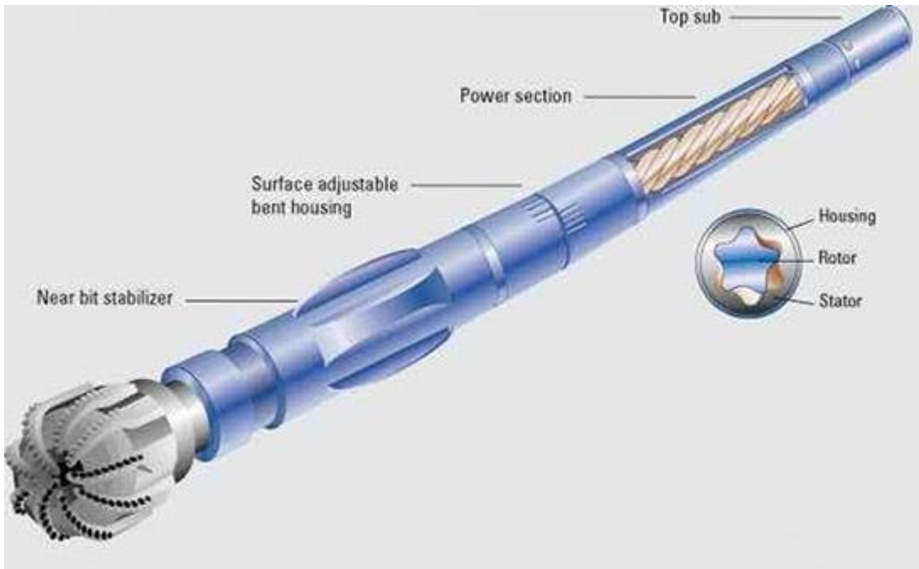

Figure 6: Mud Motor Components

Sliding is the term used when the mud motor is drilling directionally [22]. The process involves the bit being rotated by the power transfer from the rotor through connecting rods (in the bend section) and a driveshaft (in the bearing section) to the bit, all while there is no rotation of the drill string, (as seen in figure six[6]) [21]. The bit must be pointed in the desired direction with the proper bend prior to sliding, in order to reach the designed end point. With zero rpm being provided by the string, rpm is solely coming from the mud motor. Drilling the build section of the well typically takes longer (lower rate of penetration, ROP). Another thing to note is the that while drilling with the rotary on, the hole will track fairly straight, with a slightly larger than bit diameter hole due to the bend angle of the mud motor; the slightly over gauge hole size may be beneficial in tripping in and out of the well.

In terms of the wells within the determined 50-kilometer radius, mud motors were used when drilling all of the wells, considering the fact that all wells analyzed were horizontals. Though not used in the surface hole sections of the wells, each and every well in the area incorporated at least one mud motor while drilling the build section of the wellbore, some using multiple when forced to switch due to tool problems. Capable of reaching the desired inclination of 90° with relative ease, mud motors were the main means of reaching the desired well paths and the most common method used to sidetrack wells for dual or multi-leg laterals.

[6] DrillingFormulas.com, "Deviating the Wellbore by Positive Displacement Motor (Directional Drilling)," DrillingFormulas.com, 26 February 2017. [Online]. Available: http://www.drillingformulas.com/category/directional-drilling/page/2/. [Accessed 24 March 2018].

Whipstocks

The only other technique used to drill directionally in the area was the use of whipstocks. Though the vast majority of operators used only mud motors to sidetrack for new legs in dual or multi-leg laterals, Devon Canada Corporation decided to use whipstocks in their Lloydminster Formation wells [7]. The main reason it seemed for them to use whipstocks in addition to mud motors was that they had to sidetrack through a portion of the well that already had a casing string installed [7]. Forced to mill a window into the side of the intermediate casing string, the whipstock gave them an added push.

Unlike the concept of sidetracking with mud motors, where the bit is pointed via a specific bend set by the directional team at surface prior to running in hole, a whipstock is a tool set at a specific depth in the portion of the wellbore that works as a wedge pushing the bit in the desired direction, as seen in figure seven[7] [23].

Figure 7: Whipstock Process

When used in Devon's Lloydminster wells, whipstocks seemed to be a point of issue. Tour sheets disclosed many problems encountered in sidetracking for a second leg caused exclusively by the use of whipstocks [7]. As a tool that must be set at a specific depth and angle, Devon encountered problems that related to setting and retrieving the tool, being forced to run more than one tool prior to drilling their second leg [7]; the time taken up by setting and fishing of whipstocks can really eat up precious dollars that could be better spent elsewhere. The issue is not considered a major wellbore problem, but it does impact the time required and costs associated with developing a well.

In general, where applicable (dual or multi-leg wells), the use of a mud motor when sidetracking seems to be a safer bet than hoping a whipstock runs in and out of the well on the first try.

[7] C. Hogg and R. Barker, "Multilaterals In Slot-limited Platforms Expand Production, Limit Costs," Weatherford, 1 September 2015. [Online]. Available: https://www.epmag.com/multilaterals-slot-limited-platforms-expand-production-limit-costs-816436. [Accessed 28 March 2018].

Comparison to an Existing Enerplus Well

Well Design/Path

Based simply upon well path, many current operators in the Wainwright region use the same design for their single-leg lateral wells, as Enerplus did back in 2013 [3]. Shown in figure eight[8], there is a common, standard, design for the mid-grade oil wells drilled in the area.

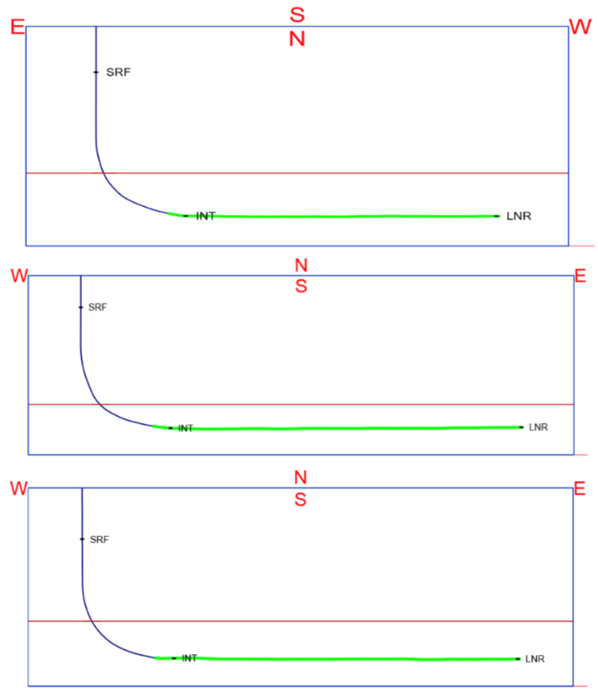

Figure 8: Well Paths from GeoSCOUT, Enerplus Lloydminster (Top), Baytex Sparky (Middle), Husky Lloydminster (Bottom) with Casing, Depths and a Red Line Indicating a Reference Depth of 500mTVD.

After a surface hole is drilled (with a tri-cone bit) and casing is set between 100 – 200mKB, an intermediate section is drilled (with a PDC bit) to the heel of the well [3]. A single kick-off point typically occurs between 200 – 400mKB, based on target depth (true vertical depth of the formation of interest) [3]. As there is only a single KOP, the build is started and finished in the intermediate portion of the wellbore, as shown in figure eight [3]. The build of these wells generally ends when the well's inclination has reached roughly 90°, the inclination at which the horizontal will be drilled. An Intermediate casing is then set and cemented prior to running in for the final drilling interval.

The lateral portions of these wells, like the build, are also drilled with a PDC bit. More variation between companies/operators occurs at this point in the design. Although the laterals are all drilled in the same fashion, the length of the lateral is dependent on the what the operator believes is the best length for recovery; reservoir, drilling, and production engineers work alongside each other in order to design a well with the best potential for future production. For these wells specifically, the lateral legs are over 1-kilometer long, usually between 1100 – 1300 meters in length.

The similarities amongst current and past wells does not end at formations. As previously discussed, Baytex's Sparky wells, aside from TVD, are designed nearly identical to both Husky's Lloydminster wells and the Enerplus' well chosen as a good example of previous design (Appendix O). Using a 375mm tri-cone bit for surface, a 270mm PDC for intermediate, and a 200mm PDC for main hole, the bits sizes and types are all the same [9] [12]. Considering identical hole sizes, the casing sizes chosen are also the same, though weight differs due to operator choice. All wells have slotted liner hung in the intermediate casing running to nearly the end of each lateral. Slot sizing could not be found for some operators and as such cannot be a point of comparison. Overall, although many operators are designing dual or multi-leg wells, the current single-legs are of very similar design to the Enerplus wells of the past.

[8] geoLOGIC Systems Ltd., "GeoSCOUT," geoLOGIC Systems Ltd., 2018. [Online]. Available: http://www.geologic.com/products/geoscout/. [Accessed 21 January 2018].

Similarities in Layout

Aside from well design, Enerplus' wells from 2013 are very similar to current wells when it comes to layout. From an aerial perspective, shown in figure nine[9], Enerplus and Repsol have similar placement of their wells [3].

Using one injector per producer to maintain reservoir pressure, the companies have planned wells in a producer, injector, producer, injector pattern. The laterals for the single-leg wells that branch off of a multi-well pad are parallel to each other.

In the producing wells, the lateral portions are run with slotted liner left uncemented, for fluid production and some extent of sand filtration. In the injectors, however, the lateral portion is left as an open hole [10]. Wellbore stability is not a large enough problem in the injector to force the operators to place a costly casing string downhole.

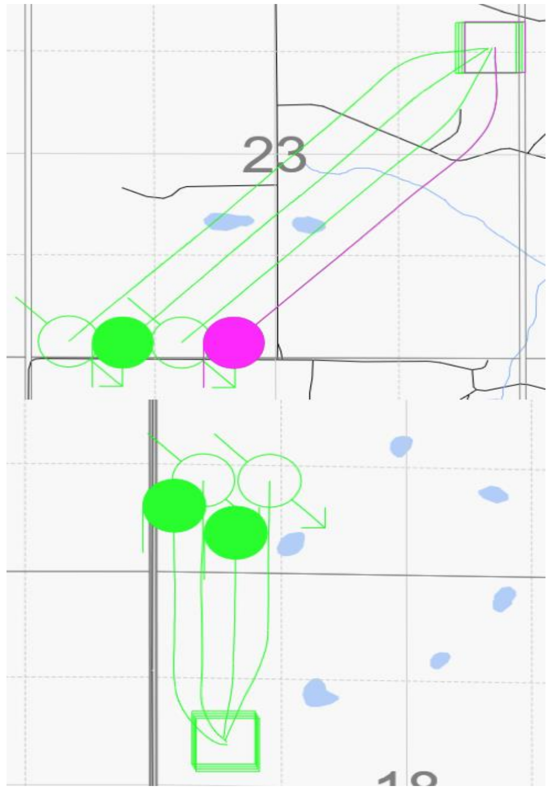

Figure 9: Enerplus (Top) and Repsol (Bottom) Well Pads, Layout of Injectors and Producers

All of the wells illustrated in figure nine, and discussed in this section, are in the Lloydminster formation. Though the layout of the wells are very similar, there are a few major differences in the actual numbers when it comes to design. Repsol's Lloydminster wells, though drilled to a similar true vertical depth, have much shorter lateral legs, and even short liner strings. Repsol's wells have roughly 550-meter laterals while the Enerplus wells are about twice the length (as can be seen in Appendices H and O) [10]. Of the shorter lateral Repsol wells, only about half of the lateral is cased, with a slotted liner run roughly halfway and the rest left barefoot (open hole at toe) [10].

On top of the differences found in the lateral section, Repsol's wells are downscaled versions of Enerplus'. The wellbore is drilled similar to the previous Husky, Baytex, and Enerplus wells, but the hole sizes and the casing sizes that fit are quite smaller. As opposed to the standard 375mm, 270mm, and 200mm holes, the Repsol wells use 311mm (with tri-cone bit), 222mm (with PDC bit), and 159mm (with PDC bit) [10]. As casing sizes are dependent on hole size, the casing strings run, although set in similar areas (surface in vertical, intermediate to heel, then liner in lateral), are each about 40 – 50 mm smaller in diameter [10].

Overall, the Enerplus wells drilled in the Wainwright area in past years have many similarities to what current operators are doing in terms of single-leg lateral well drilling design. Though there are slight differences in weights of casing strings (and sizes for some companies), the general design is nearly identical. With similar grades of casing, casing points, kick-off points, and drilling fluids used, there is no considerable difference between the past wells and what is currently going on in the Wainwright region.

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Conclusion

The data collected from all wells in Enerplus' region of interest enabled the Capstone research team to develop an introductory understanding as to what is expected and what will require a more thorough understanding.

Companies that operated in the Lloydminster formation (Devon Canada Corporation, Husky Oil Operations and Repsol Oil and Gas Canada Incorporation) utilized well designs that are commonly found across the Wainwright region. The single-leg and dual-leg lateral well setup, alongside the casing parameters that each company utilized did not encounter any significant issues.

The General Petroleum formation had two major operators working within the formation in Enerplus' region of interest (Gear Energy Limited and Devon Canada Corporation). Gear decided to develop all of their dual-leg lateral wells and extend them into the General Petroleum formation, while Devon decided to utilize a variety of wells, which ranged from a single-leg, dual-leg, three-leg, four-leg and even an eight-leg lateral section well. Both companies did not encounter any issues involved in the development processes of their wells but did face some deficiencies in developing wells in a timely manner, which ties into the cost associated in developing these projects.

The Sparky formation also contained two major operators within Enerplus' 50-kilometer radius search, those operators being Baytex Energy Limited and Broadview Energy Limited. Both companies encountered issues with their wells, specifically being a lost circulation issue for Baytex and a stuck pipe issue for Broadview. Assumptions were made in order to determine a reason as to why the issues may have occurred, but a thorough analysis of the issue was not done due to the scope of the project. The issues mentioned increased time required and costs involved in the development of the project and require an in-depth analysis in order to reduce the chances of the issue occurring on wells that Enerplus' may potentially develop in the future.

Lastly, the Cummings formation had Gear Energy Limited and Devon Canada Corporation operating within. Both companies utilized multi-leg lateral wells, with Gear utilizing a single-leg lateral as well, without encountering any issues throughout the development of the projects. Time issues did exist, which is a factor that Enerplus is interested in minimizing.

Other information pertaining to the development of the project, such as drilling fluids and additives, drilling methods and wellbore deviation tactics, well layout, well design and path, as well as special cases that may occur in the Wainwright region were also discussed in order to provide an overall understanding of the components involved in developing a project plan.

The scope of the project allowed the Capstone research team to utilize the information provided in order to assist with the understanding of how processes occur for each company and what benefits and drawback exists in each method of approach. The Capstone report is the initial and one of the numerous steps involved in developing a project plan for Enerplus. The report assists in understanding the overview of the project but will require more information in order to develop a conclusion that results in the development or the abandonment/archiving of the planned project.

The Enerplus team will utilize the fundamental information provided and build on the findings in order to come up with a conclusion in the near future.

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Glossary

B

Build – The section of a deviated well in which the inclination continuously changes. There may be multiple builds in a well if there is more than one deviation that must be made. The build begins at the kickoff point and ends at the aptly termed end of build (EOB) [22].

D

De-flocculant – A drilling fluid additive that thins the mud, reducing viscosity. Do not mix this term up with the term “dispersant” [22].

Drilling fluid/mud – The fluid circulated in a wellbore while drilling. Typically, either oil-based or water-based with additives that provide desired qualities to mitigate downhole problems and ensure operational optimization [22].

Dual-leg lateral – A well drilled with two horizontal sections that deviate from a single vertical. A dual-leg lateral has two total depths. The first horizontal will be drilled in a similar fashion as a single-leg lateral. After reaching TD in the first leg, the drill string will be pulled back to make a sidetrack from the original bore, the start of the second leg [22].

F

Fishing – An operation, where a tool or part of the drill string is lost down hole. Specific fishing tools are used to retrieve the lost item prior to resuming the rest of their operation. This is a special operation and is not very common [22].

G

Ground level (GL) – The surface elevation in relation to sea-level. Almost always numerically positive as most ground elevations are above sea-level [22].

H

Hydraulic fracturing (fracing) – A completion process in which high volumes of fluid are pumped into the target formation at high pressure to fracture the rock, resulting in greater permeability. Proppant is left behind after the operation to ensure the pathway for flow remains stable. This process is often used in tight reservoirs with minimal permeability [22].

I

Intermediate casing – The second casing string to be run in hole and cemented, often set if there is a liner to hang, or the well is too deep to run only two casing strings [22].

J

Jarring – A special operation used when pipe is stuck in the hole. Hydraulically or mechanically operated, a jar integral to the string is used to cause an impulse sent through the string that will hopefully free the pipe from the surrounding rock [22].

K

Kickoff point – The point at which a well begins to deviate from a straight path. Though the vertical section of a well often changes ever so slightly in inclination, an inclination greater than one to two degrees would typically be considered deviated. The kickoff starts the build section. There may be more than one kickoff point in a well’s design depending on the desired path [22].

Kelly bushing (KB) elevation – In terms of elevation, the height of the kelly bushing or rig floor added to the ground elevation; ground elevation plus kelly bushing height equals KB elevation [22].

L

Liner casing – A production casing string that does not run all the way to surface (not hung in the wellhead). Liners are hung off the end of the previous string and are commonly used when a different size, weight, or grade of casing must be run in the vertical portion of the well [22].

Lost circulation – A hole problem that occurs when the mud density used while drilling a specific section is much greater than the equivalent mud density of the formation. Drilling fluid is lost to the formation. This is a common problem encountered while drilling the surface hole and can lead to a kick from a permeable formation if not recognized early on [22].

M

Mid-grade oil – Crude oil with an API Gravity between 22.3° - 31.1°API [22] [24].

Mud density/weight – The density of the drilling fluid, commonly measured in kilograms per cubic meter (kg/m^3) [22].

Mud motor – A downhole tool run near the end of the drill string, attached to the bit, consisting of a dump valve, bend housing, motor section, and bearing assembly. A mud motor provides rpm to the bit when fluid circulation causes an internal rotor to move. Mud motors use the same internals as a progressing cavity pump, but in the opposite manner; rather than the rotor moving the fluid, the fluid moves the rotor. A bend housing allows a bend adjustment to be made at surface prior to running in hole, allowing the operator to slide drill for the build section of their well. Nowadays these are commonly run to drill all sections of the wellbore [22].

Multi-leg lateral – A well drilled with more than two horizontal legs. These wells are drilled in the same fashion as a dual leg lateral, just with more lateral sections coming off of the original vertical [22].

P

Polycrystalline diamond compact (PDC) bit – A cone-less drill bit often used to drill the intermediate and main hole sections. Different than a tri-cone bit in both shape and penetration style, a PDC bit shears rock through scraping. The design is much different than a roller-cone, consisting of no moving parts. In addition to shape differences, synthetic diamond disks are used to penetrate rock rather than teeth [22].

Proppant – Material left in the formation after a hydraulic fracturing job. Sand is often used (though synthetics are an option) to prop open the fractures formed by a fracing operation, keeping the permeability long after flowback [22].

S

Single-leg lateral – A well drilled to total depth with only one horizontal section. Though multiple hole sizes may be present, there is only one path from surface to the toe of the well [22].

Slide – Used to drill a deviated portion of the well, the bend in a mud motor is pointed in a specific direction while bit rpm is due to circulation (no rotary rpm at surface). This type of drilling takes longer than rotating, but is the only way to drill a deviated borehole with a mud motor [22].

Slotted liner – A liner casing string with laser-cut slots that run parallel to the pipe body. The slots provide a flow path from the producing formation and can be an alternative to perforating. Slot width is often small enough to be measured in micrometers, though inches are more common (e.g. Baytex's Sparky wells used 0.060" slots, or 1524 micrometers) [22].

Sloughing – A hole problem often encountered in shale or clay-based formations where water interacts with clays, swelling, resulting in a reduction in hole size. Often mitigated by shale-inhibitor additives or oil-based drilling fluid [22].

Stuck pipe – A problem encountered when pipe is left still in the hole for too long (when circulation is halted). The drill string can stick to the sides of the wellbore wall, resulting in the inability to move the string up or down. Jarring is commonly done after a stuck pipe situation occurs [22].

Subsea (SS) – The depth of a specific formation or point in the well in relation to sea-level. Depths above sea-level are numerically positive, while depths below sea-level are numerically negative [22].

Surface casing – The first casing string to be run in and cemented in an oil and gas well. Often set at a specific depth below a freshwater aquifer to ensure isolation between the well and potable water zones. Surface casing strings are found in all wells, both vertical and horizontal [22].

T

Tight – A term used to describe a formation, specifically a reservoir rock, that has minimal or almost no permeability. The lack of decent permeability in this type of formation presents difficulty in producing hydrocarbons from the zone. Tight formations are often hydraulically fractured, stimulating the formation, adding permeability and therefore increasing the flow area into the wellbore [22].

Tour report/sheet – A report required to be sent to the Alberta Energy Regulator after a well is drilled. The report describes the day-to-day work schedule (what was done), and contains notes and other information regarding bit runs, casing specs, and mud properties. It is essentially a daily log of operations at the wellsite [22].

Tri-cone/tooth bit – A three-coned roller-cone drill bit often used to drill the surface hole. Different than a PDC bit in both shape and penetration style, a tri-cone bit crushes rock as opposed to shearing rock [22].

V

Viscosifier – Working in the opposite manner of a de-flocculant, viscosifiers are additives used to increase the viscosity of the drilling fluid [22].

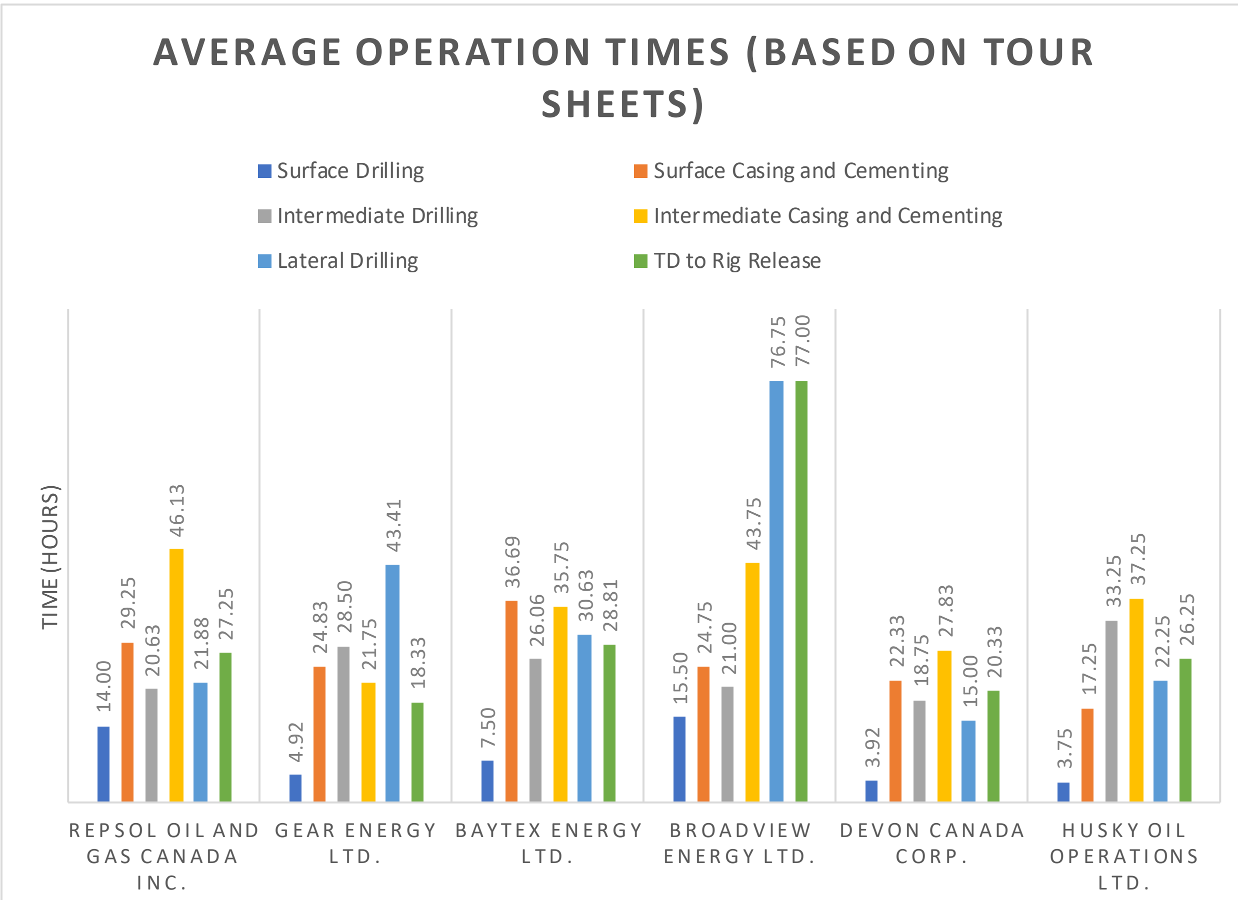
W

Wellbore – The drilled hole, only the open hole or uncased section of the well [22].

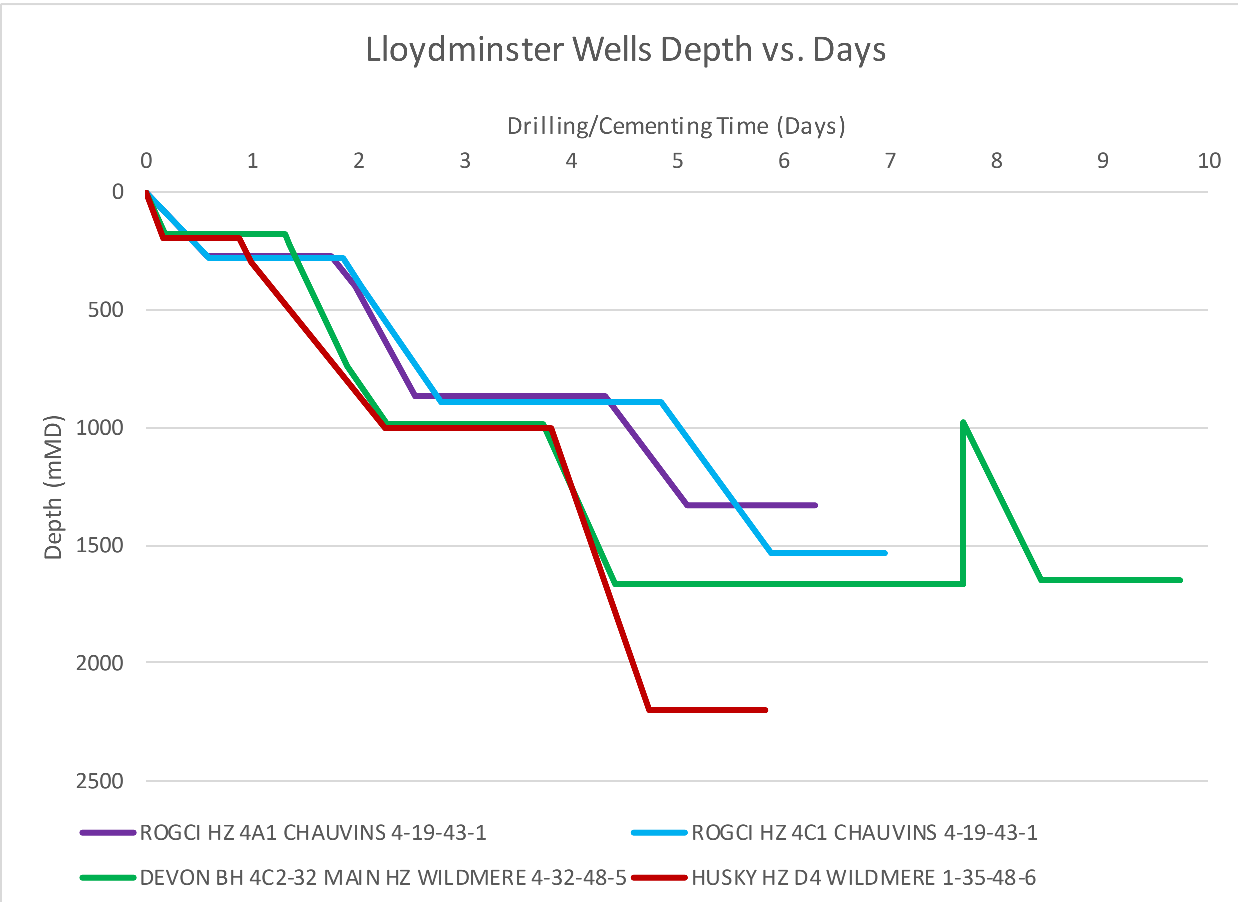
Whipstock – A downhole tool used to sidetrack a well for a new lateral section. Placed downhole, a whipstock acts as a wedge for the drill pipe to be pushed off of, directing the bit in the proper direction for a new deviated section [22].

Appendices

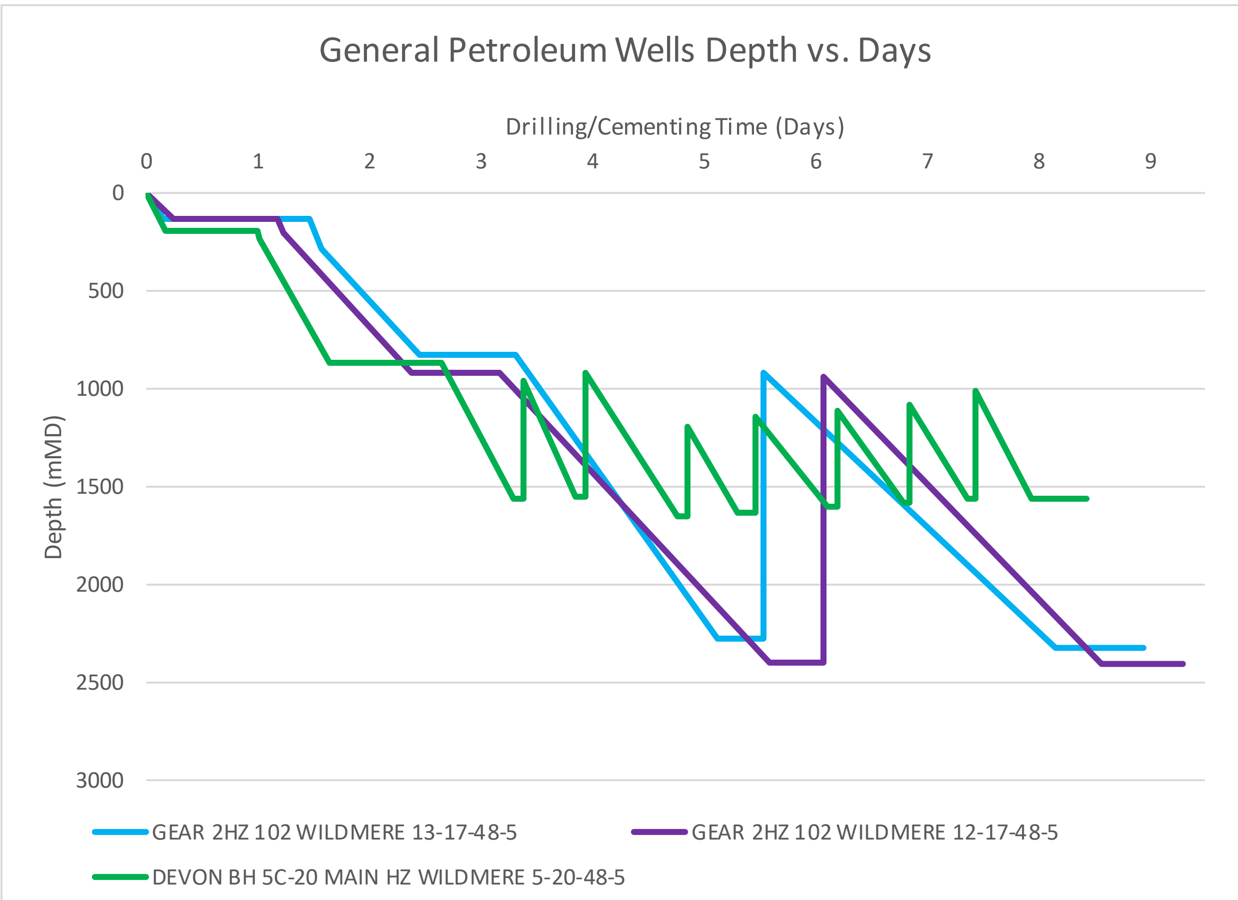
Appendix A – Average Operation Times



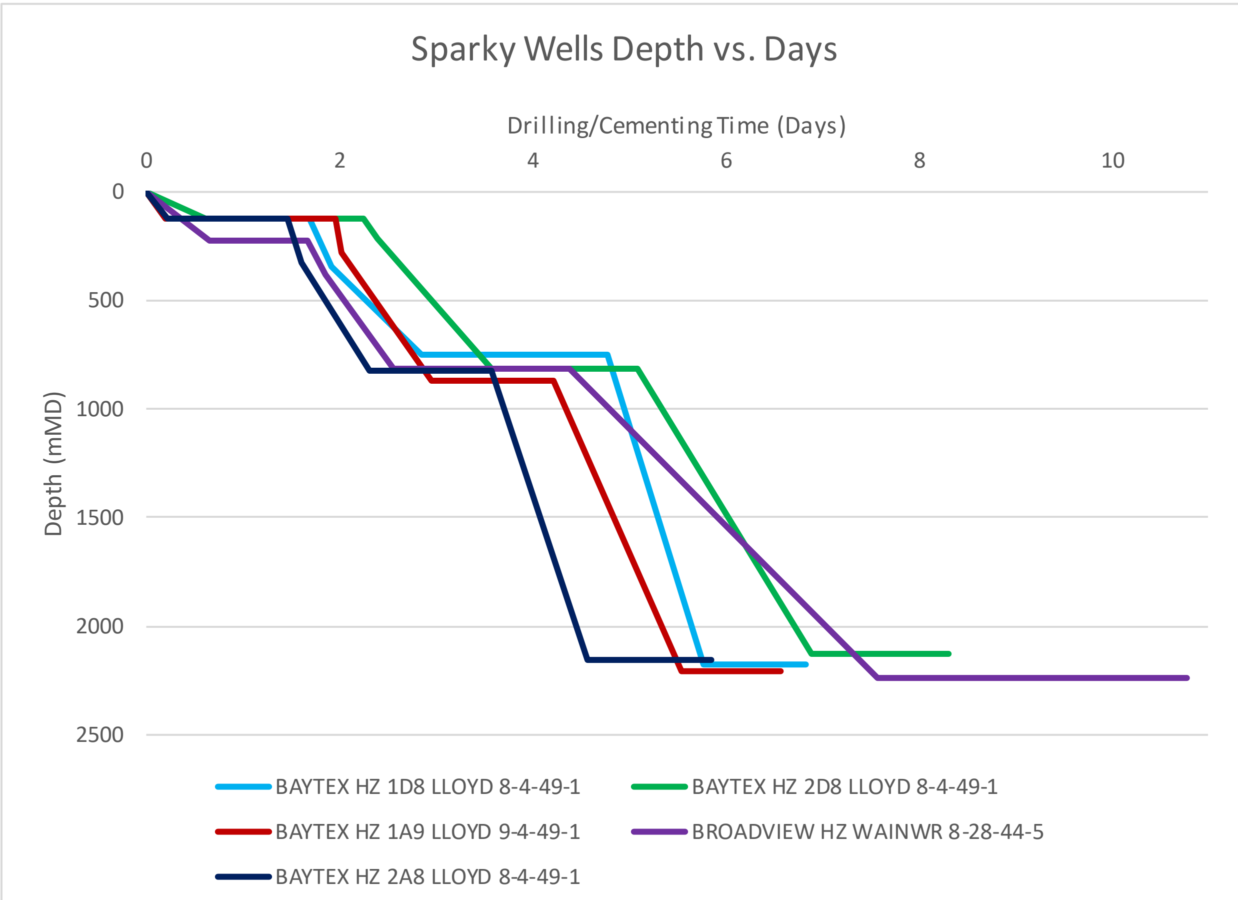
Appendix B – Lloydminster Wells Depth vs. Days



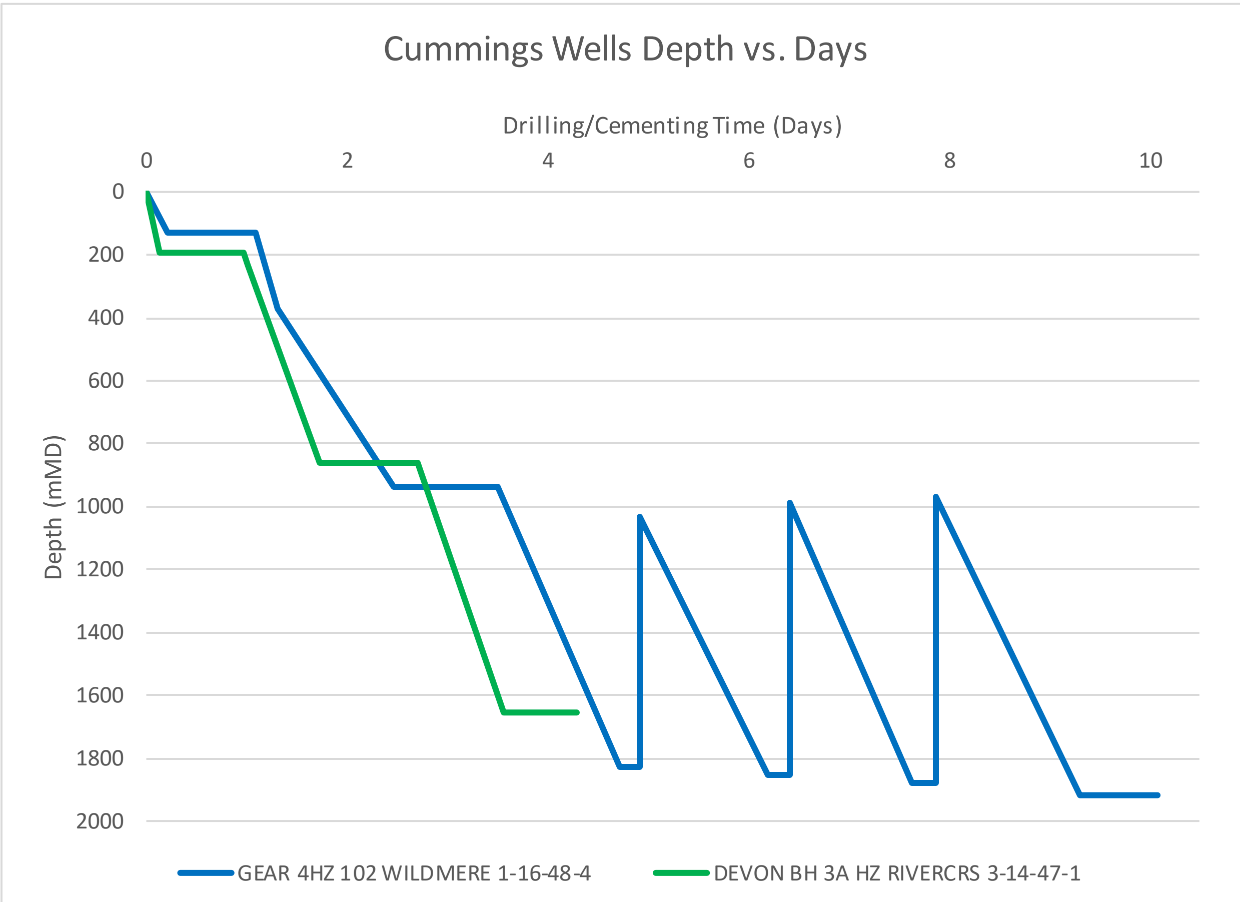
Appendix C – General Petroleum Wells Depth vs. Days



Appendix D – Sparky Wells Depth vs. Days



Appendix E – Cummings Wells Depth vs. Days



Appendix F – Devon Canada Corp. Lloydminster Stick Diagram

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Devon Canada Corp. Lloydminster Well Profile

SAIT PT

CAPSTONE 2018

Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP	WELL SUMMARY			
BOP's:	Surface location: 48-05W4 & 48-06W4	License # : Not Applicable	Rig:	Range III "Super" Single
Class III BOP's	Well Type: Development - Non-Confidential	GL: 643.55±13.55m	Well Style:	Dual Leg Lateral
Nace Trim	Status: Horizontal Lloydminster SS Production Well	KB: 647.95±13.55m	H_2S:	Out of Scope
	AFE#: Not Applicable; Working Interest: Not Applicable	KB-GL: 4.4 m	Formation:	Lloydminster Sand

GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m³)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		176.0	176.0	485.5			
KOP 1	Not Applicable		221.0	221.0	440.5			
Colorado	Shale/Sandstone		324.9	322.0	339.5			
Second White Specks	Shale/Mudstone/Siltstone		473.8	432.2	229.3			
Base of Fish Scales	Shale/Mudstone/Siltstone		530.9	465.5	196.0			
Viking	Sandstone/Conglomerate		632.7	525.2	136.3			
Joli Fou	Shale/Sandstone		672.7	547.9	113.6			
Colony	Sandstone		693.0	559.7	101.8			
McLaren	Sandstone/Shale		707.6	568.2	93.3			
Waseca	Sandstone/Siltstone/Shale		741.9	588.2	73.3			
KOP 2	Not Applicable		743.1	602.7	58.8			
Sparky	Sandstone/Shale		767.5	603.1	58.4			
General Petroleum	Sandstone		775.9	607.6	53.9			
Rex	Sandstone/Siltstone/Shale		802.4	621.1	40.4			
Lloydminster	Sandstone/Siltstone		848.4	639.0	22.5			
TD / TOE	Sandstone/Siltstone		1637.0	651.8	9.7			

*Formation Tops Based Upon Data From Well 100/04-32-048-05W4/00

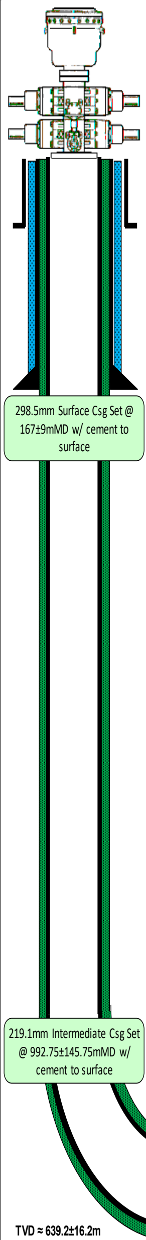
BIT PROGRAM				DRILLING FLUIDS SUMMARY (Review mud program)				
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m³)	Min. Density (kg/m³)	Max. Density (kg/m³)
Surface Hole	0m - 167±9m	375	Tooth	Gel-Chem Water	0m - 167±9m	1075	1050	1100
Int. Hole	167±9m - 992.75±145.75m	270	PDC	Polymer Water	167±9m - 992.75±145.75m	1050	1020	1080
Horizontal Leg	992.75±145.75m - 1678±232m	200	PDC	Polymer Water	992.75±145.75m - 1678±232m	1028	1010	1045

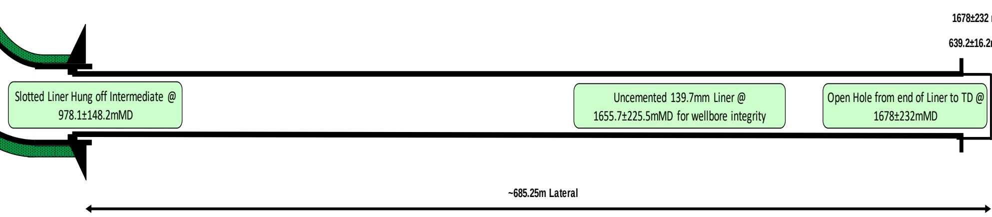
WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 167±9m	375	298.5	277.6	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 992.75±145.75m	270	219.1	198	41.67	J-55	LT&C	23400	13000	5650
Horizontal Leg	978.1±148.2m - 1655.7±225.5m	200	139.7	122.55	23.07	J-55	LT&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m³/t)	Slurry Density (kg/m³)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 167±9m
Intermediate Cement			270	219.1				0m - 992.75±145.75m





Appendix G – Husky Oil Operations Ltd. Lloydminster Stick Diagram

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Husky Oil Operations Ltd. Lloydminster Well Profile

SAIT PT

CAPSTONE 2018

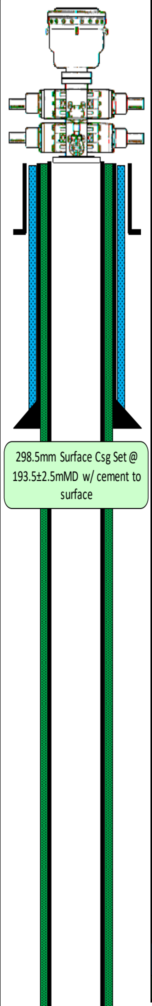
Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP	WELL SUMMARY		
BOP's:	Surface location: 48-06W4	License # : Not Applicable	Rig: Range III "Super" Single
Class III BOP's	Well Type: Development - Non-Confidential	GL: 647.5±0.25m	Well Style: Single Leg Lateral
Nace Trim	Status: Horizontal Lloydminster SS Production Well	KB: 651.8±0.25m	H_2S: Out of Scope
	AFE#: Not Applicable; Working Interest: Not Applicable	KB-GL: 4.3m	Formation: Lloydminster Sand



GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		193.5	193.5	457.6			
KOP	Not Applicable		301.5	301.5	349.6			
Colorado	Shale/Sandstone		306.1	305.3	345.8			
Second White Specks	Shale/Mudstone/Siltstone		418.6	409.8	241.3			
Base of Fish Scales	Shale/Mudstone/Siltstone		471.2	452.4	198.7			
Viking	Sandstone/Conglomerate		542.4	500.5	150.6			
Joli Fou	Shale/Sandstone		604.1	534.9	116.2			
Colony	Sandstone		621.3	542.5	108.2			
McLaren	Sandstone/Shale		631.0	546.6	104.5			
Waseca	Sandstone/Siltstone/Shale		656.9	555.8	95.3			
Sparky	Sandstone/Shale		740.1	577.9	73.2			
General Petroleum	Sandstone		811.0	596.2	54.9			
Rex	Sandstone/Siltstone/Shale		867.2	610.8	40.3			
Lloydminster	Sandstone/Siltstone		1021.6	638.1	13.0			
TD / TOE	Sandstone/Siltstone		2212.0	646.4	4.7			

*Formation Tops Based Upon Data From Well 100/09-35-048-06W4/00 and Average Depths of Wells/Casings

BIT PROGRAM / **DRILLING FLUIDS SUMMARY (Review mud program)**

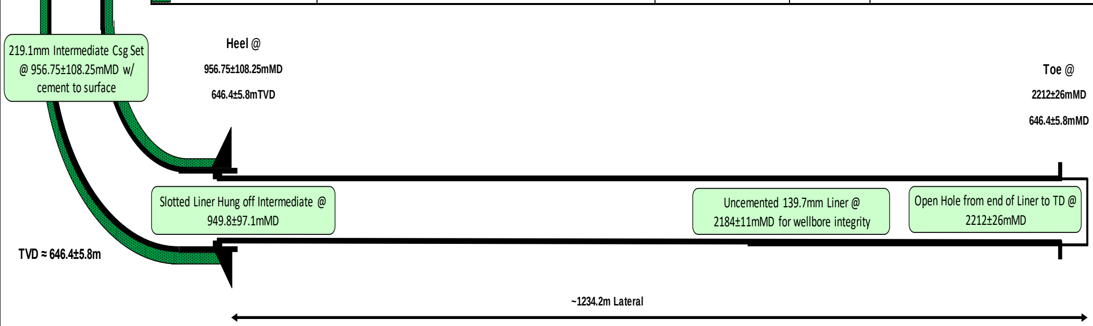
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Surface Hole	0m - 193.5±2.5m	375	Tooth	Polymer Water	0m - 193.5±2.5m	1054	1028	1080
Int. Hole	193.5±2.5m - 956.75±108.25m	270	PDC	Polymer Water	193.5±2.5m - 956.75±108.25m	1058	1025	1090
Horizontal Leg	956.75±108.25m - 2212±26m	200	PDC	Polymer Water	956.75±108.25m - 2212±26m	1068	1045	1090

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 193.5±2.5m	375	298.5	277.56	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 956.75±108.25m	270	219.1	202.48	35.72	J-55	ST&C	20300	9400	3310
Horizontal Leg	949.8±97.1m - 2184±11m	200	139.7	122.55	23.07	J-55	LT&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 193.5±2.5m
Intermediate Cement			270	219.1				0m - 956.75±108.25m



Appendix H – Repsol Oil & Gas Canada Inc. Lloydminster Stick Diagram

enerPLUS

Repsol Oil & Gas Canada Inc. Lloydminster Well Profile

SAIT PT

CAPSTONE 2018

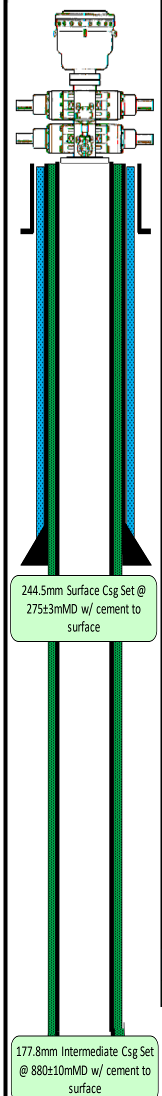
Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP
BOP's:
Class III BOP's
Nace Trim



WELL SUMMARY

Surface location: 43-01W4		License # : Not Applicable		Rig:	Range III Single
Well Type:	Development - Non-Confidential	GL:	648.85±0.35m	Well Style:	Single Leg Lateral
Status:	Horizontal Lloydminster SS Production Well	KB:	652.85±0.35m	H_2S:	Out of Scope
AFE#: Not Applicable	Working Interest: Not Applicable	KB-GL:	4.0m	Formation:	Lloydminster Sand

GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		275.0	275.0	377.7			
Colorado	Shale/Sandstone		378.1	378.1	274.6			
KOP	Not Applicable		397.0	397.0	255.7			
Second White Specks	Shale/Mudstone/Siltstone		472.3	470.9	181.8			
Base of Fish Scales	Shale/Mudstone/Siltstone		511.8	507.6	145.1			
Viking	Sandstone/Conglomerate		556.6	547.1	105.6			
Joli Fou	Shale/Sandstone		607.4	587.6	65.1			
Mannville	Sandstone/Shale		633.1	605.4	47.3			
McLaren	Sandstone/Shale		655.4	619.1	33.6			
Waseca	Sandstone/Siltstone/Shale		674.6	629.9	22.8			
Sparky	Sandstone/Shale		709.2	648.1	4.6			
General Petroleum	Sandstone		744.6	665.1	-12.4			
Rex	Sandstone/Siltstone/Shale		768.2	674	-21.3			
Lloydminster	Sandstone/Siltstone		822.1	687.3	-34.6			
TD / TOE	Sandstone/Siltstone		1431.5	695.9	-43.2			

*Formation Tops Based Upon Data From Well 100/04-19-043-01W4/00 and Average Depths of Wells/Casings

BIT PROGRAM / **DRILLING FLUIDS SUMMARY (Review mud program)**

	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Surface Hole	0m - 275±3m	311	Tooth	Water	0m - 275±3m	1060	1020	1100
Int. Hole	275±3m - 880±10m	222	PDC	Water	275±3m - 880±10m	1095	1080	1110
Horizontal Leg	880±10m - 1431.5±101.5m	159	PDC	Water	880±10m - 1431.5±101.5m	1080	1070	1090

WELLBORE AND CASING INFORMATION

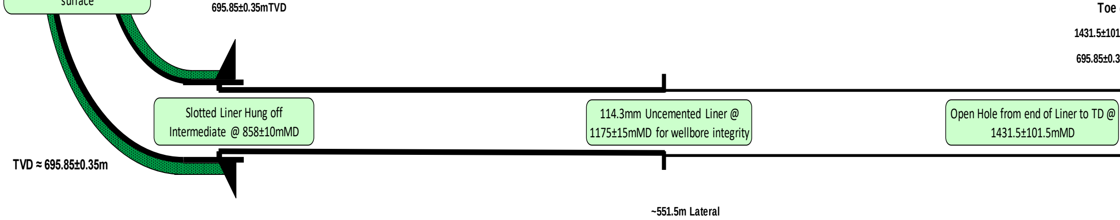
Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 275±3m	311	244.5	224.7	48.07	H-40	ST&C	15700	9400	3440
Intermediate Hole	0m - 880±10m	222	177.8	158.5	34.23	J-55	LT&C	25800	15700	3170
Horizontal Leg	858±10m - 1175±15m	159	114.3	100.7	14.14	J-55	ST&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		311	244.5	Out of Project Scope			0m - 275±3m
Intermediate Cement			222	177.8				0m - 880±10m

Heel @
858±10 mMD
695.85±0.35mTVD

Toe @
1431.5±101.5 mMD
695.85±0.35mTVD



Appendix I – Gear Energy Ltd. General Petroleum Stick Diagram

enerPLUS

Gear Energy Ltd. General Petroleum Well Profile

SAIT PT

CAPSTONE 2018

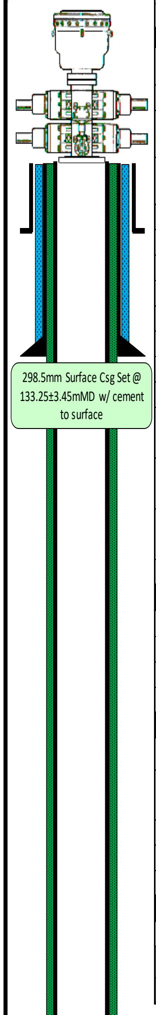
Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP
BOP's:
Class III BOP's
Nace Trim



WELL SUMMARY

Surface location:	48-05W4	License # :	Not Applicable	Rig:	Range III Single
Well Type:	Development - Non-Confidential	GL:	660.2±17.1m	Well Style:	Dual Leg Lateral
Status:	Horizontal General Petroleum SS Production Well	KB:	664.7±17.1m	H_2S:	Out of Scope
AFE#: Not Applicable	Working Interest: Not Applicable	KB-GL:	4.5 m	Formation:	General Petroleum Sand

GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		133.3	133.3	515.9			
Colorado	Shale/Sandstone		307.2	307.2	341.9			
KOP	Not Applicable		318.1	318.1	331.0			
Second White Specks	Shale/Mudstone/Siltstone		425.3	420.8	228.3			
Base of Fish Scales	Shale/Mudstone/Siltstone		468.8	459.2	189.9			
Viking	Sandstone/Conglomerate		519.6	499.7	149.4			
Joli Fou	Shale/Sandstone		574.9	537.8	111.3			
Colony	Sandstone		586.3	545.0	104.1			
McLaren	Sandstone/Shale		600.7	553.6	95.5			
Waseca	Sandstone/Siltstone/Shale		611.8	559.7	89.4			
Sparky	Sandstone/Shale		718.0	600.0	49.1			
General Petroleum	Sandstone		787.9	610.9	38.2			
TD / TOE	Sandstone		2318.5	629.5	19.7			

*Formation Tops Based Upon Data From Well 100/04-19-043-01W4/00 and Average Depths of Wells/Casings

BIT PROGRAM

	Interval (MD)	Bit size (mm)	Bit type
Surface Hole	0m - 133.25±3.45m	375	Tooth
Int. Hole	133.25±3.45m - 869.75±46.75m	270	PDC
Horizontal Leg	869.75±46.75m - 2318.5±87.5m	200	PDC

DRILLING FLUIDS SUMMARY (Review mud program)

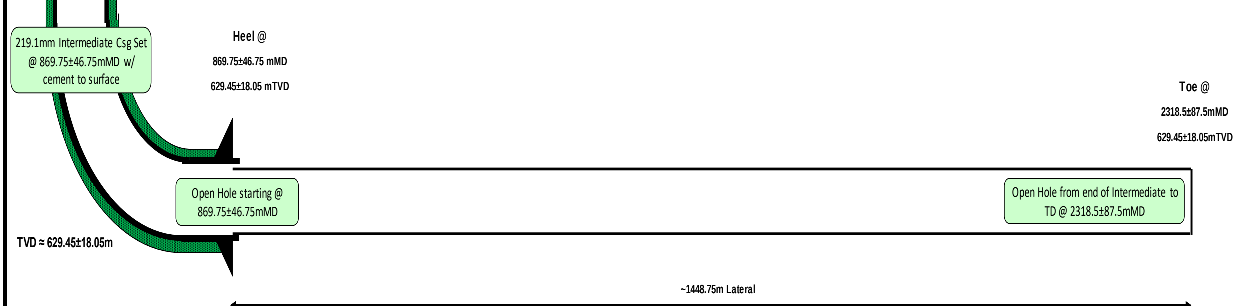
Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Gel-Chem Water	0m - 133.25±3.45m	1010	1010	1010
Polymer Water	133.25±3.45m - 869.75±46.75m	1100	1100	1100
Polymer Water	869.75±46.75m - 2318.5±87.5m	1020	1000	1040

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 133.25±3.45m	375	298.5	277.6	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 869.75±46.75m	270	219.1	198	41.67	J-55	LT&C	23400	13000	5650
Horizontal Leg	869.75±46.75m - 2318.5±87.5m	200	Open Hole to TD					No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 133.25±3.45m
Intermediate Cement			270	219.1				0m - 869.75±46.75m



Appendix J – Devon Canada Corp. General Petroleum Stick Diagram

Devon Canada Corp. General Petroleum Well Profile

SAIT PT

CAPSTONE 2018

Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

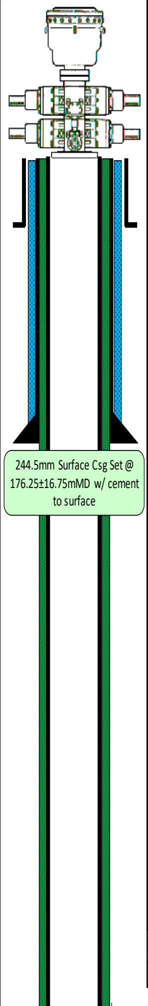
TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP

BOP's:

Class III BOP's

Nace Trim



WELL SUMMARY

Surface location: 48-05W4 & 48-06W4	License # : Not Applicable		Rig: Range III "Super" Single
Well Type: Development - Non-Confidential	GL: 644.35±15.15m		Well Style: Dual Leg Lateral
Status: Horizontal General Petroleum SS Production Well	KB: 648.65±15.15m		H_2S: Out of Scope
AFE#: Not Applicable	Working Interest: Not Applicable	KB-GL: 4.3m	Formation: General Petroleum Sand

GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		176.3	176.3	457.9			
KOP	Not Applicable		229,7	229.7	404.5			
Colorado	Shale/Sandstone		304.5	302.8	331.4			
Second White Specks	Shale/Mudstone/Siltstone		422.3	401.1	233.1			
Base of Fish Scales	Shale/Mudstone/Siltstone		479.7	437.3	196.9			
Viking	Sandstone/Conglomerate		549.6	482.2	152.0			
Joli Fou	Shale/Sandstone		591.0	507.7	126.5			
Colony	Sandstone		627.7	528.4	105.8			
McLaren	Sandstone/Shale		649.8	539.6	94.6			
Waseca	Sandstone/Siltstone/Shale		681.2	553.3	80.9			
Sparky	Sandstone/Shale		739.5	572.9	61.3			
General Petroleum	Sandstone		770.6	580.7	53.5			
TD / TOE	Sandstone		2141.5	609.9	24.3			

*Formation Tops Based Upon Data From Well 104/04-36-048-06W4/00 and Average Depths of Wells/Casings

BIT PROGRAM / **DRILLING FLUIDS SUMMARY (Review mud program)**

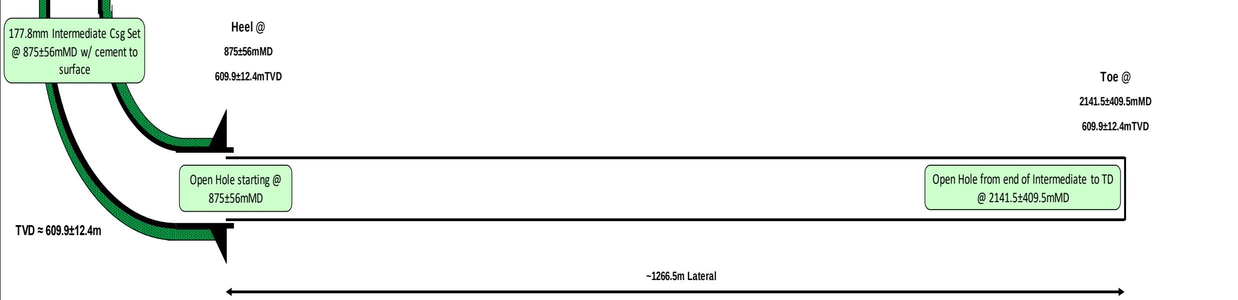
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Surface Hole	0m - 176.25±16.75m	311	Tooth	Gel-Chem Water	0m - 176.25±16.75m	1030	1030	1030
Int. Hole	176.25±16.75m - 875±56m	222	Tooth	Polymer Water	176.25±16.75m - 875±56m	1045	1000	1090
Horizontal Leg	875±56m - 2141.5±409.5m	156	PDC	Polymer Water	875±56m - 2141.5±409.5m	1033	1010	1055

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 176.25±16.75m	311	244.5	222.6	53.58	J-55	ST&C	24	13900	6140
Intermediate Hole	0m - 875±56m	222	177.8	158.5	34.23	L-80	LT&C	43700	26400	5890
Horizontal Leg	875±56m - 2141.5±409.5m	156	Open Hole to TD					No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		311	244.5	Out of Project Scope			0m - 176.25±16.75m
Intermediate Cement			222	177.8				0m - 875±56m



Appendix K – Baytex Energy Ltd. Sparky Stick Diagram

enerPLUS

Baytex Energy Ltd. Sparky Well Profile

SAIT PT

DRILLING STICK DIAGRAM

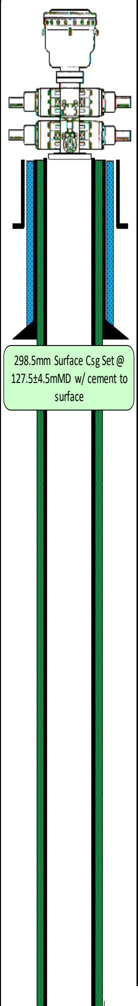
Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

CAPSTONE 2018

Matthew McDonald, Ali Mukyan, David Lee

WELLHEAD / BOP	WELL SUMMARY		
BOP's:	Surface location: 49-01W4	License # : Not Applicable	Rig: Range III "Super" Single
Class III BOP's	Well Type: Development - Non-Confidential	GL: 662.15±6.85m	Well Style: Single Leg Lateral
Nace Trim	Status: Horizontal Sparky SS Production Well	KB: 666.65±6.85m	H_2S: Out of Project Scope
	AFE#: Not Applicable — Working Interest: Not Applicable	KB-GL: 4.5 m	Formation: Sparky Sand



GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	One Incidence of Lost Circulation in Surface Hole	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		127.5	127.5	539.1			
KOP	Not Applicable		218.0	218.0	448.6			
Colorado	Shale/Sandstone		327.6	324.5	342.1			
Second White Specks	Shale/Mudstone/Siltstone		414.3	399.3	267.3			
Base of Fish Scales	Shale/Mudstone/Siltstone		479.2	453	213.6			
Viking	Sandstone/Conglomerate		542.9	501.1	165.5			
Joli Fou	Shale/Sandstone		601.6	538.2	128.4			
Mannville	Sandstone/Shale		613.0	544.4	122.2			
Colony	Sandstone		613.8	544.8	121.8			
McLaren	Sandstone/Shale		635.7	555.3	111.3			
Waseca	Sandstone/Siltstone/Shale		659.7	565.2	101.4			
Sparky	Sandstone/Shale		903.9	593.7	72.9			
TD / TOE	Sandstone/Shale		2188.5	596.0	70.6			

*Formation Tops Based Upon Data From Well 105/08-04-049-01W4/00 and Average Depths of Wells/Casings

BIT PROGRAM

	Interval (MD)	Bit size (mm)	Bit type
Surface Hole	0m - 127.5±4.5m	375	Tooth
Int. Hole	127.5±4.5m - 818.5±79.5m	270	PDC
Horizontal Leg	818.5±79.5m - 2188.5±61.5m	200	PDC

DRILLING FLUIDS SUMMARY (Review mud program)

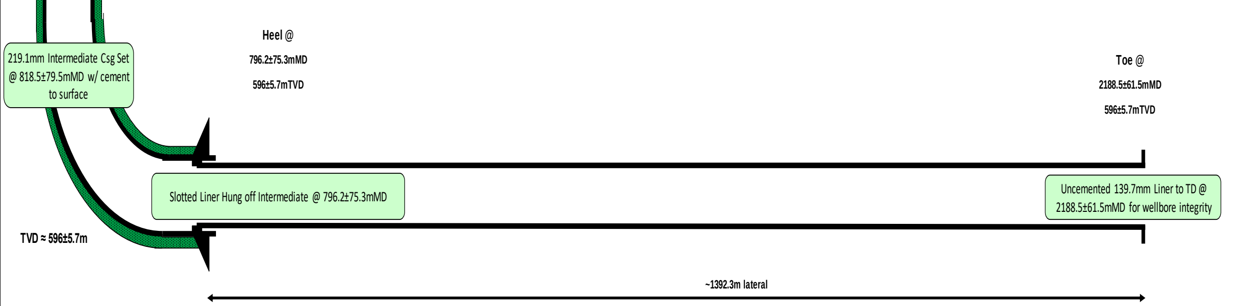
Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Water	0m - 127.5±4.5m	1010	1010	1010
Gel-Chem Water	127.5±4.5m - 818.5±79.5m	1105	1100	1110
Polymer Water	818.5±79.5m - 2188.5±61.5m	1020	1010	1030

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 127.5±4.5m	375	298.5	277.56	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 818.5±79.5m	270	219.1	202.48	47.62	J-55	ST&C	27100	17400	5650
Horizontal Leg	796.2±75.3m - 2188.5±61.5m	200	139.7	121.08	25.30	J-55	LT&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 127.5±4.5m
Intermediate Cement			270	219.1				0m - 818.5±79.5m



Appendix L – Broadview Energy Ltd. Sparky Stick Diagram

Broadview Energy Ltd. Sparky Well Profile

SAIT PT

DRILLING STICK DIAGRAM

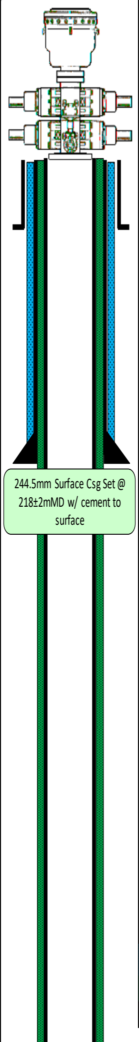
CAPSTONE 2018

Horizontal Producer

Matthew McDonald, Ali Mukyan, David Lee

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP	WELL SUMMARY			
BOP's:	Surface location: 44-05W4	License # : Not Applicable	Rig:	Range III "Super" Single
Class III BOP's	Well Type: Development - Non-Confidential	GL: 654.55±1.25m	Well Style:	Single Leg Lateral
Nace Trim	Status: Horizontal Sparky SS Production Well	KB: 648.75±1.25m	H_2S:	Out of Project Scope
	AFE#: Not Applicable; Working Interest: Not Applicable	KB-GL: 4.2m	Formation:	Sparky Sand



GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	Stuck Pipe After Drilling Lateral Portion of Well	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		218.0	218.0	439.5			
Colorado	Shale/Sandstone		229.7	229.7	427.8			
KOP	Not Applicable		385.0	385.0	272.5			
Second White Specks	Shale/Mudstone/Siltstone		465.8	450.7	206.8			
Base of Fish Scales	Shale/Mudstone/Siltstone		519.8	492.5	165.0			
Viking	Sandstone/Conglomerate		568.8	527.5	130.0			
Joli Fou	Shale/Sandstone		632.0	568.6	88.9			
Colony	Sandstone		664.4	587.0	70.5			
McLaren	Sandstone/Shale		685.4	596.8	60.7			
Sparky	Sandstone/Shale		797.3	629.6	27.9			
TD / TOE	Sandstone/Shale		2228.0	637.5	20.0			

*Formation Tops Based Upon Data From Well 102/04-32-044-05W4/00 and Average Depths of Wells/Casings

BIT PROGRAM / **DRILLING FLUIDS SUMMARY (Review mud program)**

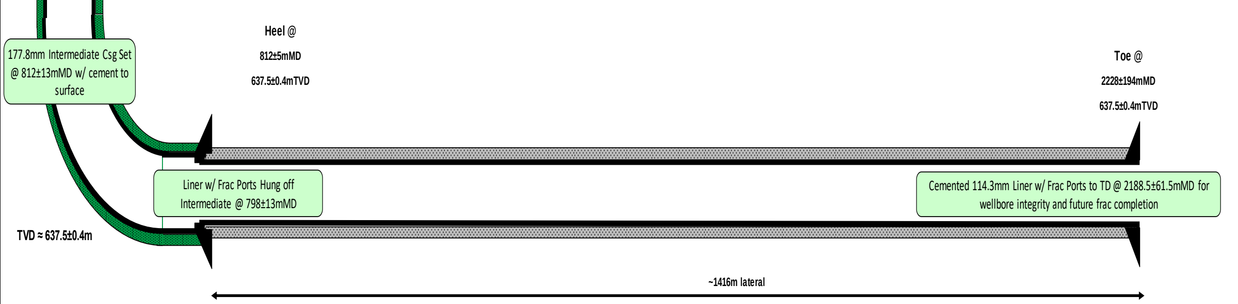
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Surface Hole	0m - 218±2m	349	Tooth	Water	0m - 218±2m	1090	1080	1100
Int. Hole	218±2m - 812±5m	222	Tooth	Water	218±2m - 812±5m	1050	1010	1090
Horizontal Leg	812±5m - 2228±194m	159	PDC	Water	812±5m - 2228±194m	1055	1010	1100

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 218±2m	349	244.5	224.7	48.07	H-40	ST&C	15700	9400	3440
Intermediate Hole	0m - 812±5m	222	177.8	158.5	34.23	J-55	LT&C	30100	22500	4240
Horizontal Leg	798±13m - 2228±194m	159	114.3	98.4	17.26	L-80	LT&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		349	244.5	Out of Project Scope			0m - 218±2m
Intermediate Cement			222	177.8				0m - 812±5m
Production/Liner Cement			159	114.3				798±13m - 2228±194m



Appendix M – Gear Energy Ltd. Cummings Stick Diagram

Gear Energy Ltd. Cummings Well Profile

DRILLING STICK DIAGRAM

Horizontal Producer

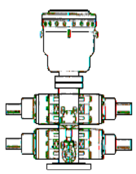
TO BE POSTED IN THE DOG HOUSE

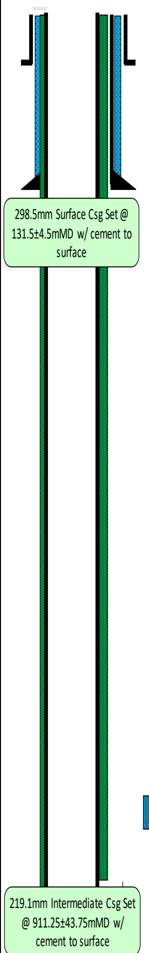
SAIT PT

CAPSTONE 2018

Matthew McDonald, Ali Mukyan, David Lee

WELLHEAD / BOP	WELL SUMMARY		
BOP's:	Surface location: 48-04W4	License # : Not Applicable	Rig: Range III Single
Class III BOP's	Well Type: Development - Non-Confidential	GL: 660.6±13.4m	Well Style: Multi Leg Lateral
Nace Trim	Status: Horizontal Cummings SS Production Well	KB: 665.1±13.4m	H_2S: Out of Scope
	AFE#: Not Applicable Working Interest: Not Applicable	KB-GL: 4.5 m	Formation: Cummings Sand





GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m³)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		131.5	131.5	520.0			
Colorado	Shale/Sandstone		315.3	315.3	336.2			
KOP	Not Applicable		371.0	371.0	280.5			
Second White Specks	Shale/Mudstone/Siltstone		423.5	423.2	228.3			
Base of Fish Scales	Shale/Mudstone/Siltstone		465.0	463.6	187.9			
Viking	Sandstone/Conglomerate		513.8	508.9	142.6			
Joli Fou	Shale/Sandstone		536.1	528.5	123.0			
Mannville	Sandstone/Shale		564.7	552.0	99.5			
McLaren	Sandstone/Shale		579.7	563.5	88.0			
Waseca	Sandstone/Siltstone/Shale		591.0	571.7	79.8			
Sparky	Sandstone/Shale		622.6	592.5	59.0			
General Petroleum	Sandstone		652.3	610.0	41.5			
Rex	Sandstone/Siltstone/Shale		682.6	626.4	25.1			
Lloydminster	Sandstone/Siltstone		723.3	644.7	6.8			
Cummings	Shale/Sandstone		785.0	661.8	-10.3			
TD / TOE	Shale/Sandstone		2004.0	676.4	-24.9			

*Formation Tops Based Upon Data From Well 103/10-16-048-04W4/00 and Average Depths of Wells/Casings

BIT PROGRAM / DRILLING FLUIDS SUMMARY (Review mud program)

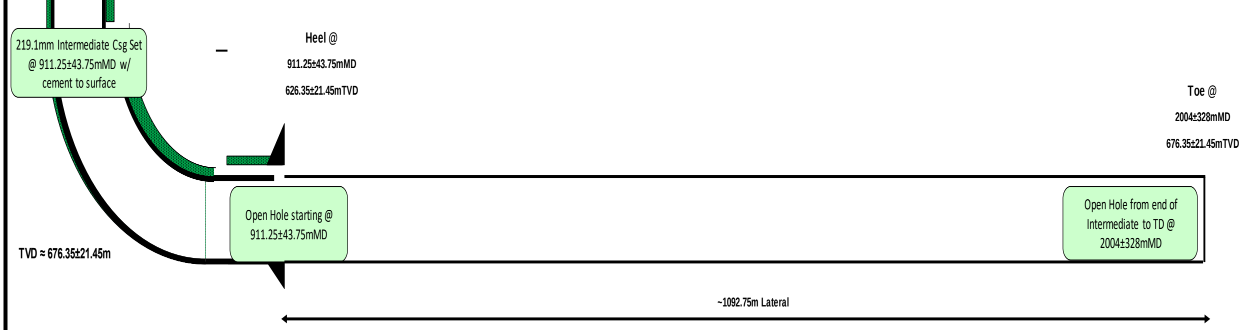
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m³)	Min. Density (kg/m³)	Max. Density (kg/m³)
Surface Hole	0m - 131.5±4.5m	375	Tooth	Floc/Gel-Chem Water	0m - 131.5±4.5m	1010	1000	1020
Int. Hole	131.5±4.5m - 911.25±43.75m	270	PDC	Water	5±4.5m - 911.25±43.	1077.5	1075	1080
Horizontal Leg	911.25±43.75m - 2004±328m	200	PDC	Polymer Water	911.25±43.75m - 2004±328m	1025	1015	1035

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 131.5±4.5m	375	298.5	277.6	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 911.25±43.75m	270	219.1	198	41.67	J-55	LT&C	23400	13000	5650
Horizontal Leg	911.25±43.75m - 2004±328m	200	Open Hole to TD					No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m³/t)	Slurry Density (kg/m³)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 131.5±4.5m
Intermediate Cement			270	219.1				0m - 911.25±43.75m



Appendix N – Devon Corp. Cummings Stick Diagram

enerPLUS

Devon Canada Corp. Cummings Well Profile

SAIT PT

CAPSTONE 2018

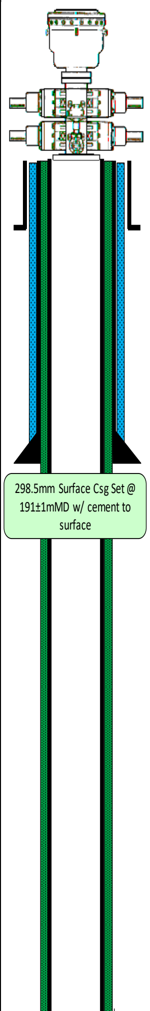
Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP	WELL SUMMARY					
BOP's:	Surface location: 47-01W4		License # : Not Applicable		Rig:	Range III "Single" Single
Class III BOP's	Well Type:	Development - Non-Confidential	GL:	634.25±0.15m	Well Style:	Single Leg Lateral
Nace Trim	Status:	Horizontal Cummings SS Production Well	KB:	638..55±0.15m	H_2S:	Out of Scope
	AFE#:	Not Applicable; Working Interest: Not Applicable	KB-GL:	4.3m	Formation:	Cummings Sand



GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m^3)	Maximum H_2S
Base of Groundwater Protection	Not Applicable	No Recorded Problems on Tour Sheets	No Data Available			No Drill Stem Tests/Pressure Data Available (Refer to Mud Weights Section for Insight on Formation Pressures)		Out of Project Scope
Surface Casing	Not Applicable		191.0	191.0	447.3			
KOP	Not Applicable		232.0	232.0	406.3			
Colorado	Shale/Sandstone		297.5	296.5	341.8			
Second White Specks	Shale/Mudstone/Siltstone		399.5	386.7	251.6			
Base of Fish Scales	Shale/Mudstone/Siltstone		444.4	425.9	212.4			
Viking	Sandstone/Conglomerate		495.3	470.1	168.2			
Joli Fou	Shale/Sandstone		536.1	504.9	133.4			
Colony	Sandstone		557.1	521.9	116.4			
McLaren	Sandstone/Shale		570.4	532.2	106.1			
Waseca	Sandstone/Siltstone/Shale		583.8	542.0	96.3			
Sparky	Sandstone/Shale		632.2	573.8	64.5			
General Petroleum	Sandstone		649.7	584.0	54.3			
Rex	Sandstone/Siltstone/Shale		670.1	594.9	43.4			
Lloydminster	Sandstone/Siltstone		699.7	608.4	29.9			
Cummings	Shale/Sandstone		738.1	622.1	16.2			
TD / TOE	Shale/Sandstone		1755.0	637.1	1.2			

*Formation Tops Based Upon Data From Well 100/03-14-047-01W4/00 and Average Depths of Wells/Casings

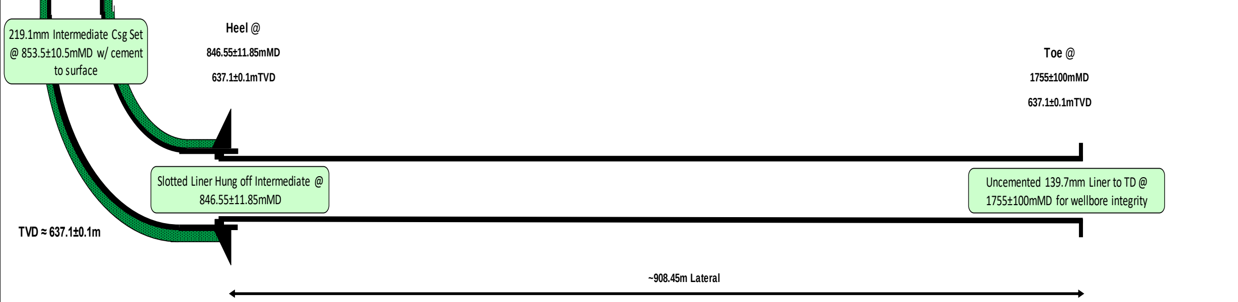
BIT PROGRAM				DRILLING FLUIDS SUMMARY (Review mud program)				
	Interval (MD)	Bit size (mm)	Bit type	Type	Interval (MD)	Density (kg/m^3)	Min. Density (kg/m^3)	Max. Density (kg/m^3)
Surface Hole	0m - 191±1m	375	Tooth	Gel-Chem Water	0m - 191±1m	1075	1050	1100
Int. Hole	191±1m - 853.5±10.5m	270	Tooth	Polymer Water	191±1m - 853.5±10.5m	1065	1050	1080
Horizontal Leg	853.5±10.5m - 1755±100m	200	PDC	Polymer Water	853.5±10.5m - 1755±100m	1030	1015	1045

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible	Out of Project Scope								
Surface Hole	0m - 191±1m	375	298.5	277.6	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 853.5±10.5m	270	219.1	198	41.67	J-55	LT&C	23400	13000	5650
Horizontal Leg	846.55±11.85m - 1755±100m	200	139.7	122.55	23.07	J-55	LT&C	No Data Available		

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m^3/t)	Slurry Density (kg/m^3)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5	Out of Project Scope			0m - 191±1m
Intermediate Cement			270	219.1				0m - 853.5±10.5m



Appendix O– Enerplus Corp. Lloydminster Stick Diagram

enerPLUS

Enerplus Corp. Lloydminster Well Profile (For Comparison)

SAIT PT

CAPSTONE 2018

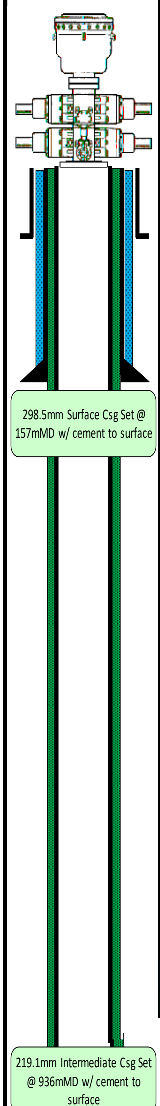
Matthew McDonald, Ali Mukyan, David Lee

DRILLING STICK DIAGRAM

Horizontal Producer

TO BE POSTED IN THE DOG HOUSE

WELLHEAD / BOP
BOP's:
Class III BOP's
Nace Trim



WELL SUMMARY

UWI:	105/03-23-047-05W4/00	License # :	461849	Rig:	Range III Single
Well Type:	Development - Non-Confidential	GL:	646.1 m	Well Style:	Single Leg Lateral
Status:	Horizontal Lloydminster SS Production Well (Pumping Heavy Oil)	KB:	650.3 m	H_2S:	Out of Scope
Spud Date:	16-Jan-14 Rig Release: 25-Jan-14	KB-GL:	4.2 m	Formation:	Lloydminster Sand

GEOLOGICAL SUMMARY

Formation	Lithology	Drilling Occurances	Depth MD (m)	Depth TVD (m)	Depth SS (m)	Gradient (kPa/m)	EMD (kg/m³)	Maximum H_2S
Base of Groundwater Protection	Not Applicable		No Data Available					
Surface Casing	Not Applicable		157.0	157.0	493.3			
Colorado	Shale/Sandstone		306.2	306.2	344.1			
KOP	Not Applicable		378.0	378.0	272.3			
Second White Specks	Shale/Mudstone/Siltstone		423.0	422.6	227.7			
Base of Fish Scales	Shale/Mudstone/Siltstone		470.0	466.5	183.8			
Viking	Sandstone/Conglomerate	No Data Available	527.1	514.7	135.6	No Drill Stem Tests/Pressure Data Available		Out of Project Scope
Joli Fou	Shale/Sandstone		560.0	538.6	111.7			
Colony	Sandstone		586.0	555.1	95.2			
Sparky	Sandstone/Shale		633.8	579.1	71.2			
Lloydminster	Sandstone/Siltstone		919.0	647.0	3.3			
TD / TOE	Sandstone/Siltstone		2020.0	648.5	1.8			

Info Directly off GeoSCOUT and AccuMap for Well 105/03-23-047-05W4/00

BIT PROGRAM

	Interval (MD)	Bit size (mm)	Bit type
Surface Hole	0m - 157m	375	Tooth
Int. Hole	157m - 936m	270	PDC
Horizontal Leg	936m - 2020m	200	PDC

DRILLING FLUIDS SUMMARY (Review mud program)

Type	Interval (MD)	Density (kg/m³)	Min. Density (kg/m³)	Max. Density (kg/m³)
	0m - 157m			
No Data Available	157m - 936m		No Data Available	
	936m - 2020m			

WELLBORE AND CASING INFORMATION

Casing	Interval (MD)	Hole Size (mm)	Casing Size (mm)	Drift (mm)	Wt (kg/m)	Grade	Thread	Burst (kPa)	Collapse (kPa)	Optimum Torque (Nm)
Conductor	As Deep As Possible				Out of Project Scope					
Surface Hole	0m - 157m	375	298.5	277.6	62.50	H-40	ST&C	13700	7200	4160
Intermediate Hole	0m - 936m	270	219.1	202.5	35.72	J-55	ST&C	20300	9400	3310
Horizontal Leg	915.8m - 2012m	200	139.7	124.1	20.83	J-55	ST&C		No Data Available	

CEMENTING PROGRAM

Interval	Pre-Flush	Cement Blend	Hole Size (mm)	Casing (mm)	Yield (m³/t)	Slurry Density (kg/m³)	% Excess	Cement Interval (m)
Surface Cement	Out of Project Scope		375	298.5		Out of Project Scope		0m - 157m
Intermediate Cement			270	219.1				0m - 936m