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Drilling Fluids Program Report

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Executive Summary

A prospective well to be drilled in the Kakwa Region has been thoroughly analyzed in order to create a drilling program with the goal of maintaining effective well control and providing an estimate of the total costs. The surface hole will be drilled with water-based mud so it does not affect the “Base of Ground Water”. Both the intermediate and main hole will be drilled with invert mud. The main drilling problems that were faced was lost circulation, sloughing hole and high pressures. In order to combat these problems, it was found that adjusting mud weights and or using appropriate concentrations of select additives would help alleviate these difficulties. In total, all the additives needed for this project will cost **\$881,591.93**.

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Introduction

This report has been written to fulfill the requirements for the PROJ 310 course at SAIT Polytechnic serving as an educational opportunity for both the team and the readers. This paper will provide the reader with information about the anatomy and purpose of the drilling fluid program created. The report strictly focuses on the purpose, methods, problems faced and specific configurations of onshore drilling fluid program mechanisms that are used during the drilling of hydrocarbons.

Objective

The primary objective is to have a drilling fluid program that fits the specification process of the well. The secondary objective is the team developed strategies to deal with formation challenges. The third objective is managing the cost to provide a mutual economic benefit for Halliburton's service to the client.

Scope

Halliburton's main interest is to provide a resulting product that allows preventions of damage, kick, lost circulation and a blowout to the well. The project involves the design of drilling fluids in Montney formation in the Kakwa area. The intent of this project is to propose drilling fluids for the 3 sections of the well; surface, intermediate and main.

Background [5]

It is necessary for the reader to have a basic understanding of the main purpose of a drilling fluid program prior to reading this in order to comprehend the nature of the report. A blow out occurs when the kick is not controlled or it can also happen by equipment failure. Kicks occur when there is a reduction of hydrostatic pressure in the wellbore. In conventional drilling operations, the well bore pressure is greater than the pressure in the formation. Common causes of kicks:

- Failure to keep the hole full
- Swabbing
- Surge pressures
- Insufficient fluid density
- Lost circulation
- Abnormal formation pressure

This is where a drilling fluid program comes into play. Drilling fluid program is considered a primary well control method for drilling a well. The selection of drilling fluid type and the properties required of this fluid will determine how efficient the well will be drilled. The correct type of drilling fluid for the formation must coat the wellbore with a filter cake that seals off porous zones, helps prevent collapse of the wellbore, minimizes lost circulation and aids in the protection against formation fluid contamination. The drilling fluid must also be chemically compatible with the formation and formation fluids.

Methods

This report is comprised of information gathered mostly from, Company information, first year drilling, offset data, first year drilling engineering course notes, and internet sources. A combination of drilling, economics, rheology and geology knowledge is required for completing the drilling fluid design

Preview

Firstly, a brief information of the geological prognosis and drilling fluid. The explanation of the chosen drilling fluids will also cover basic functions and characteristics for each stage with recommendations and reasoning. Next, we have the cost break down and conclusion of why we chose what type of fluid.

Area of Study

Kakwa

The prospective well will be drilled in the Kakwa Region. The Kakwa region is next to northernmost border of Jasper National Park along the North-South border of British Columbia.

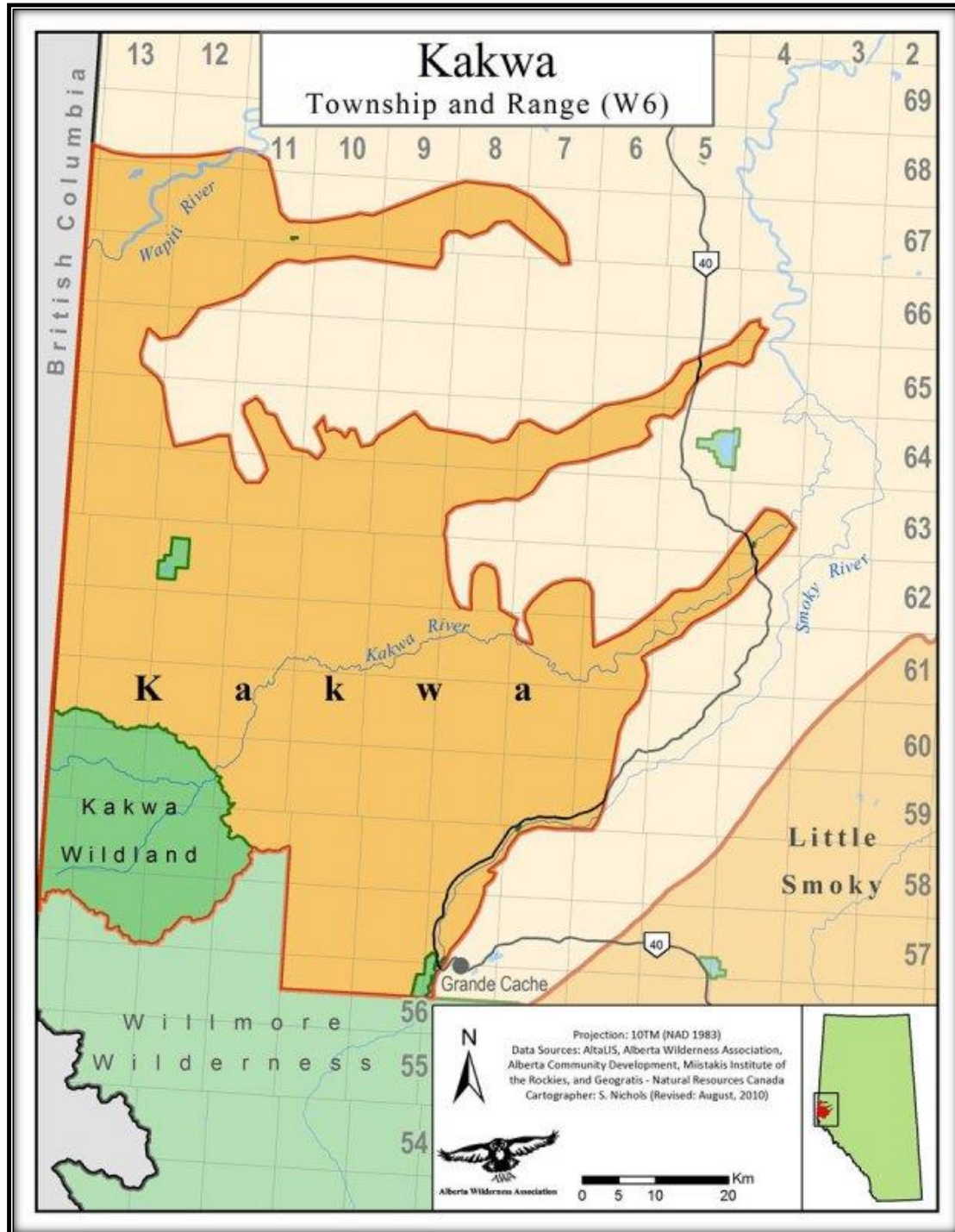


Figure 1: Kakwa Map

Offset Wells Study

Offset Well Summary of 5 Nearby Wells

#	Well Name	Location	Yr	TD	Days	Surface	Depth	Main	Mud Up
1			2005	2975	25	311	490	222	490
	<p>Spud 311mm hole with light gel slurry, drill to 147m, ream from 86m-114m. Drill to 490m, wiper trip. Run and cement 244.5mm surface casing with 5m³ cement returns. Main Hole: Drill out and displace with invert 980Kg/m³. Drill to 1051m with a deviation of 5.5 degrees, density was 1020 Kg/m³. Drill to 1450m, increase angle to 12.4 degrees, drop density to 990 Kg/m³. Drill to 1763m, angle dropped to 1.4 degrees, density maintained to 1070Kg/m³. Drill to 2503m without problem, circ out gas, density was 1100Kg/m³, drill to 2824m, Shut in well, circ through choke, increase density to 1290Kg/m³, flare out gas. Drill to 2900m, density up to 1330 Kg/m³. Drill to 2975m, Run logs, RIH circ and cond mud, lay down BHA, run and cement 139.7mm production casing, good 4m³ cement returns.</p>								

Figure 2: Well #1

#	Well Name	Location	Yr	TD	Days	Surface	Depth	Main	Mud Up
2			2008	3230	41	311	563	222	n/a
	<p>Spud with AQUAGEL Chem mud. Lost circulation at 54m. Pump LCM slug and build volume. Drill to 533m with bit runs at 220, 349 and 407m. Circ hole clean and raise vis to 120 s/l. Wiper trip and POOH. Run & cement 244.5mm casing. Drill out with ENVIROMUL Invert and 222mm PDC bit. Work tight hole at 910m. Drill to 1471, wiper trip to 700m. Drill to 1746 and POOH for bit. RIH and ream to BTM. Drill ahead, slowly raising density to 1360kg/m³ by 2518m (Fahler C). Drill to 2571m, circ clean and POOH for bit. RIH, ream bridges and wash to BTM. Drill to 2903m, circ clean and POOH for bit. RIH and wash 20m to BTM. Lower density to 1295kg/m³. Drill to 2961m and POOH for bit. RIH with tri-cone. Drill to 3233m with 3 tri-cone bits. Wiper trip to 2990m, POOH to log. Log hole in one run. RIH and wash 9m to BTM. Circ clean, POOH and lay down pipe. Run and cement 139.9mm casing with good returns. Invert lost = 116m³.</p>								

Figure 3: Well #2

#	Well Name	Location	Yr	TD	Days	Surface	Depth	Main	Mud Up
3			2005	2820	26	349	603	222	603
	<p>Spud 349mm hole with Gel mud, drill to 135m, rough drilling through sandstone to 135m, work tight hole. Drill to 242m, increased hook load, pump out singles, work stuck pipe, pump out singles. Trip, reaming, wash to bottom. Drill to 603m, POH wiper trip, wash to bottom. POH to run and cement 244.5mm casing. Main Hole: Drill out 222mm hole, displace water to invert, Density was 980 Kg/m³, Viscosity was 48 s/l, drill to 1443m without problem Density was 1010Kg/m³, $\mu=50$ s/l. Drill to Cardium top at 1559m, Drill to 1626m trip for bit, RIH circulate out gas Density was 1050Kg/m³, Viscosity was 55 s/l. Drill to 2668m, increase gas readings to 1400 units, probably from the Blue Sky formation. Density was 1100Kg/m³, Viscosity was 60 s/l. Drill to 2820m, wiper trip, POH to log hole. After logs RIH circulate hole, burnt 3m flare for 10 min. lay down drill string. Run 178mm casing, circulate casing while waiting for cementers, loss 20m³ during casing circulation. Cement casing with good returns.</p>								

Figure 4: Well #3

#	Operator	Location	Yr	TD	Days	Surface	Depth	Main	Mud Up
4			2004	2860	32	311	542	222	542
	Successfully drilled a 311mm hole to casing point at 542m using Gel mud, no major problems encountered, Run and cement 244.5mm surface casing. Main Hole: Drill out 222mm hole, displace with invert 940 Kg/m³ . Drill to 2085m with a deviation of 1.5 degrees, mud density 970 Kg/m ³ . Drill to 2363m, increase mud density to 1030Kg/m ³ . weight up system while drilling to 2446m, mud density 1130Kg/m ³ , no gas to surface. Drill to 2860m, mud density lowered to 1115Kg/m³ . Log hole. Hole was in good condition. Circulate hole and condition mud, lay down pipe. Run and cement 139.7mm casing in two stages.								

Figure 5: Well #4

#	Well Name	Location	Yr	TD	Days	Surface	Depth	Main	Mud Up
5			2007	2758	24	311	465	156	n/a
	Spud with AQUAGEL Chem mud. Mixing sawdust while drilling to control seepage. Drill to 465m with no problems reported. Run & cement 244.5mm casing. Drill out with ENVIROMUL Invert. Programmed to drill to TD (2772m) with this system. Drill to 2557 with 4 bit trips. Weight up to 1205kg/m ³ for Bluesky pressures. Total losses occurred. Pump two pills with no success. Waiting for Invert. Ran 177.8mm CSG and cement. Drill out 156mm hole with BARAZAN/PAC R mud. Take kick at 2562m. Pump kill mud. Weight up to 1210kg/m ³ and drill to 2635m. Wiper trip. Drill to 2758m (TD) with minor reaming. Wiper trip. Raise Vis to 86s/l and log hole with no problems. Run 114mm CSG and cement.								

Figure 6: Well #5

The 5 tables above depict a well summary of five nearby wells. The main similarities between all five of them is that they spud the well with gel mud. Gel mud does not contaminate ground water and does require weighting agents. It only needs a viscosifier. Another similarity is that the main hole was drilled with invert mud. This is because invert mud reduces friction which can also prevent further problems downhole.

Well numbers 2 and 5 experienced loss circulation. They were both controlled through the use of lost circulation materials. More on LCM (lost circulation materials) will be discussed in the *Formation Challenges with Solutions* section of this report.

Throughout all five wells, density was constantly being changed at different depths of drilling.

For example, well #1 had a mud density of 1020 kg/m³ when being drilled to a depth of 1051m with a deviation of 5.5°. The mud density was then decreased to 990 kg/m³ when being drilled to a depth of 1450m with a deviation of 12.4°.

The is mostly likely a result of maintaining proper bottom hole pressures, as changing the mud density is a primary mean of well control.

Area Drilling Events

Within the radius of 4 miles from the proposed drilling location, 329 wells were found

- **29 wells had lost circulations (8.8%)**

In the Falher formation, at a top depth of 2677m, this lost circulation occurred when casing, while all of the other lost circulation events occurred when drilling.

With minor loss circulation being defined as losses of 75 m³ or less and less than 48 hours to control, there are 15 wells with minor lost circulation.

Also, with severe loss circulation being defined as losses in excess of 75 m³ or more than 48 hours to control, there are 11 wells with severe lost circulation.

Most of the lost circulation events occurred from surface to 467 m.

- **3 wells had kicks (0.9%)**

The kicks occurred in the Banff, Falher and Gething formations. In order to combat these kicks, these wells had their final mud weight increased.

- **0 wells had water flow (0%)**

Area Acid Gas Summary

Out of the 329 wells within the search radius, 275 wells (84%) had a concentration of CO₂ ranging from 0.01% to 10.48%.

6 wells (2%) were found with an H₂S concentration ranging from 0.02% to 0.07%.

Area Formation Pressures

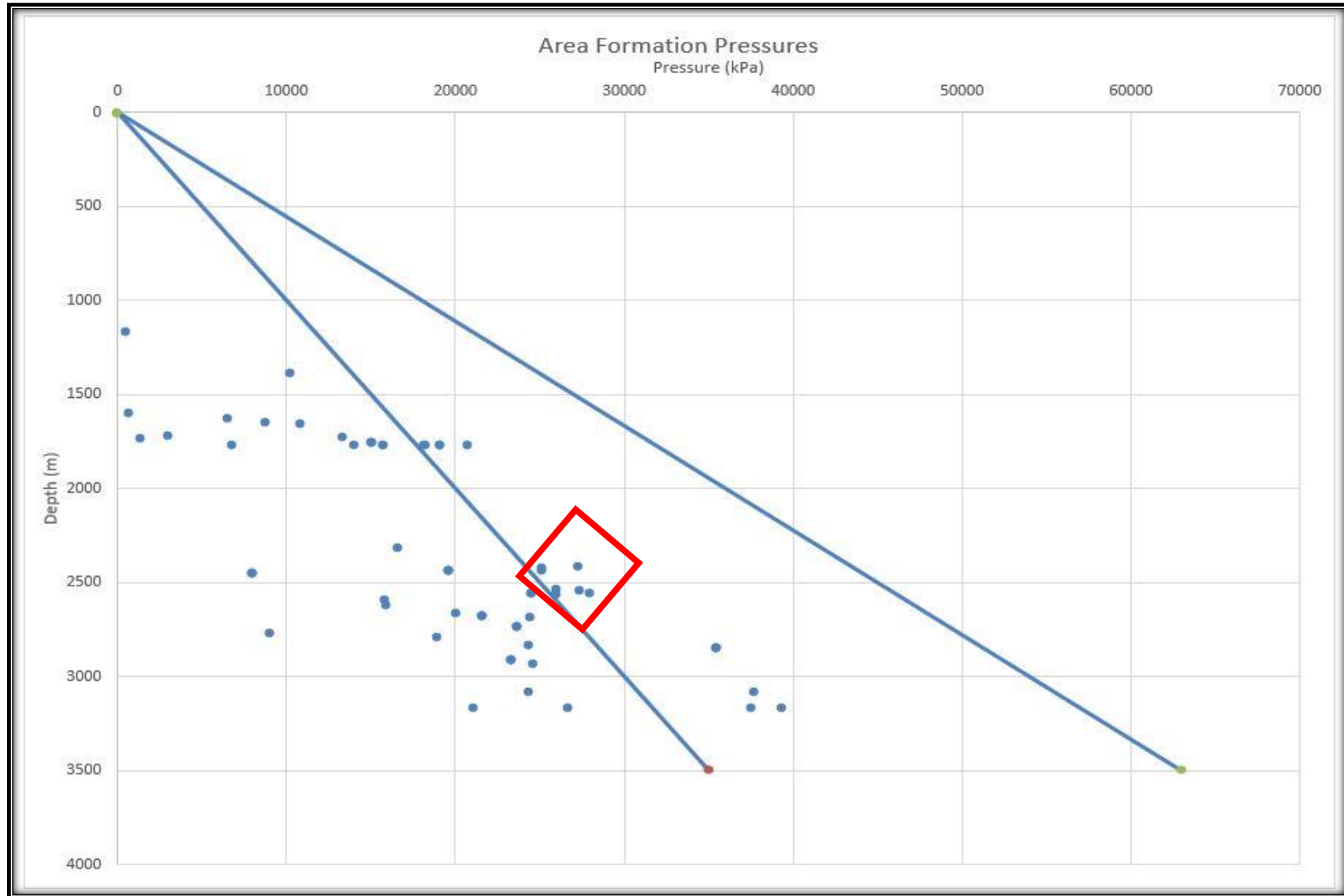


Figure 7: Area Formation Pressures

Explanation of Results

The geological prognosis and the offset information was all provided to us by Craig Bothwell.

In this section, how the equivalent mud densities came about will be discussed here.

On the geological prognosis, possible high pressures occur at the Falher formation which is at a depth of approximately 2467m.

The graph shown on the previous page depicts the pressures of the formations of nearby wells. As noted in the geological prognosis, near the depth of 2467m, the pressure gradient is higher than normal, in which the normal would be 9.81 kPa/m.

It was also determined that the type of test used to find this pressure was an AOF (absolute open flow).

From the given depth and pressure, the gradient of the Falher formation was found:

Depth = 2434m

Pressure = 25106kPa

Gradient = Pressure/Depth

Gradient = 25106/2434

Gradient = $10.31 \cong 11$ kPa/m

With this given gradient, the EMD (equivalent mud density) of the Falher formation in the proposed location can be established.

EMD = Gradient/Gravity

EMD = $11/0.00981$

EMD = 1121 kg/m³

Possible high pressures also occur at these depth (3102, 3174 and 3197). To determine their EMDs, the same process will be used as the Falher formation. Find the gradient based on the area formation pressures, which will then lead to the appropriate EMD of that formation.

Geological Prognosis

Montney [3]

The target formation is Montney. Montney formation produces oil sands, condensates and natural gas. The Montney is in the lower Triassic period that is a stratigraphic unit.; made mainly of 8 interbred sandstone/shale and dolomitic siltstone. Depending on location of Montney (upper or Lower) it varies of what type of depositional environment it is; ranging from outer shoreface to offshore. Storm dominate is the offshore-transition. The average gross thickness of the Montney is 200 meters. The Montney formation in the Kakwa area is known for their lost capital and operating cost.

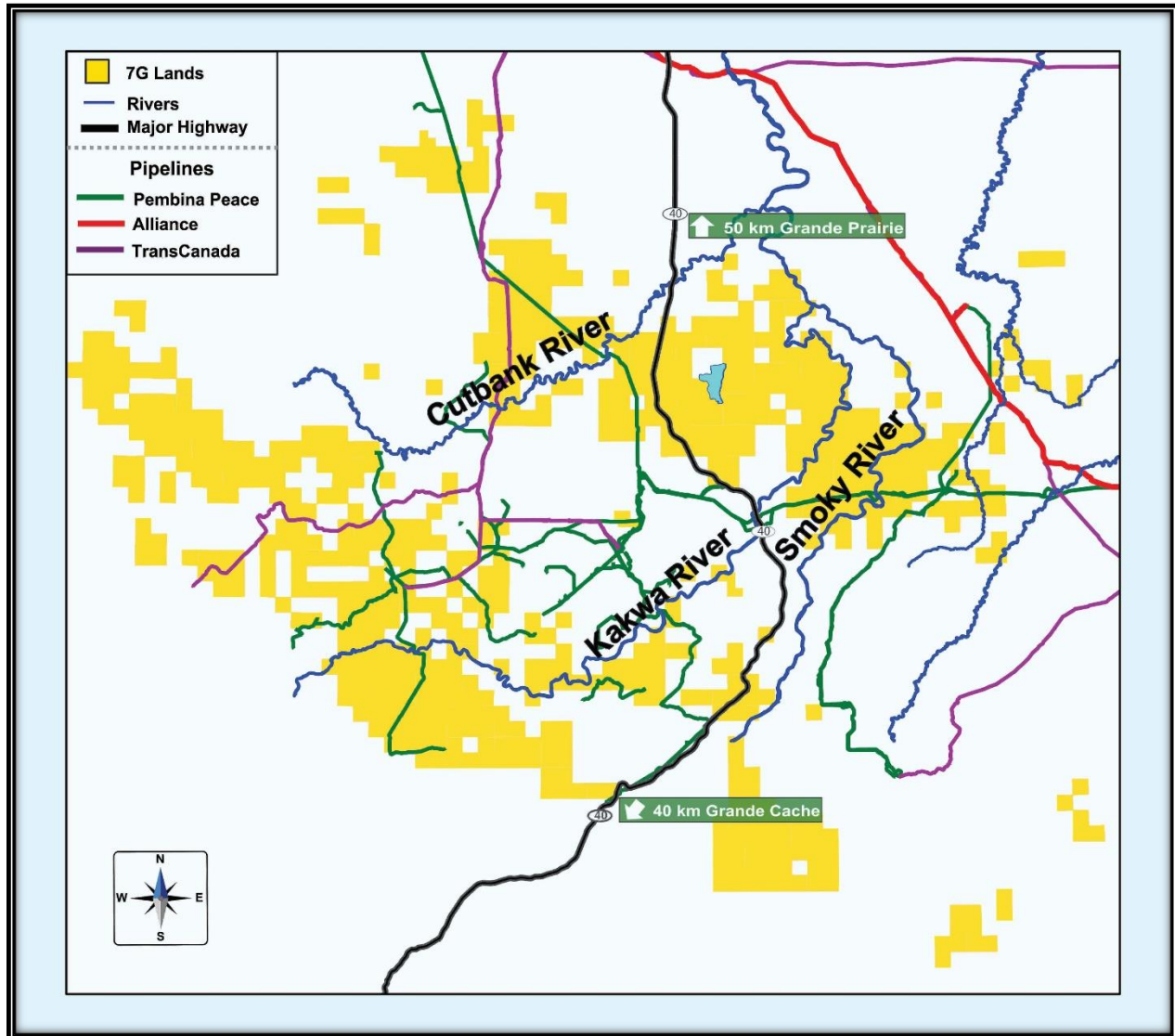


Figure 8:Kakwa Map #2

Hole and Casing Design

Casing	Interval	Hole Size	Size (OD)	Drift	Weight	Thread	Burst Rating	Collapse Rating	Optimum Torque	Joint Rating	Tensile Body Yield
	m	mm	mm	mm	kg/m		kPa	kPa	N*m	daN	daN
Conductor	0-12.2	508	406.4	-	-	-	-	-	-	-	-
Surface	0-615	311.2	244.5	222.6	53.57	LT&C	24290	13920	6150	201500	250410
Intermediate 1	0-2800	222.2	177.8	158.52	34.23	LT&C	43700	33780	6660	193500	236600
Intermediate 2	2800-3282	222.2	177.8	156.24	38.69	LT&C	68700	43000	6950	308300	369200
Production 1	0-3155	156.6	114.3	96.4	20.09	TSH XP	97200	80100	10500	213100	213100
Production 2	3155-5882	156.6	114.3	96.4	20.09	TSH XP	97200	80100	10500	213100	213100

This table represents the type of casing, their specifications and intervals.

Directional

KOP	Build Rate	End Build	Hold Angle	Hz Section	Target	Drop Rate	Begin Drop	Azimuth
m	°/30m	m	°	m	m	°/30m	m	°
294	2	429	9	1035	1599	2	1464	340
3088	14	3282	90.5	2600	3282	-	-	315

This table characterizes the direction of the wellbore. As all wells are never perfectly straight, the vertical section of this well will have a slight deviation to it resulting in a shallow kick off point at 294m. The second kick off point at 3088m is intended as it deviates the well to make it go through 2000 (3088 to 5882) meters of the target formation laterally.

Formation Pressures

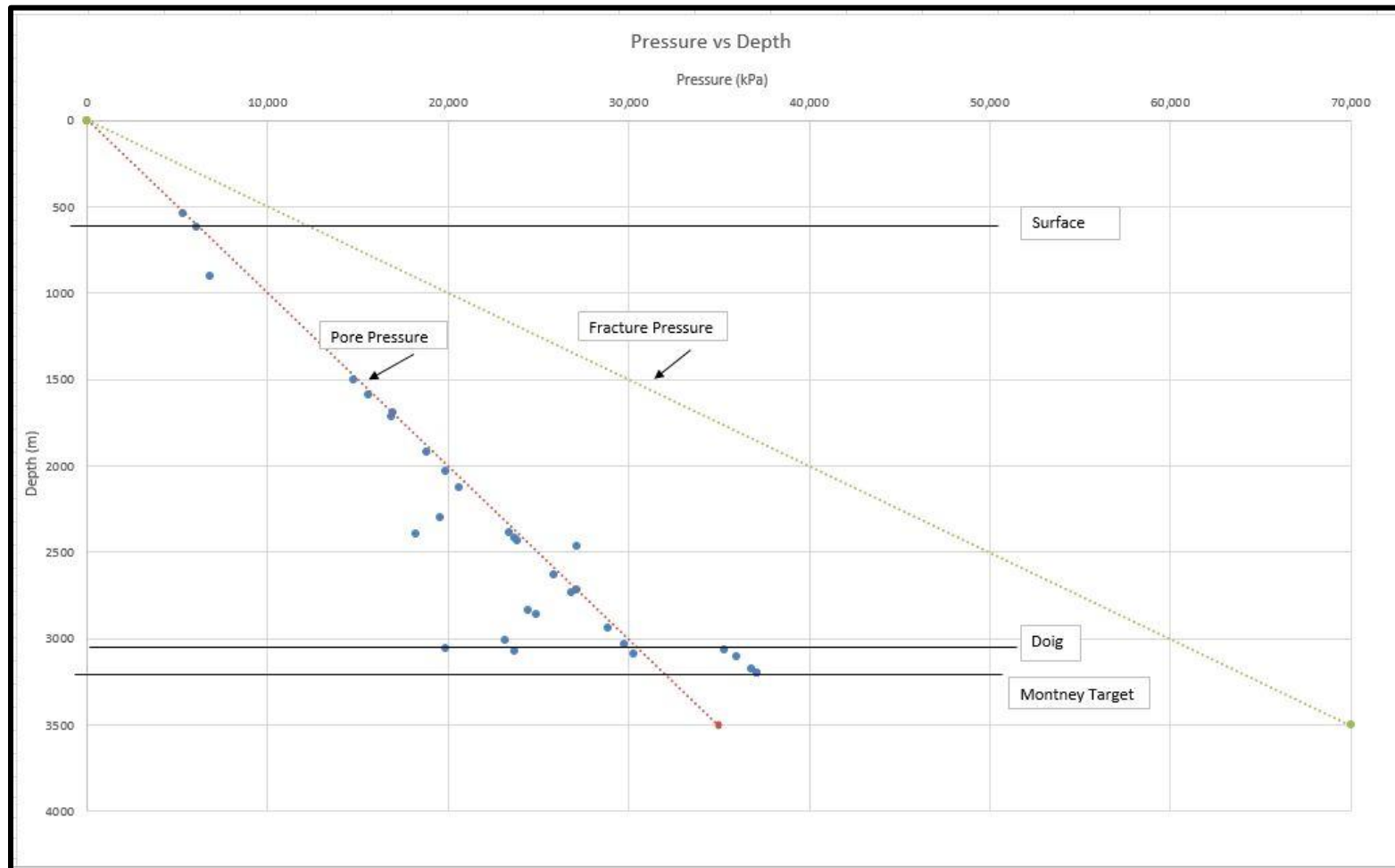


Figure 9: Formation Pressures

This graph displays the formation pressures from the geological prognosis. Most of the formations have a pressure gradient near the pore pressure of the well with the exception of the Doig formation.

Drilling Fluids Recommendations [1]

Products and Concentrations

Surface Hole

Surface section is typically drilled through a relatively unconsolidated material, therefore lost circulation is expected. Also, in Western Canada, this section contains fresh waters hence a great deal of care should be taken in designing drilling muds to ensure the ground water is not contaminated. Gravels, which are expected for surface section, require high viscosity to keep the hole clean [6]. For this well, a water based system will be used for the surface, with Aquagel (bentonite) additive for viscosity and caustic potash for pH, also, BARAZAN will be added to contingency in case hole cleaning problems becomes an issue.

Mud System			
Aquagel			
Interval	0 - 615	m	
Density (kg/m ³)	ALAP		
Viscosity (sec/L)	35-40		
Yield Point (Pa)	12-16		
Plastic Vis (mPa.s)	6-8		
pH	10-11		

Figure 11: Surface drilling mud properties

Product Usage		
AquaGel	196	sx
Caustic Potash	2	sx
Lime	2	sx
Sawdust	250	sx
(Contingency)		
BARO-SEAL	600	sx
Desco		

Figure 10: Surface Drilling Usage

Intermediate Hole

According to the geological prognosis, shale is present throughout the intermediate section, therefore inhibited fluid or an invert mud is necessary to avoid formation swelling which could potentially cause the wall collapse. According to the area search, invert muds are dominate in the area, using any other type would make it challenging to sell for a client. Another reason for choosing invert over inhibited water mud is the long lateral section that requires lubricity.

Tight-Emulsion System		
Interval	615 - 3282	m
Density (kg/m ³)	Min 1020 kg/m ³	
Keep ALAP		
Increase to 1180 kg/m ³ prior to Doig	Max 1100 kg/3	
Viscosity (sec/L)	45-50	
Yield Point (Pa)	24-30	
Plastic Vis (mPa.s)	12-15	
pH	10-11	
HTHP	Maintain an all-oil HPHT filtrate	

Figure 12: Tight-Emulsion System

DRILL SOL PLUS 90/10	295.0	m3
Barite 41	2631	sx
Invermul NT	32	dm
Lime	130	sx
DURATONE® HT	221	sx
GELTONE V	52	sx
EZ MUL NT	8	dm
(Contingency)		
H2S SCAVENGER	30	
BAROLIFT	44	
Barite 41	500	

Figure 13: Product makeup

Drillsol plus 90/10 will be used as the base for this tight-emulsion system, it consents 90% mineral oil and 10% water. Mineral oils are environmentally safer than diesel and has less effect on surface equipment.

Invermul NT is a primary emulsifier used in mineral oil drilling system, its primary function is to help stabilize emulsion and improve solids wetting, and it also reduces HPHT filtration.

Duratone HT is a modified lignite product that acts as a fluid loss control agent, it also helps promote stability of the invert emulsions.

The following is a summary of the make-up used to this system:

Additive	Function	Concentrations, lb/bbl (kg/m ³)	
		To 300°F (149°C)	To 400°F (205°C)
Oil	Continuous phase	As needed	As needed
INVERMUL or INVERMUL NT	Primary emulsifier	6-8 (17-23)	8-16 (23-46)
Lime	Alkalinity source	3-4 (9-11)	4-8 (11-23)
DURATONE HT or DURATONE E	Fluid loss control agent	6-8 (17-23)	8-20 (23-57)
Water	Discontinuous phase	As needed	As needed
GELTONE II/V	Viscosifier	0.5-3 (1.4-9)	2-8 (6-23)
EZ MUL or EZ MUL NT	Secondary emulsifier	1-2 (3-6)	2-8 (6-23)

Figure 14: Summary of Make-ups

Main Hole

For the main hole, the same drilling system will be used, additional barite will be required to maintain density at 1180 kg/m³

Product	Concentration
DRILLSOL PLUS 90/10	
Barite 41	441.6
Invermul NT	20.0
Lime	10.0
DURATONE® HT	17.0
GELTONE V	4
EZ MUL NT	5
(Contingency)	
H2S SCAVENGER	2
BAROLIFT	1
Barite	

Figure 15: Main Hole Product Concentration

For a higher ROP, centrifuge cutting at surface then mud up to 1180 kg/m³

Procedures and Maintenance [5]

Surface Hole

Spud with a 35 - 40 sec/L viscosity Aquagel. Raise viscosity as required to clean hole with Aquagel.

Ensure to have an adequate supply of LCM contingency on location prior to spud.

- 1) Fill with adequate volume of fresh water.
- 2) Add 2 sacks Soda Ash and 30-35 kg/m³ Aquagel slowly through a jet mixer for a 35-40 sec/L viscosity.
- 3) Spud and drill ahead adding small amounts of Caustic Potash or Soda as needed for a short term viscosity.
- 4) Increase the viscosity as required with Aquagel.
- 5) Maintain density as low as hole will allow with fine screens/centrifuge.
- 6) Mix 1 sack of Sawdust every other connection. Mix 1 Vis cup of Drilling Detergent down the drill pipe every other connection.
- 7) Increase viscosity to 70+ sec/L or as required to clean the hole prior to running casing.
- 8) For cementing, isolate the suction and drop viscosity to 45 sec/L with Desco.

Circulate casing adequately until the hole cleans up prior to cement.

Intermediate Hole

- 1) While WOC, dump and clean the mud pits and fill with 60 m³ DRILLSOL PLUS 90/10.
- 2) Add 240 kg (11 sx) GELTONE V through the hopper at 2 min/sx to a viscosity of \pm 40 s/L.
- 3) Add 1200 kg (53 sx) Duratone
- 4) Add 1200 kg (6 dm) Invermul NT
- 5) Drill out with water and then displace the hole to clean mud.

Additions:

- Add 1 Sack of DURATONE every 26 m of new hole.

Main Hole

The procedures in this section of the well will be similar to the intermediate hole.

Formation Challenges with Solutions [1]

Types of Challenges that have occurred throughout drilling

- Lost Circulation
- Stuck Pipe
- High Pressures
- Tight Hole
- Potential H₂S

Possible causes of Lost Circulation

- Excessive overbalanced mud weight
- Cuttings loading in the annulus due to poor hole cleaning
- Elevated viscosity and rheological properties
- Restricted annular space
- Excessive surge pressure while running the drillstring or casing in the hole
- Combination of the above factors

Possible Causes of Stuck Pipe

In drilling operations, the drill pipe is considered stuck when it cannot be raised, lowered, or rotated. Typical stuck pipe situations include the following:

- Differential-pressure effects
- Packing off
- Undergauge hole
- Keyseating

According to the offset data, packing off is mostly likely causing this stuck pipe.

Packing off occurs when the drilling fluids exhibit poor suspension characteristic. For example, if cutting beds are present and the junk slot area is not sufficient to allow cuttings to pass through, pack off will occur.

Possible Causes of High Pressure

A probable cause of high pressure in formations could be a result of the way the formation was deposited.

During deposition, water can become trapped before compaction is finished. As compaction continues, the fluid will be compressed, increasing the pore pressure. Formations that were originally normally pressured can become abnormally high pressured if they are shifted up from their original position due to faulting or deformation of the rock layers. As erosion occurs at surface, the trapped pressure in the formation would be higher than expected at that depth based on the normal pressure gradient range.

Possible Causes of Tight Hole

Poor cutting transportation can cause tight hole.

When lift velocity of the drill fluids is lower than the slip velocity, the cuttings will drop and accumulate into mini beds within the wellbore, therefore reducing the original hole size.

Surface Hole

Within the interval of 0 – 615 m, the only challenges encountered was lost circulation.

Lost Circulation Solutions

Pre-Treatment

These would be solutions that would prevent lost circulations:

- Pre-treat with saw dust before drilling high risk lost circulation zone
- Add 10 sacks of saw dust treatments as sweeps
- Spot across thief zones
- Keep additional saw dust on site if needed

Remediation

These would be solutions that would correct occurring lost circulations:

- Wellbore breathing (also known as ballooning)
 - When the mud is static (pumps off), then all or most of the lost fluids re-enters the system
- Drilling must be slowed or suspended (for partial losses)
- Hole should be kept full to the equilibrium point with water or base oil (for severe losses)
- The annulus should be kept full with monitored volumes of lighter mud and or water or base oil (for complete losses)

Stuck Pipe Solutions

The procedure to remediate this problem is to:

1. Do not jar up on the string
2. Attempt to go down one stand and try and clean up the hole with rotation and flow
3. Back off and wash over

Intermediate Hole

Within the interval of 615 – 2950 m, the challenges encountered were sloughing, high pressures and tight hole and potential H₂S.

Sloughing Solutions

Sloughing occurs when water-based muds are used in shale formations. The clays in the formations swell up when it is encountered with water.

Treatment:

- Increase mud weight
- Convert mud to an inhibitive fluid
- Increase mud viscosity
- Reduce pressure surges
- Reduce drill pipe whipping

High Pressures Solutions

- Ensure the mud weight is adequate to handle the pressure from this formation prior to entering it.
- Maximum density should be 1120 kg/m³

Tight Hole Solutions

- Pump 4-5 m³ of water in sweeps
- Pump down hole ¼ sack of Barazan and 0.5-1.5 kg/m³ of Barolift

Potential H₂S Solutions

- Maintain pH above 10.5 for the duration of this well to prevent Sulphides from entering the mud system.
- Watch for a sudden drop in pH and check for Sulphides if pH drops below 10.5.
- If this happens, check the mud for Sulphides using a hach test to determine if they are present.
- If Sulphides are found using a Hach test, then preform a GGT to determine the concentration.
- If H₂S is evident, increase the pH back up to 11 with Potassium Hydroxide and a start mixing a sulphide scavenger (SOURSCAV®).
- Aquatreat H₂S treatment is 2 L/m³ for 500mg/L scavenging ability.
- Do not add either product unless absolutely necessary to avoid failing mircotox tests for disposal

Main Hole

The problems encountered within the interval of 2950 – 5882 was high pressures and potential H₂S.

High Pressure Solutions

- Ensure the mud weight is adequate to handle the pressure from this formation prior to entering it. Max density 1180 kg/m³

Potential H₂S Solutions

- If H₂S is evident, increase the pH back up to 11 with Potassium Hydroxide and a start mixing a sulphide scavenger (SOURSCAV®)
- Aquatreat H₂S treatment is 2 L/m³ for 500mg/L scavenging ability
- Do not add either product unless absolutely necessary to avoid failing mircotox tests for disposal

Cost Estimate

The cost breakdown was designed by which drilling fluid chosen and additives used. Prices for drilling fluid are updated frequently in Bariod-Halliburton within the company and the additives are found in a Price handbook created by Halliburton. Volumes/ mass of additives were selected by various equations that changes the fluid levels.

Surface Hole

Product	Size	Price List	Estimate	Est. Cost
AquaGel	22.7 kg	\$12.69	196	\$2,487.24
Caustic Potash	25 kg	\$194.05	2	\$388.10
Lime	22.7 kg	\$40.80	2	\$81.60
Sawdust	9 kg	\$7.38	250	\$1,845.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00

Interval Cost **\$4,801.94**

Figure 16: Surface Hole Costs

Intermediate Hole

Product	Size	Price List	Estimate	Est. Cost
DRILLSOL PLUS 90/10	m3	\$961.46	295	\$283,630.70
Barite 41	40 kg	\$37.82	2631	\$99,504.42
Invermul NT	190 kg	\$1,948.61	32	\$62,355.52
Lime	22.7 kg	\$23.91	130	\$3,108.30
DURATONE® HT	22.7 kg	\$265.84	221	\$58,750.64
GELTONE V	22.7 kg	\$183.99	52	\$9,567.48
EZ MUL NT	22.7 kg	\$2,566.03	8	\$20,528.24

Interval Cost **\$537,445.30**

Figure 17: Intermediate Hole Cost

Main Hole

Product	Size	Price List	Estimate	Est. Cost
DRILLSOL PLUS 90/10	m3	\$961.46	96	\$92,300.16
Barite 41	22.7 kg	\$37.82	1060	\$40,089.20
Invermul NT	22.7 kg	\$1,948.61	11	\$21,434.71
Lime	22.7 kg	\$23.91	43	\$1,028.13
DURATONE® HT	22.7 kg	\$265.84	72	\$19,140.48
GELTONE V	22.7 kg	\$266.84	17	\$4,536.28
EZ MUL NT	22.7 kg	\$267.84	3	\$803.52

Interval Cost **\$179,332.48**

Figure 18: Main Hole Cost

Contingency Materials

Product	Size	Price List	Estimate	Est. Cost
Surface Hole				
BARO-SEAL	18.1 kg	\$66.58	600	\$39,948.00
Desco	22.7 kg	\$129.15	100	\$12,915.00
0	22.7 kg		0	\$0.00
Intermediate				
H2S SCAVENGER	20 L	\$913.68	30	\$27,410.40
BAROLIFT	22.7 kg	\$553.39	44	\$24,349.16
Barite 41	22.7 kg	\$37.82	500	\$18,910.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
Main Hole				
H2S SCAVENGER	22.7 kg	\$913.68	10	\$9,136.80
BAROLIFT	22.7 kg	\$553.39	15	\$8,300.85
Barite	22.7 kg	\$37.82	500	\$18,910.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00
0	22.7 kg		0	\$0.00

**Contingency
Total**

\$159,880.21

Figure 19: Contingency Materials Cost

Miscellaneous Charges

Product	Size	Price List	Estimate	Est. Cost
Pallets - DT	ea			\$0.00
Pallets - Cr	ea			\$0.00
Engineering				
<4 hrs	day			\$0.00
4-8 hrs	day			\$0.00
>8 hrs	day			\$0.00
Envir.disposal	drum	\$60.00	1	\$60.00
Envir.disposal	pail			\$0.00
Misc. Cost				\$60.00

Figure 20: Miscellaneous Costs

Materials Cost: \$721,579.72
Contingency Materials: \$159,880.21
Miscellaneous: \$60.00
TOTAL COST with Contingency: \$881,519.93

Cost Breakdown

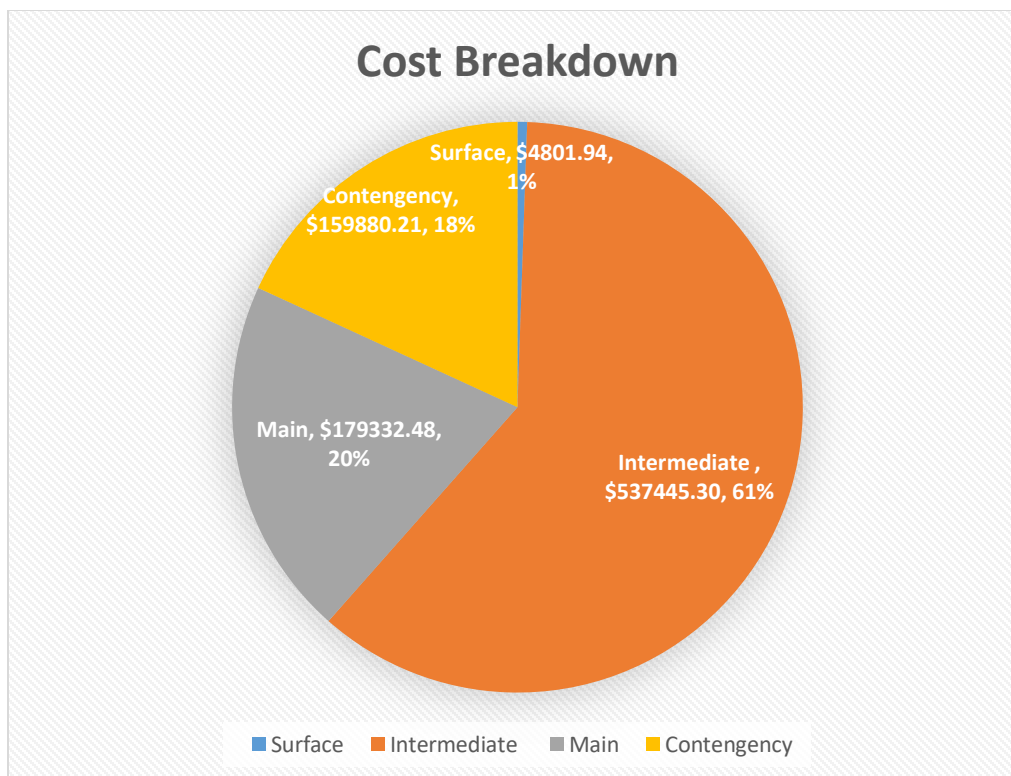


Figure 21: Cost Breakdown Chart

The pie chart above portrays the cost breakdown of each section of the well.

Conclusion

The primary objective is to have a drilling fluid program that fits the specification process of the well. The secondary objective is the team developed strategies to deal with formation challenges. The third objective is managing the cost to provide a mutual economic benefit for Halliburton's service to the client.

The choice of drilling fluid was based on looking at the offset wells data and geological prognosis. By observing the offset data we have analyzed the problems encountered and what drilling fluids was used. The geological prognosis helped summarize what pressures and problems that may occur in each formation, plus the lithology. Through looking at both documents, the team decided what fluids and additives is needed to use shown at the end of the report.

Cost Estimate's was figured out by how much volume and weight of the fluids and additives needed. The prices' of the fluids and additives were figured by price book provide by Halliburton.

Appendix

ABC Well

Days to Drill: 38

GEOLOGICAL PROGNOSIS

Formation	Lithology	Drilling Occurrences	Depth TVD (m)	Depth MD (m)	Depth SS (m)	Formation Pressure (kPa)	Gradient (kPa/m)	Est. Mud Weight Req'd for OB	Min. Mud Weight While Drilling	H ₂ S PPM
BGWP		Possible Lost Circulation	542	542	427	5,318	9.81	1000	1000	No
SURFACE	Lost Circulation has been noticed on offsetting wells. Ensure a good supply of LCM is stocked on location prior to spudding. Possible gravel at 50m.	Potential for Sever LOC	615	615	354	6,033	9.81	1000	1000	No
Belly River	Sandstone/Shale	Possible Sloughing Hole	902	908	67.0	6,854	7.60	775	1000	No
Colorado	Sandstone/Shale		1504	1518	-535.0	14,753	9.81	1000	1000	No
AER Required Cement Top			1593	1606	-623.7	15,623	9.81	1000	1020	No
Cadium	Sandstone		1693	1706	-723.7	16,926	10.00	1019	1020	No
Kaskapau			1718	1732	-749.0	16,852	9.81	1000	1020	No
1WSPK			1922	1936	-953.0	18,853	9.81	1000	1020	No
SSPK	Radioactive Shale/Silt/Sandstone		2028	2042	-1059.0	19,893	9.81	1000	1020	No
Dunvegan	Sandstone/Shale		2128	2142	-1159.0	20,640	9.70	989	1020	No
BFS	Shale		2299	2313	-1330.0	19,540	8.50	866	1020	No
Paddy	Sandstone		2383	2397	-1414.0	23,376	9.81	1000	1020	No
Cadotte	Sandstone		2396	2410	-1427.0	18,208	7.60	775	1020	No
Harmon	Shale		2416	2430	-1447.0	23,699	9.81	1000	1020	No
Notikewin	Sandstone		2431	2445	-1462.0	23,847	9.81	1000	1120	No
Falher	Sandstone/Shale/Coal	Possible High Pressure	2467	2481	-1498.0	27,135	11.00	1121	1120	No
Wilrich	Shale/Siltstone/Sandstone		2634	2648	-1665.0	25,838	9.81	1000	1120	No
Bluesky	Sandstone		2717	2731	-1747.9	27,168	10.00	1019	1120	No
Gething	Mixed Sandstone/Silt/Shale		2735	2749	-1766.0	26,829	9.81	1000	1120	No
Cadomin	Conglomerate		2839	2853	-1869.9	24,413	8.60	877	1120	No
Nikanassen	Sandstone/Shale		2860	2874	-1890.9	24,880	8.70	887	1120	No
Femie	Shale	Possible Tight Hole	2943	2957	-1974.0	28,869	9.81	1000	1120	No
Nordeg	High radioactive Shale		3010	3024	-2041.0	23,176	7.70	785	1120	No
Kick Off Point			3074	3088	-2105.0	23,669	7.70	785	1120	No
Charlie Lake			3034	3048	-2065.0	29,762	9.81	1000	1120	400
Halfway			3055	3069	-2086.0	19,857	6.50	663	1170	No
Doig	Shale/Siltstone/Sandstone		3069	3083	-2100.0	35,292	11.50	1172	1170	No
Doig PHSPT	Shale/Siltstone/Sandstone		3090	3104	-2121.0	30,311	9.81	1000	1180	No
Montney	Shale / Minor Sandstone & Siltstone	Possible High Pressure	3102	3116	-2133.0	35,981	11.60	1182	1180	400
Int. Casing Point	Shale / Minor Sandstone & Siltstone	Possible High Pressure	3197	3282	-2228.0	37,083	11.60	1182	1180	400
Montney HZ Target	Shale / Minor Sandstone & Siltstone	Possible High Pressure	3197	3282	-2228.0	37,083	11.60	1182	1180	400
Total Depth	Shale / Minor Sandstone & Siltstone	Possible High Pressure	3174	5882	-2205.0	36,817	11.60	1182	1180	400

(P) Primary Target (S) Secondary Target

Figure 22: Geological Prognosis

References

(IEEE Format)

- [1] Haliburton, "Baroid Fluids Handbook," Haliburton, Calgary, 2017.
- [2] "Alberta Wilderness Association," [Online]. Available: <https://albertawilderness.ca/issues/wildlands/areas-of-concern/kakwa/>.
- [3] "Seven Generations Energy - Kakwa," [Online]. Available: <https://www.7genergy.com/operations/kakwa>.
- [4] "Alberta Wilderness Association," [Online]. Available: <https://albertawilderness.ca/issues/wildlands/areas-of-concern/kakwa/>.
- [5] "Sait D2L," September 2014. [Online]. Available: https://learn.sait.ca/content/enforced/149492-68010.201503/content/mod_04/documents/drlg266_mod04_reading.pdf?_&d2lSessionVal=gYp2ouZxWQUR6PyOrmQOAF5CR&ou=149492. [Accessed 4 March 2017].
- [6] "Sait D2L," December 2014. [Online]. Available: https://learn.sait.ca/content/enforced/149492-68010.201503/content/mod_05/documents/drlg266_mod05_reading.pdf?_&d2lSessionVal=gYp2ouZxWQUR6PyOrmQOAF5CR&ou=149492. [Accessed 4 March 2017].
- [7] "Sait D2L," December 2014. [Online]. Available: https://learn.sait.ca/content/enforced/149492-68010.201503/content/mod_06/documents/drlg266_06_reading.pdf?_&d2lSessionVal=gYp2ouZxWQUR6PyOrmQOAF5CR&ou=149492. [Accessed 4 March 2017].