Well Control in Drilling Process

By

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Dissertation report submitted in partial fulfillment of the requirements for the Bachelor of Engineering (Hons) Petroleum Engineering

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CERTIFICATION OF APPROVAL

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A project dissertation report submitted to the
Petroleum Engineering Programme
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In partial fulfillment of the requirements for the
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Approved

…………………………..
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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
May 2013

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgments and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

……………………………….

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ABSTRACT

Kicks represent the most dangerous situations that could happen while drilling a well, since it can easily develop into a serious blowout.Well control is one of the important issues because improper well control will lead to a blowout which is the most feared operational hazards and expensive cost. Wells are not only drilled vertically or deviated nowadays but also horizontally and adding up extended reaches wells (ERD) for economical and technical reasons.

For this study, the project focused on well control in ERD well by using Halliburton‟s software, WELLPLAN. WELLPAN is very useful software which is provides various functionalities such as torque drag analysis, analyze hydraulics, analyze surge/swab pressures and ECD‟s, investigate well control and etc. This project is focused on investigate well control using the Well Control Analysis Module. The Well Control module can be used to determined predicted kick type, estimate influx volume and kick tolerance, evaluate pressure and generate kill sheet.

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NOMENCLATURE

BHP	Bottom hole pressure, psi
BHA	Bottom hole assembly
BOP	Blowout preventer
EOB	End of build point
FCP	Final circulating pressure, psi
FP	Formation pressure, psi
HCR	High closing ratio gate valve placed before the choke
ICP	Initial circulating pressure, psi
KOP	Kick off point
KMW	Kill mud weight, ppg
MD	Measured depth of any point, ft
MW1	Original mud weight before kick occurred, ppg
MW2	Kill mud weight, ppg
OMW	Original mud weight, ppg
RRCP	Reduced rate circulating pressure, psi
SB	Strokes from surface to bit
SICP	Shut-in casing pressure, psi
SIDPP	Shut-in drill pipe pressure, psi
SCP	Slow circulating pressure, psi
STB	Total number of strokes to bit
TDMD	Total depth point measured depth, ft
TVD	True or total vertical depth, ft
TMD	Total measured depth, ft
W&W	Wait and Weight method or Engineer's method of well control

Chapter 1: Introduction

1.1Background

Well control means to keep the down hole formation pressures under control which, if it lost will result in: the resources which are valuable to be lost, the costs of drilling go up and damages hit the environment. The probability of happening loss of lives, injuries to the personnel and piling up regulations are the consequence of this loss. Of course, this can be avoided in case of applying the well correct control procedures. Controlling will keep required surface equipment reliable to work at any time it will be needed and good practical procedures the followed to bring the well under control and avoid blowout (5).

Well control levels are divided into three levels: the primary, secondary and tertiary control. The primary control, which is the right usage of hydrostatic pressure because of the loss balance of the formation and keeping no longer, wanted formation fluids from going into the wellbore. Secondary control is using the equipment in order to put the well under control in case of primary control is lost. If formation fluids are not well controlled, which have already sneaked into the annulus may cause a blowout. To restore the control as soon as a blowout occurs man use another one of the levels of well control that is tertiary control, in which man use the equipment and hydrostatic pressure together. This includes the drilling of a relief well. A lot of things can be done on planning and drilling of a relief well to be able to restore the control of the well and make the final kill procedure simpler in spite of handling the tertiary control normally by experts. If a blowout is not controlled quickly, a gas kick may occur while drilling a well because it could simply turn into a blowout and this shows how gases kick are making embarrassing situation (9).

In order to prevent the incident happen, kick must be detected and killing the kick immediately. One of the solutions is by using the Halliburton"s software which is WELLPLAN. WELLPLAN offers integrated, scalable and configurable technology solutions that require pore pressure prediction, analysis and interpretation. This software can improve the drilling performance through reduction of kicks, stuck pipe, lost circulation and blowouts for significant reductions in non-productive time.

1.2 Problem Statement

If the well control system couldn't detect the kick (the formation pressure higher than wellbore pressure) and killing the kick immediately and properly, blowout will occur. In ERD, the well control system is different from conventional drilling or vertical drilling as it is exposed to high pressure zones more than other wells .Another example is gas Kick accumulated and trapped (buoyancy of the gas) at the end of the well if that section inclined upwards. Besides the gas can also get trapped in gas pockets in the high-lying parts of an undulating well trajectory and washouts. This gas kicks problem is not present in conventional vertical wells. The problem is the method on how to remove the gas kicks in ERD wells.

Moreover, kill procedures in conventional wellbores usually are conducted at a pump rate between 1/3 and ½ of the normal drilling rate. The reasons for this procedure are to lower the annulus friction pressure loss and less pressure fluctuation in response to a change in choke setting. In addition, the supervisor has more time to analyze the pressures and make wiser decisions (Advanced Well Control, Watson, et al. 2003). So, this project was performed to see whether the kill procedures in ERD well is same with conventional well or not.

1.3 Research Objectives:

1. To use WELLPLAN to simulate well control in ERD well
2. To Determine the best well control method and practice in ERD well

Chapter 2: Literature review

2.1 Drilling Engineering Overview:

The study of drilling is obviously an important part of any petroleum engineer's education and one topic in that area can be particularly difficult to teach is the proper control of the system during a threatened blowout. Years ago, much of the drilling activity was performed by inexperienced people, the rate of blowouts increased. The massive experienced people reduction of the past few years, suggest that renewed activity will lead again to inexperienced supervision. As a review of the basic concepts involved a short summery will be given. Studying the process of drilling is clearly enough to go on a vital role in educating the petroleum engineer; moreover it is rather hard to teach one topic in regard to this but it is the suitable method to control the system in case of a blowout. The number of blowout had gone up in the recent years owing to untrained supervision. That needs us to recheck the basic guidelines to be handed with brief notes. While drilling any hole, the engineer uses a drilling fluid (dirt and mud) which includes certain points like lifting the stuff was cut, getting both of the bit and the drill string cooled and greased and lubricated, meanwhile getting the subsurface pressure under control (12,19).

In the figure of (2-1), it is showed that having pulling out the mud pump which is done at big pressure, you will see how the fluid during drilling goes up the standpipe, there is a pipe vertically long, affixed to the derrick leg, after that out of the Kelly hose or so called rotary hose, again out of the swivel and to pass down the Kelly. The mud shifts down the drill string to come to the bit. Any bit normally has more than one nozzle or so called jets which speed up the dirt or mud swiftly. The jet of the unwanted matter "dirt or mud" rubbed typically the bottom of the hole so as to clean the cutters of the bit until it has the ability to bite a rock well. Through the bottom of the hole the unwanted matter is shifted towards the top in a ring-shaped region which is called annulus, moving from the drill string to the wellbore bearing the cuttings which had been done by the bit. It normally happens, during drilling a well, for the hydrostatic pressure of the mud the equilibrium of liquids and the pressure exerted by liquid at rest, to bear an excess of weight or a regular increase of unwanted matter, to find that the hydrostatic pressure is higher than the common formation of pressure in a hole in order to keep the main control of a well. Moreover, on drilling, this loss of balance always let exploitation of the drill pipe without absorbing the formation of fluid into the hole (3, 12).

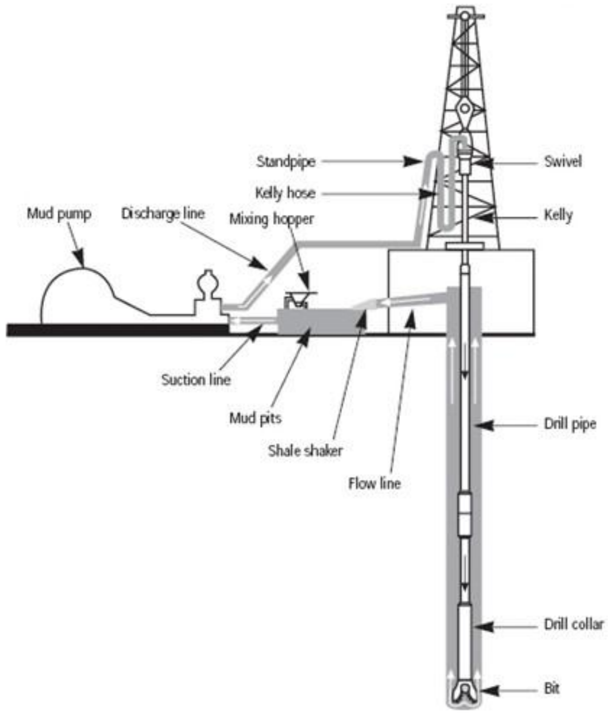

Figure (1) Mud circulation system (12)

2.2 Well Control

Recently "Well control “has become the focal point increasingly, as long as its importance came to a great degree for all who are interested in it. The impression of Pressure control procedures have been somewhat old but are still being used in several areas all over the world. Well Control as a term and technical word suggests controlling the bottom hole formation pressure being penetrated by the well (5).

Many losses of the vital resources came as results from the well control events, as well as running up the costs of drilling, environmental contaminant, increasingly the process of regulating, and the personnel liable to get injured and that comes to death. The large amount of an uncontrolled flow of gas, oil, or other well fluids from the well is owing to the people are involved committing technical mistakes, that may have been refrained in case of having genuine well control procedures. Well control is considered kind of an art which is performed many times on daily basis on rigs. It needs the right mud density, the mass or weight of a substance per unit volume, reasonable hole cleaning, speeds to be slow for moving, abundant checking and maintaining of blowout preventer (BOP), the crew needs training too. The pressure obstacles and the main and second flow, which means the mud column and BOP, have to be available permanently in order to keep the unexpected or the worst conditions of the blowout away (7,20).

2.2.1 Kick

A kick is the access or sneaking of water, gas, oil, or whatever components fluid into the wellbore on drilling. It happens because of the pressure being done by the column of drilling fluid is not strong accordingly to get over the pressure done by the fluids in the components drilled. In case of not taking an action we, then, can't control the kick, or else a blowout might happen. A kick is considered not to be a blowout, it is mishandled. Gas and salt water are the most composition; however gas is considered in large play a theatrical part more than other types for the following reasons:

- Due to the rate of moving and getting into the wellbore,
- Due to the low density fluid, the high pressure comes out of incompletely.
- Due to the gas being extended during getting close to the surface,
- Travelling the fluid upward the wellbore, and then
- The fluid is easily getting in flammability (22) .

2.2.2 Blowout

A blowout is an uncontrolled flow of gas, oil, or other well fluids from the well or we can say loss of control of a kick. There are surface blowouts and underground blowouts. A blowout can be under controlled in case of spotting a kick swiftly. Lack of controlling flow of gas, oil, or other well fluids from the well, which we call blowout or kick, may occur for two reasons: Firstly, due to equipment failure. Secondly, it is due to humanly error. AS mentioned above about the definition of blowout, it is to be added here that a surface blowout is divided to two parts: an underground flow and an above-ground uncontrolled flow (7, 25).

2.2.3 Types of blowouts

The kinds of blowouts:

- A surface blowout,
- A subsurface blowout,
- An underground blowout.

2.2.3.1 Surface blowouts

The title shows that a surface blowout is a loss of control for the flowing fluid which is looking for the weak surface. The crew and equipment involved may face, as well as the environment, a high sudden risk because of the surface blowouts are very risky as long as the fluids' compositions are loosely running to the atmosphere. The fluid which is a substance has no certain form and produces gas or a liquid such as saltwater and oil, however the injected fluid would also be driven out of a blowing well. The surface blowout is liable to catch fire so resisting of the fire is a fundamental role of surface intrusion. Getting rid of the silt or debris and getting the well ready for future action is considered important thing (17, 26).

2.2.3.2 Subsurface blowouts

The blowouts that are subsurface blowouts cannot leak out through the surface easily. However, they pierce and get through a well at the bottom of the sea. Naturally the seawater controls to a great degree the exit conditions. The new geologic formations are unexpectedly faced unpleasant resistance in offshore operations. The somewhat disorganized sand may allow broaching to happen. However, the process of broaching might become negative changes to the structure of the platforms or increase considerable amount in case of its occurring under the rig right away (27).

2.2.3.3 Underground blowouts

The nature of blowout does not show the signs of warning straightly to be eyed easily at the surface. Underground blowouts are defined as the uncontrolled flow of the structure fluids from one a series of layers of rock to the other one. Therefore, its action is variable and hidden out of sight. This sort of flow is sure to happen in case of taking a kick; meanwhile a fissure in the rock or the loss of the circulation happens inside the wellbore. We finally come to assure that this is the most manifest sort of the blowout while it shows nearly two thirds of the whole blowouts. It is somewhat difficult to handle the underground blowouts which also can be very expensive business. Preventing the underground blowouts from being happened is depending on careful planning, directing, monitoring, and the technique of carrying out this at the whole time of the well life (17, 24 &28).

2.2.4 Kicks and blowouts and the connected problems

These problems as follow:

- The damage occurs to the environment.
- Reducing the reservoir in where fluid collects in the rock strata.

The reserves of the hydrocarbon may get lost.

- In the bottom of water reservoirs where the fluid may cone.
- The dangerous flammable and potentially toxic cases safety to be at risk owing to the action of gas, salt water, hydrogen, oil and others.
- Equipment and materials are likely to be lost.

Controlling blowout costs much,

- The credibility of both the operator and personnel come to be at risk.

Endangering lives of the human beings. .

The eventual cost of the blowout is most likely to come to lots of millions of dollars, but the funds that may be wasted is not rather so important as the expected damage which may come out of a blowout. Blowouts bring about losing worthy resources which can do the most dreadful damage to the environment and will be impossible to be repaired, destroy equipment; however the most important point here is that the blowouts jeopardize the status of the safety and the lives of the crew of the rig. We must put in our consideration arranging the most important and the least important, i.e. the safety of the rig crew and their being comfortable and getting on well, then keeping the rig in sound condition, finally the state of the well. To keep the situation under control we must pay the same big attention and care to the people's lives as the equipment undergoing (9, 17&21).

2.2.5 The importance of well control

The most critical situation is most likely to be gas kick which may happen on drilling a well because it may be come to a blowout unless it is to be controlled right away.

The question brings up here “In case of blowout, who do expect to give you a hand?" It is the operator's duty to find the answer. Any mistakes can be eliminated by well trained personnel, well planned well programs in a harmony way. Making the initial drilling may cause a blowout. The people who are entitled to start putting to the well under control are drilling engineers while the process of planning going on to select the satisfactory quality of drilling equipment and decide the right size of a hole and frame or casing points. Both the BOP equipment and the rating of the pressure for the well head must be selected well to stand the well pressure. The crew must be well-trained enough to be able to understand the principles of how to control a well, as well as their fast response and being analytical to any situation. Circulating out the kick is as much as important; they must be supplied with good understanding of the causes and the reasons of the history of the actions. In spite of this, the people who are included in both of the executing of the programs and its planning are liable to make errors. To solve this problem is to train the personnel well and select the right equipment for that (29, 30&31).

2.3 Types of Pressures

2.3.1 Hydrostatic pressure

Water and static are the words that hydrostatic pressure is derived from. The pressure that is performed by a column of fluid whether it is at rest which is "static” or moving "hydro". All forms of fluid inside the wellbore apply hydrostatic pressure. Both the vertical height of the fluid column and the density of the fluid are depending on the pressure as its function. As it is shown in Figure (2-2) the vertical depth is a function of the hydrostatic pressure. Regarding the terms of a psi/ft of depth or "pressure gradient" both are applied to the pressure exerted by a fluid (7, 19).

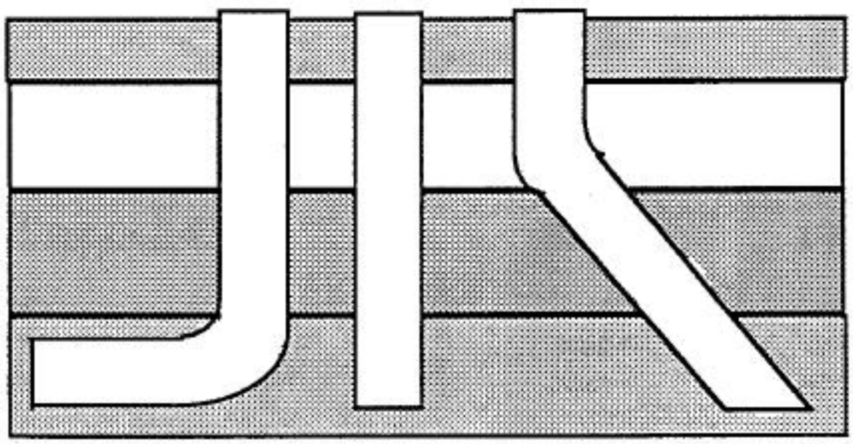

Figure (2) Hydrostatic pressure is depending on vertical depth and fluid density (7)

2.3.2 Formation pressure

It is the pressure hold within the structure itself. It is the pressure hold in the pore or passage spaces of the formation, in other words the pressure involved in the formation fluid. This pressure is emerged from the hydrostatic pressure of the structure fluids above the depth concerning with any sort of pressure e probably be trapped in place. This in turn will raise the formation pressure's gradual degree is expressed as "abnormal pressure" (4).

Abnormal pressure is known as any sort of pressure larger than normal pressure, and which needs the weight of mud for more than 9.0 ppg in order to control the structure of pressures (33).

Subnormal pressure is found in the structures and formations which are subjected to a pressure regression which is a return to its earlier condition attributed to the more deeper burial because of tectonic action, however it is often faced by in an old field in where the formation is reduced thanks to the production of the structures fluids mainly found in place (33).

2.3.3 Overburden pressure

An excessive burden of pressure is the pressure under big effort on a structure owing to the rock's weight and fluids above the area of the intended point. The formation upon which is imposed by densifying the vertical force. On the ordinary level the density of the rocks ranges from eighteen to twenty two ppg (33).

2.3.4 Fracture pressure

Fracture pressure is the crack pressure needed a certain structure, however the pressure needed to make the formation may not succeed and break. It is important to be able to crack a formation to pump into it by a pressure in the wellbore which is more than necessary to formation pressure, then, so as to crack the formation it is to do with exceeding the wellbore pressure over strength of the matrix of the rock particularly. Besides, the exceeding must be applied to the three forms of the stresses inside the formation. It is well stated that the state of stress under any degree below the surface of the earth is likely to be known through those three stresses' forms, Figure (2-3). At the lowest form of the three forms of stresses, the formation will crack at an angle of 90 degree (34, 35).

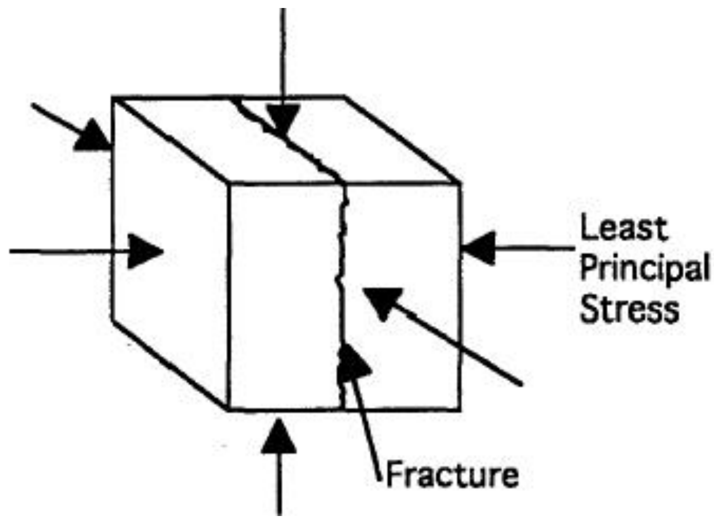

Figure (3) Formation fracture orientation (7)

2.3.5 Surge and swab pressure

The movement of the drill-string in and out of the well hole is the cause of both of the surge of the pressure and the swap of the pressure as well. The cause of surge pressure is tripping in the hole; meanwhile pulling out of the hole is the result of swab pressure. Of course the pistons' effect causes both of the surge of the pressure and the swap of the pressure to move as a result of the drill-string in the hole. While lowering a pipe into a hole, the surge raise the pressure applied to the wellbore, on the contrary the swab lowers the wellbore pressure. Overdoing surge pressures may affect on the structure fracture, while excessive swabbing may cause overflow of the fluids into the wellbore. Both the surge and the swab are being affected by: the speed movement of a pipe subjected to be tripped, the characteristics of the mud such as" weight, viscosity, and the strength of being gel), the process of cleaning the gathering mud between the bottom hole and the wellbore and ring-shaped restrictions all have big part in this (21).

2.4 Causes of Kicks

The most common causes of kicks are:

1. The weight of the drilling fluid is not sufficient.
2. The loss of circulation.
3. Gas or water is used in cutting by drilling fluid.
4. The disability to keep the well hole filled with of drilling fluid
5. Swabbing.
6. The zones of abnormal pressure.

2.4.1 Insufficient drilling fluid weight

The main cause of kicks is the insufficient of the weight of the mud. In case of the formation pressures are being awarded of, so it is rarely the insufficient of the weight of the mud to be the cause of a kick in a well under developing. At exploring a well in which the insufficient knowledge endangering insufficient drilling fluid weight as well and it is believed that this is great risk (17).

2.4.2 Failure to keep the hole full of drilling fluid

One of the main problems that cause kick is the inability to keep the fluid to the reasonable level in a hole during a trip. That cause ought not to occur since it is a certain one of well kick, it is still happening though. The volume of a metal which is pulled must be exchanged with drilling fluid while pulling the stand of a pipe out of the well. In case of not doing so, the drilling fluid's level in the well is sure to drop, is due to be lowered in case of the column's height is reduced as long as the hydrostatic pressure of the bottom hole will be produced by the drilling fluid density and times the height of the column. When decreasing in height is big enough to be noticed the hydrostatic pressure of the bottom hole could be reduced to a great degree in a way that the safety margin could be reduced and the well could kick (9).

2.4.3 Swabbing

Tripping out of the pipe hurriedly results in swabbing. Naturally the pipe work as a piston, but if it is pulled too fast it may cause sort of partly effect of vacuum or suction which leaves a vacant supposed to be filled by the falling mud and dirt downward into the well. The vacant or void space is not going to be filled quickly, besides to a decrease in the bottom-hole pressure may happen if the pipe has been pulled too fast (17).

Many other things can cause swabbing:

a. The balled bit, stabilizers, drill collars, or reamers

b. Pulling pipe too quickly

c. The properties of drilling fluid

d. Swelling the structures.

Minimizing swabbing is strongly aimed at forcing the drilling fluid in good state, while pulling the pipe at a reasonably enough speed, add to this using some sorts of desired lubricant and grease, and the addition of drilling fluid to the purpose of reduce balling. Naturally enough the good hydraulics should assist cleaning a balled up bit or even the bottom well altogether. When a well swabs, despite of the well training, the pipe likely to be withdrawn to the bottom at once, the drilling fluid will circulate out, and its weight is going to be increased prior of making the trip (9).

2.4.4 Lost circulation

The loss of circulation implies to the condition in which the amount of fluid which is going inside the hole is not equal the amount coming out of.

The following reasons could cause the lost circulation during drilling operation:

a. The weight of the drilling fluid may be high.

b. Hastily going downward the well unusually.

c. The blowouts coming underground.

d. Ring-shaped circulating friction pressure.

In case of the gradient of the fracture for formation lacking physical strength are exceeded over by the hydrostatic head of the drilling fluid, then the loss of circulation is expected to happen as well as the level of the fluid in the well drops. This decreases the strength of hydrostatic head which is acting in opposite of the formations that don't not break down yet. When the level of the drilling fluid in a well decreases enough so as to reduce the pressure of bottom hole below the structural pressure, the well is sure likely to start flowing. Therefore, it is recommended to refrain from losing circulation. In case of the top of the drilling fluid being difficult to be visible from the surface, then the kick could be hardly observed for some time. This means that controlling the situation will be somewhat out of control (23).

2.4.5 Gas or water cut drilling fluid

It is not considered to be that risk the process of gas cut mud, however it is just a caution to take full care of the situation. Either oil or water may cut drilling mud the fluids will be difficult to be compressed, this ,in turn, may cause intense reductions the gross of hydrostatic, moreover, this may cause well loss of control troubles in the presence of either gas or oil productive areas. Whether an interstice gas zone is being drilled, the gas which stays inside the pores of the cuttings is expected to be released because of the methods of cutting on the surface. Although an overbalance of 200 psi, which is seen as good enough quantity,
is carried out in drilling the density of fluid column. If the gas is imprisoned and not released out to the surface and not permitted to circulate, a lot of troubles will appear to the surface of the situation unexpectedly and the situation will be out of control. The advice is to stop pumping when in doubt and have a look over whether the flow of the well (10, 21).

2.4.6 The zones of abnormal pressure

The unusual pressures are defined that they are greater than the natural pressures for an area. The process of drilling into unusual pressured structures may get us to possible kicks.
The continual formation pressure could be bigger than the bottom hole pressure, which is resulted in a kick.

The Abnormal pressures can be the result of:

1. Structures fluids which are being trapped during normal consolidation.
2. Unsatisfactory and uplifting
3. Anticline, where the formation or strata of a rock go downward, structures.
4. The formations of Salt

5. Massive shale, where the formation or strata of a rock formed soft owing to consolidated

6. Zones unnaturally charged

Usually a formation with such pressures gives enough warning that proper steps can be taken. The right actions can be taken as soon as one realizes a formation with such pressures which imply something unusual is likely to happen. Having detected these zones, it is usually likely to good to drill into them a reasonable distance when increasing the weight of the drilling fluid when necessary to put gas entry under control. Still, when the pressure owing to the weight of the drilling methods then the fracture gradient of the highest exposed formation, it is good application to set casing. Underground blowouts and lost well could be resulted in failing this precautions (10, 12).

2.5 The Signs of Warning about Kicks

A blowout always occurs under unusual circumstances giving warming signals of its actual condition. The system of both of the drilling fluid and the wellbore is a closed circulation one. Any flowing coming out of the formation into this system is most likely to turn up taking the shape of increasing returns out of the ring-shaped and raising the gross of drilling fluid volume at the system of the surface which include the tanks of drilling fluid (2).

The most common warning signs of kicks are:

1. The rate of increasing of penetration "ROP"
2. The volume of increasing mud pits "Gain"
3. The rate of increasing the returns of mud flow
4. Drilling fluid against Gas "gas-cut"
5. The increasing of both of number and size of cuttings
6. The density of decreasing shale.
7. The flowing of the well with pumps to be shut down

2.5.1 The rate of increasing of penetration "ROP"

Drilling break is one of the most common signs that a kick is possible to occur. The rate of a sudden increasing in penetration is a good definition for a drilling break. Normally a drilling break indicates to sort of change after lithology, for instance a drilling from a shale inside the sand. In general, the rate of a sudden increasing is a warning sign of either a well kick or a drilling break, which show that the pores in formation could have been broken into. In the interval of the potential pay, the crews shouldn't be forgotten but must be alerted that the normal minimum interval ranges from 2 to 5 feet regarding to whatever drilling break could be penetrated. This is one of the most important aspects of pressure control. Many multimillion-dollar blowouts could have been avoided by limiting the open interval. By doing a limit for the open interval, this may be reducing a large amount of money which comes to millions as a kind of the pressure control (7, 23).

2.5.2 The volume of increasing mud pits "Gain"

Supposing an influx the fluid of structure or formation formed into the wellbore from a kicking formation, this influx is going to take the place of mud from the ring-shaped "annulus" into the pits of the surface creating a pit gain. This pit gain is another kick indicator, and the increase in volume in mud pits is assumed to be equal to the volume of formation fluid that has entered the wellbore. Another kick indicator is this pit gain. Any increasing in the volume of mud pits is supposed to be equal to the formation fluid volume which had come into the wellbore. Any unaccounted pit gain for is attributed to a warning sign of a kick, which is also called a “positive kick indicator” wherein the effective proper actions must be taken right away (7).

2.5.3 The rate of increasing the returns of mud flow

The constant volume of fluid break into the hole while the constant volume come out equally in the two cases when mud pumps run at constant speed. The process of formation fluid which replace the mud from the ring-shaped, the annulus, while it moves constantly and continuously in a current from the formation into the wellbore takes place when the mud returns start rising without any increase in the speed of pumping. Here another sign of a possible kick that is to say any increase in influx rate. The first sign of taking place a kick is the rising influx at the flow-line. A positive kick indicator is the indication of the rate of increasing the returns of mud flow, which doesn't need flow check, but it needs to shut the well right away to minimize the volume of the flow (7, 9).

2.5.4 Drilling fluid against gas "gas-cut"

When observing water-cut mud, oil, or gas, the effective actions and precaution must be taken into effect. Usually, this sign is coming together with the other signs when the well is suffering from an influx. Any increase in chloride or water cut mud or even calcium which has been circulated from the bottom; it always shows the fluid of the formation has broken into the wellbore. This may show that a well influx in progress or it could be made by swabbing. Any increase in calcium or Small chloride may show that some zone which have high pressure cannot allow the fluid out or to pass though. In case of a bit breaks into a zone of high pore pressure, a background gas could be rising suddenly. This background gas is the gas which collected between the wellbore cuttings. This gas would run up to the surface and may form fifty percent of the volume of the drilling fluid volume in case of this gas has got high pore pressure which allow to it to expand and force its way up. If this situation is prepared well in advance, the trouble can be saved the day (21, 22).

2.5.5 The increasing of both of number and size of cuttings

On penetrating a high pressure zone, the size of the cuttings may be changed. They can be long and come into splinters. Naturally the shale pressured create little cuttings with circular tips flat, whereas the over pressured shale cuttings form long and splintery with angular edges. Since the decrease of hydrostatic differs the pressure of the pores from bottom-hole pressure then it occurs, and the hole cuttings are going to greatly tend to come off bottom. A cracking may also occur because of a shale expansion, and a collapse into a hole could be underway. The changes in the shapes of cuttings and the shakers loaded by these cuttings need proper directing to the surface (21).

2.5.6 The density of decreasing shale.

The compactness of a rock formation is mostly reduced when this is connected to a high pressure zone. That is due to minute interstices which are considered good evidence to examine the several cuttings at the shale shaker. The compactness of shale naturally rises with depth, while this decreases if the pressure zones are being drilled. The compactness of the cuttings may be decided while at surface and marked out in opposite of the depth. In the pore pressure changes could be determined by the deviations and a usual trend line (9, 21).

2.5.7 The flowing of the well with pumps to be shut down.

One taking notice of the indicators of the kick, they will need to be justified and certain of its being true. By stopping the process of both of rotating and circulating and taking hold of the pipe from bottom to connection height is a well-tried way of verifying a kick. When pumping off, make sure of the flow from annulus. To realize if there is a kick, see if the well keeps flowing even after closing the pumps, however the flow still running on at steadily rate, it is believed that you have got a kick, Immediately shut the well in (17).

2.6 Kick Detection Techniques

After getting to know the reasonable of the motives and causes of kicks, it gets easily known what the kicks' warning signs are. To put any event under control it is essential to take the time into account as a decisive element which will serve efficiently to spot any kick early enough to take the suitable precautions. Flowing of the gas of hydrocarbon into the wellbore hole at the time of drilling is viewed as danger act. Avoiding a blowout of the well is considered the most important step in case of a gas kick badly handled. The more soon enough identifying and detecting the possibility of happening gas kicks the more important step to get ready the suitable steps against. The rate of output flow was the most suitable measurable system for spotting and detecting the unusual conditions of the well in the nearest future (36, 37).

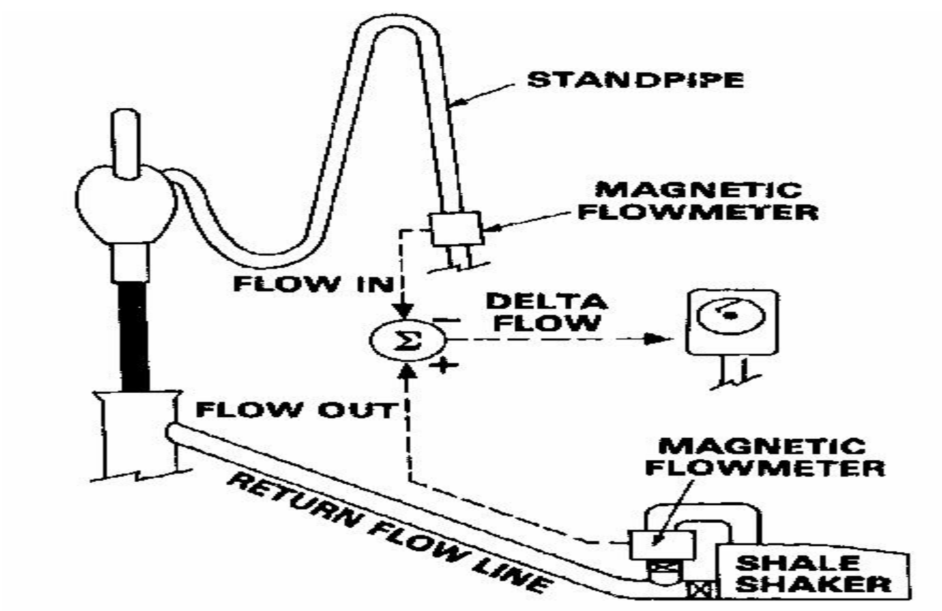

Figure (4) Schematic representation of the delta flow system (37)

2.7 Shut-in Procedures

When a kick is declared about its happening, soon the well must be locked at both the drillpipe and the preventers. If stopping the flowing of the well got failed, mostly a blowout would be underway. It is defined as the most common steps for shutting-in the well during the operations of drilling to avoid a kick. They are the rough shut-in and the smooth shut-in (2).

2.7.1 Soft shut-in procedures

1. At first on observing any sign of a kick during drilling, the well is likely to flow, we must not go on rotating the drill string and lift with pumps on the drill string till we get the tool joint comes above the floor of the drill.
2. Stop pumping then go to check the flow, if it is positive.
3. Next open the choke line HCR valve.
4. After that close BOP
5. Finally close the choke.

Note: While drilling, choke in an open position (21).

2.7.2 Hard shut-in procedures

1. At first on observing any sign of a kick during drilling, the well is likely to flow, we must not go on rotating the drill string and lift with pumps on the drill string till we get the tool joint comes above the floor of the drill.
2. Then stop pumping then go to check the flow, if it is positive.
3. Next close the annular or pipe rams.
4. Finally open choke line of the valve of HCR (21).

There is a connection to rough shut-in which probably gives rise to the damage of formation thanks to series of a pressure pulse in the fluid of the wellbore. That may encourage some operators to decide or choose a soft, smooth, shut-in by which the valve of the chock at the act of closing of the BOP left open. An additional of flux from the formation may be resulted in owing to the delay of closing the chock so as to go on shutting-in the well. A good general term which is to describe the wave of the pressure generation or series, besides going on increasing through liquids in the networks of pipe and in the pipes this term is called "Water hammer". In case of shutting the flow of a well hurriedly, then the wave of the pressure will be emerged and will cause increase in the well. Whenever the well is flowing in great speed and whenever the kick is detected late, the time delay the two of them may lead to differences of a big pit gain and pressure. On the subsequent of a well control, the higher pressures may appear because of a smooth shut-in. Any increase in casing pressure because of an additional influx into the wellbore may exceed the maximum amount of the water hammer pulse (39).

2.8 Well Control Techniques

The operations got under control should keep on as soon as the detection of a well kick and shutting-in are done. Conventional well controlled operations depend on the fixed pressure of the bottom hole methods, in other words keeping the pressure of wellbore nearly equal to the pressure of formation thus there is not going to be any additional flow nor formation breakdown. However, by removing the flow from the wellbore, in the meantime, putting up again the main well control in accompanied with weight and balance. This needs of us to remove the flow from the wellbore, in the meantime, putting up again the main well control in accompanied with balance mud and weight. Well control does not mean only both of detecting a kick but also preventing a kick, as well as the removal operation for kick fluid from the kicking well and also to circulate drilling mud which is heavy in controlled states. At the bottom lots of kicks break into the well. The main point of controlling a well is supposed to make the bottom hole (BHP) in progress as possible to a value which nearly reach the same level of the pressure of the formation. A constant BHP is controlled by a predetermined drill pipe pressure schedule. This procedure is well protected so as not lead to a lot of catastrophes as "lose of life ". Many engineering designs are divided into conventional and non-conventional procedures. The conventional ones depend on the concept of a continuous bottom hole pressure which the pressure at the bottom is maintained slightly greater than the formation pressure (40).

2.9 Conventional Kick Circulation Techniques

2.9.1 Driller's method

In the method of Driller, the mud weight circulates the kick which achieve the required level as a minimum for this method. When it deals with the removal of the kick and the addition of kill weight mud, which results in being the most control method ever. These results in the well being circulated under pressure are the longest of the three methods which has more or less choke problems. During the first circulation, the annular pressures already are finished as the high annular pressure may arise when killing a gas kick with this method. This annual pressure will reach the maximum point before the arrival of gas .This method is most used on small land rigs where the driller has just simple equipment, also used on deviated and horizontal wells. The Driller's method has a lot of benefits in case of availability of the limited information about the well conditions. There are many procedures for Driller's method are shown in figure (2-5), considers the following:

1. The information is extremely recorded and the well is highly closed.
2. The Initial Circulation Pressure is well organized through the calculation of the pressure required on the drill pipe for the first circulation of the well.
3. The choke is opened through one quarter by starting the break circulation and the pump which is reaching the kill rate.
4. During the matching between the pump and the kill rate processing, the choke operator should operate the choke to avoid the farness between the casing pressure and the casing pressure reading.
5. As soon as the pump is up to the kill rate, the choke operator has to notice drill pipe pressure gauge and adjust the choke to retain the initial circulating pressure on the drill pipe pressure gauge.

6. The initial circulating pressure should be in progressive holding on the drill pipe pressure gauge through moderating the choke depending on the first circulation till the circulating of all the kick fluid of the well.

7. Right after going out the kick, the well shut and the kill mud weight required is combined.

8. No sooner than readiness of the kill mud, the choke opens one quarter, beginning of the pump, the circulation is already broke.

9. During the deliverance of the pump to the kill rate, the choke operator must turn the choke on with the aim of maintaining the casing pressure steady at the same level of the pressure.

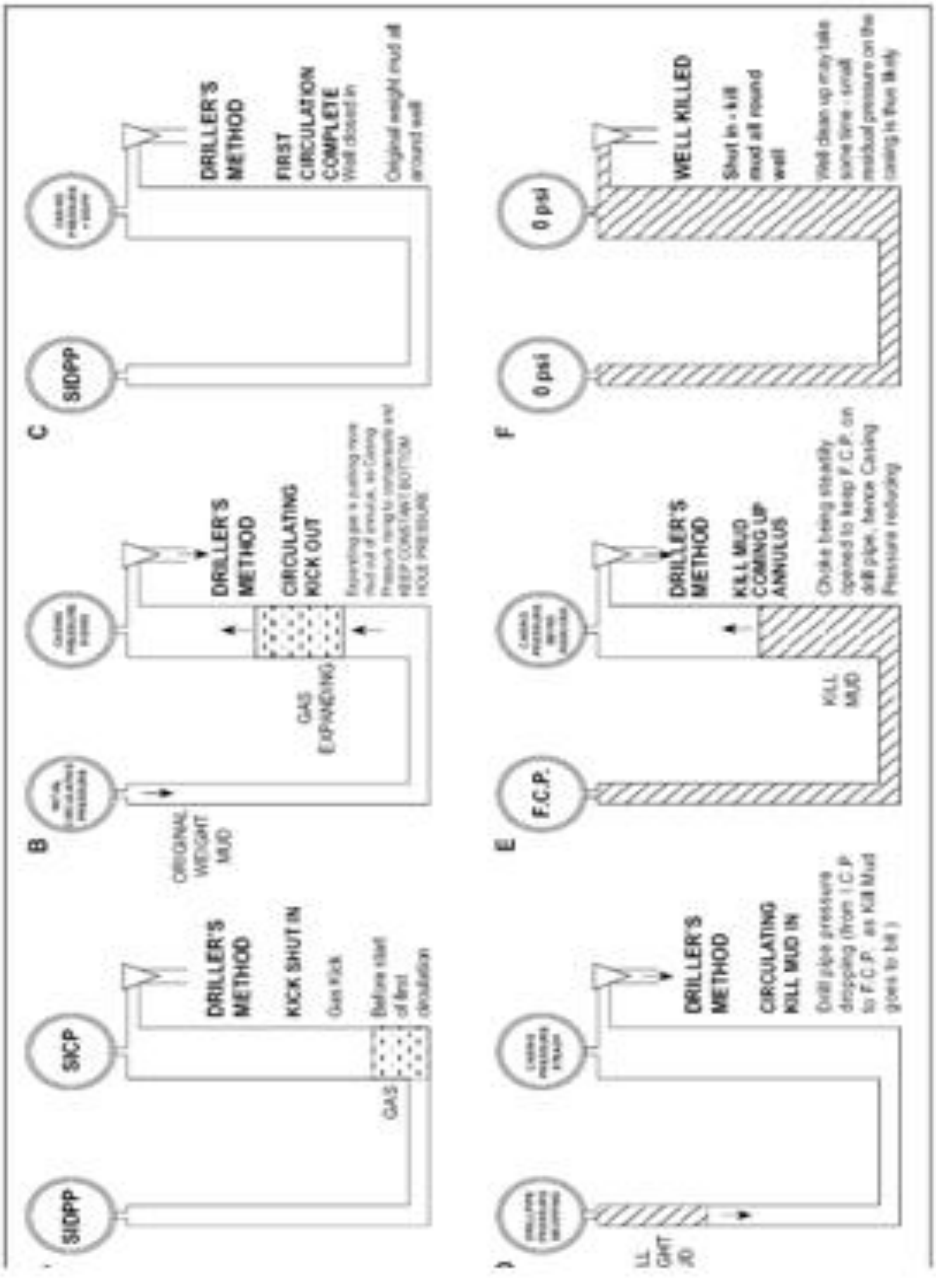

Figure (5) Driller's method **(21)**

10. The moment that the drill pipe contained a heavy mud there are two options for keeping B.H.P. constant, it should maintain the casing pressure also constant or let the graph going from ICP to FCP, if the influx was gas and all the gas was not removed in first circulation. after reaching the bit , the pressure held on the drill pipe which is hoped for the circulating of the kill mud around the well, This is the final circulating pressure which growing for the extra mud weight. Thereafter, the drill pipe pressure is held at the final circulating pressure by controlled opening of the choke, as the kill mud moves up the annulus (9, 21).

2.9.2 Wait and Weight method

The "Wait and Weight" indicate the Engineer's method or the one circulation method, at least show the theory, and kill the well in one circulation. As soon as the well is shut-in and pressures fixed, the closed drill pipe pressure made up in the mud pits. Once the well is shut-in and pressures stabilized, the shut-in is used to calculate the kill mud weight. This original circulating pressure firmly reduces because the mud goes down to the bit, until with kill mud at the bit, the demanded pressure is humbly that needed to pump kill mud around the well. The choke is prepared to decrease drill pipe pressure while kill mud is pumped down the string. With kill mud at the bit, the static head of mud in the drill pipe balances formation pressure for the remainder of the circulation, because the influx will reach the surface, followed by the drill pipe contents and the kill mud, throughout the choke adjustment the drill pipe pressure will take hold of the final circulating pressure. Procedures for the Wait and Weight method are shown in Figure (2-6). Right after kill mud is prepared; the start-up procedure is as the example description. The choke is cracked open; the pump started to change circulation, and then rose with extreme slowness to the kill rate. During the arrival of the pump up to the kill rate by the driller, the choke operator works the choke with the aim of keeping the casing pressure at or as near as possible to the closed in casing pressure reading. Because of the processing down the drill pipe, the drill pipe pressure is allowed to drop firmly from the initial circulating pressure to the final circulating pressure, by choke adjustment .As a result of the smallness of the kick, and being fixed side by side to the bottom of the hole, the drill pipe pressure leads to drop of its own accord as the kill mud already reduces. Only in the state of diffused gas kicks with gas far up the annulus will significant choke adjustments be needed

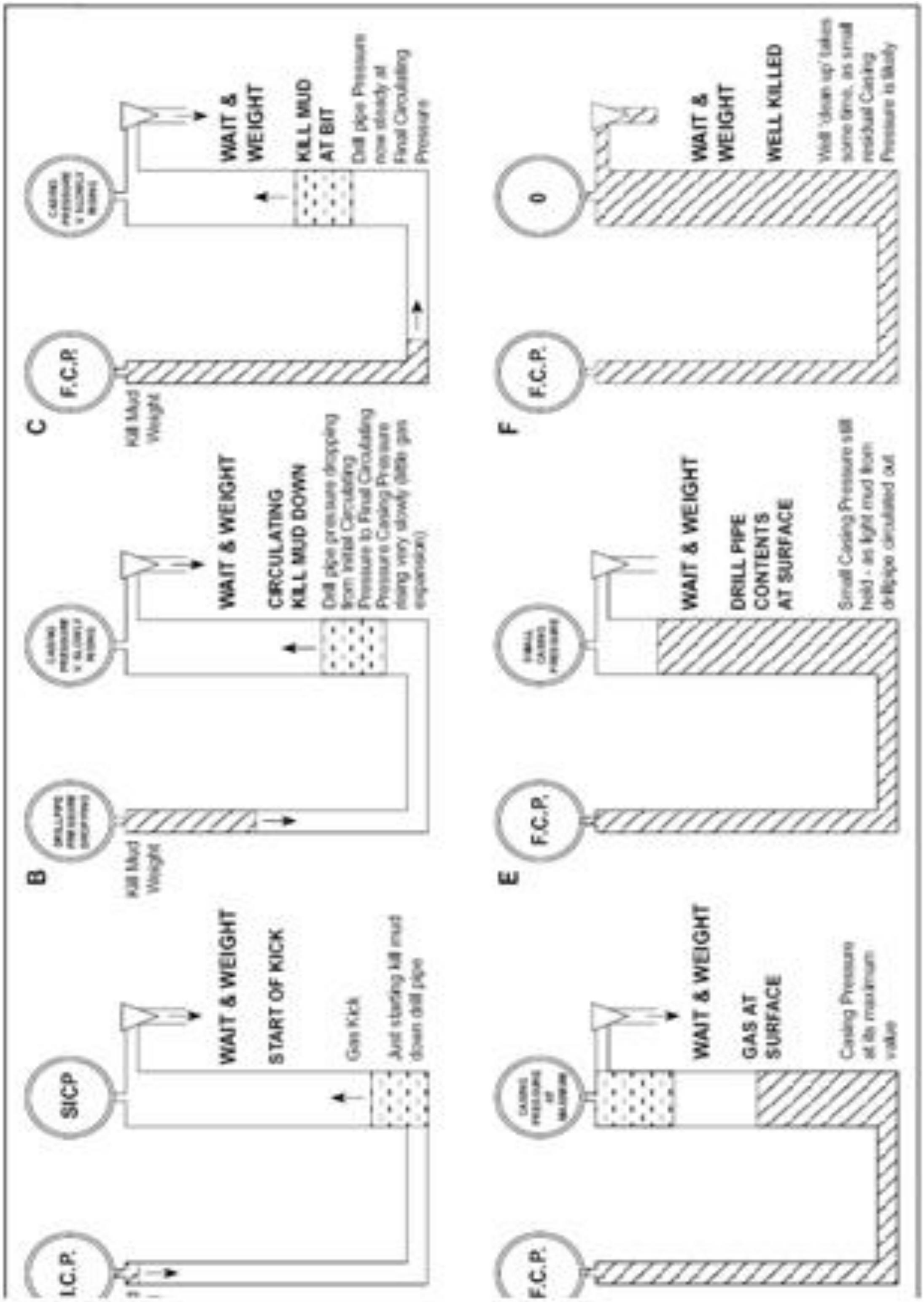

Figure (6) Wait and Weight method **(21)**

During this period after kill mud has reached the bit, the drill pipe pressure is maintained at the Final Circulating Pressure, till the kill mud returns to surface (11, 18).

2.9.3 Concurrent method

The Concurrent Method is considered a group of the Driller's method and the Wait and Weight method. The crew starts rotating the kick out of the well right away, by using the earliest mud weigh. The fashion of gradually in increasing the weight of the mud whereas rotating out the kick is called concurrent method. The increasing rate counts on mixing the feature of many services which are available with the equipment on the rig. The circumstances that are complicated are when the drill pipe is filled with several varieties of the densities of the fluids, calculating the hydrostatic pressure of the bottom of the wellbore to find out its condition in case of being difficult. The most powerful way to kill a kick is through supplying sufficient supervision to be found on the rig. The following steps of Concurrent method are: On recording all the information and data about the kick, slowly open the pump at the time of altering the chock till the initial circulating pressure to be reached at the point of reduced rotating rate. At the maximum rate the drilling fluid will be weighted up with the available rig equipment, since the fluid of drilling varies in the suction tank as the choke operator supposed to be informed. The operator goes to check the series of repeated actions of the pump if gone during the weight of the fluid of the new drilling shown on his chart, likewise with every change of the fluid of the new drilling to adjust and fix the choke pressure until this match the conditions of the new drill pipe as has been recorded before on the surface for the purpose of bitting the graph. To keep the operation in progress, the pressure should be stayed steady and that come by arriving the final kill drilling fluid at the bit, so the final circulating pressure will be highly possible to be reached. Then operation will be well done (9, 12&21).

2.9.4 Driller's method vs. Wait and Weight method

The main characteristics of the driller's methods are simple and straightforward. Using the driller's method long time to close a well, and casing pressures may happen as a result. Casing pressures are greater than those of the "weight" and "wait" methods. The "weight" and "wait" method supplies both of the casing pressures and the lowest surface. Much arguing might be arisen, as a merit, at the times of drilling in certain environments in case of there is a narrow window between both of the fracture pressure and the pore pressure. The capabilities of mud mixing have already developed well, while killing weight mud is possible to be mixed up to 600 sacks hourly, this, in turn, will reduce the wait before pumping down KWM through the well. The best way to kill a well is the "wait" and "weight" method (17).

Well-control challenges in ERD wells

Extended reach (ERD) wells are defined as wells that have a horizontal departure (HD) at least twice the true vertical depth (TVD) of the well (41). ERD wells are kicked off from vertical near the surface and built to an inclination angle that allows sufficient horizontal displacement from the surface to the desired target. This inclination is held constant until the wellbore reaches the zone of interest and is then kicked off to near horizontal and extended into reservoir. This technology enables optimization of field development through the reduction of drilling sites and structures, and allows the operator to reach portions of the reservoir at a much greater distance than possible with a conventionally drilled directional well. These efficiencies increase profit margins on viable projects and can make the difference whether or not the project is financially viable (42).

The Wytch Farm field was discovered in 1974 and is located southwest of London on the UK coastline near Poole, England. It is an area of outstanding natural beauty with many sites of special scientific interest. About a third of the Sherwood reserves are under Poole Bay, where an artificial island was first planned to be developed (**Figure (2- 7)**. Drilling ERD wells from an onshore location may have reduced the development costs by as much as $150 million(43)

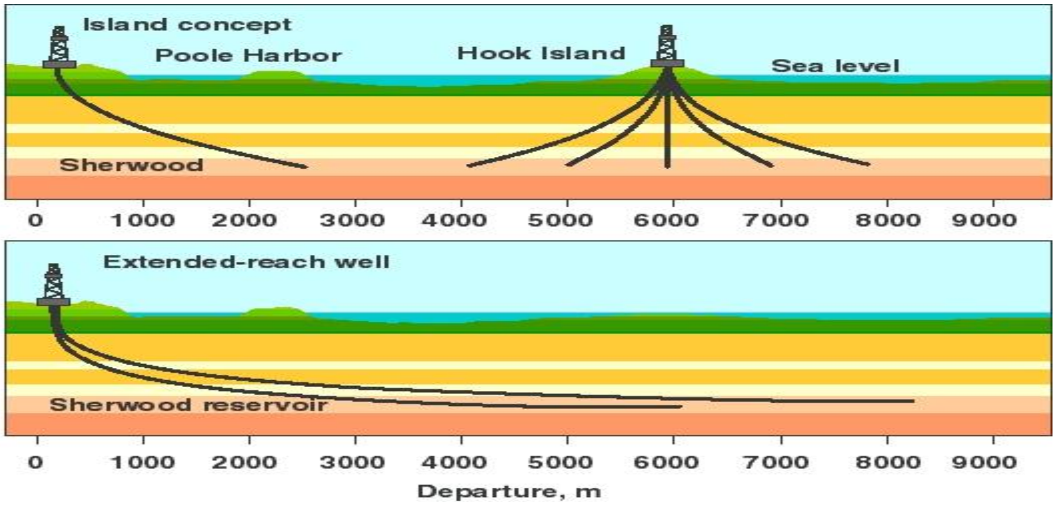

Figure (7) the artificial island development concept versus the ERD wells

A gas kick represents probably the most dangerous situation that can occur when drilling a well since it can easily develop to a blowout if it is not controlled promptly. ERD wells are more prone to kicks and lost-circulation problems than more conventional and vertical wells, but have some advantages when the well takes a kick because gas migration rates are lower (44). The maximum migration velocity occurs at 45^o inclination and the velocity rapidly drops to zero as the wellbore approaches horizontal (45), and a kick will rise faster in a viscous mud than in water (46).Significant migration rates are found at inclinations up to 80^o; the inclination which efficiently stops migration is close to 90^o in smooth wellbores and may be as low as 70^o if the wellbore is extremely rugged (47). The gas will then be trapped and accumulate in the top side of the hole until its original volume is depleted (Fig. 2-8). The trapped gas may be brought out of the traps and circulated up in the well when the normal drilling operation resumes. This may lead to an underbalanced situation that could result in another kick.

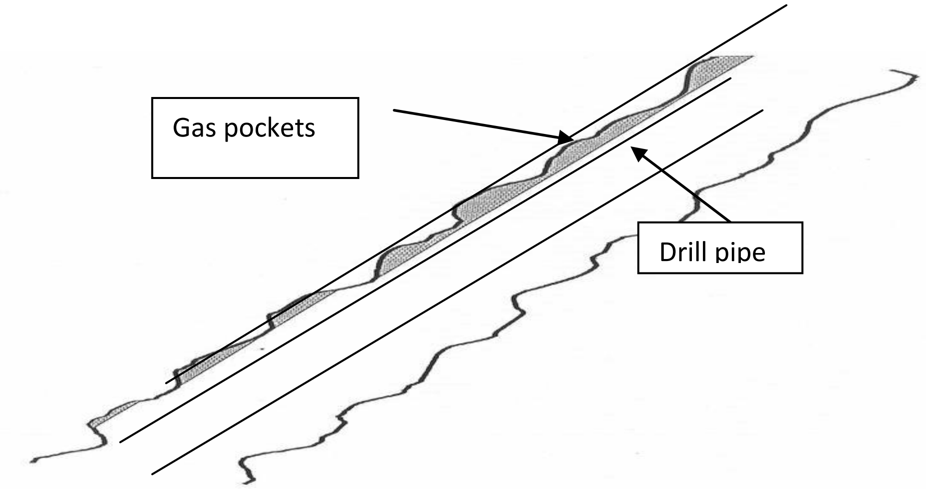

Figure (8) Gas migration in a highly inclined and rugose wellbore.

In ERD and horizontal wells the maximum casing-shoe pressure during a well control procedure is usually smaller and the choke pressures remain lower for a longer period of time than in a vertical well. The reason for this is that the TVD at casing shoe is often very close to the TVD of the influx zone. As long as the kick is in the horizontal section, the shut-in casing pressure (SICP) and shut-in drill pipe pressure (SIDPP) are about the same because hydrostatic pressure on both sides of the U-tube are the same. **Fig. 3** shows a horizontal well that has taken a kick and is shut-in.

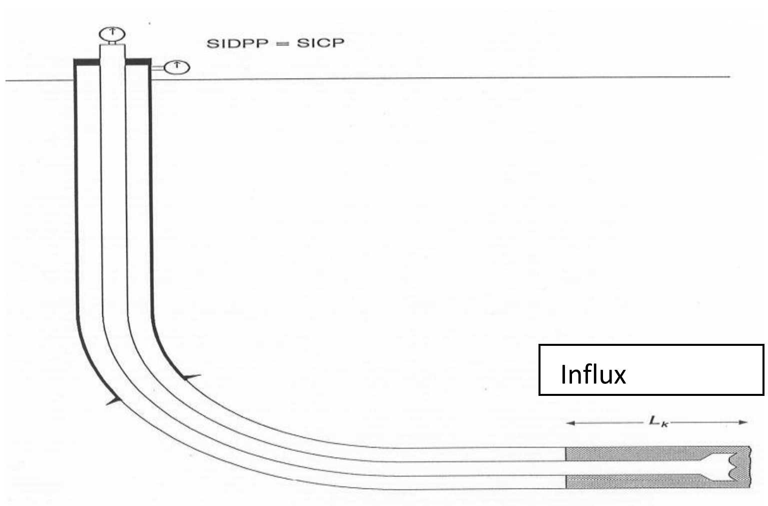

Figure (9) well shut in after taking a kick in horizontal well

CHAPTER 3

METHODOLOGY

3.1 Research Methodology

In the process of preliminary works, first of all, the student should has a better understanding the well control procedure in conventional well and also in ERD well. In order to get the information, the student has to refer various good books and journals that related to the well control procedure. Then, the student should learn the Landmark‟s software by using WELLPLAN software training manual.. For this study, the student have to focus only in Drilling chapter that contain investigate well control using the Well Control Analysis Module.

Project Work Flow

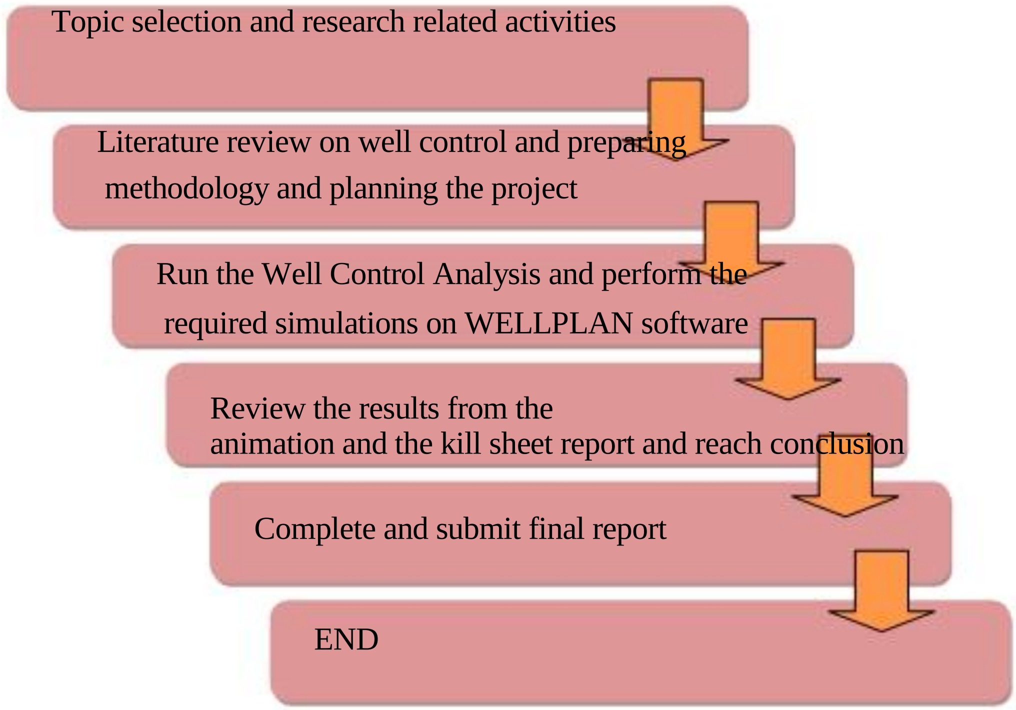

Figure 10: Flow diagram of Project Work Flow

3.2 Equipment and Tools

This project is is not dealing with equipment but only use tools which are two softwares. The project is divided into two parts, first run the WELLPLAN software. For the second part, macro visual basic is used to compare the results with WELLPLAN.

3.3 Project Activities

Below are the activities for this project:

a) Get the actual data from lecturer
b) Run the WELLPLAN
c) Fill up the basic information fields as Procedure 1 in 3.1.3.

d) Make sure the kick class is kick while drilling by changing the kick interval gradient value

e) Changing parameters in kick tolerance with different values such as kill rate and total influx volume

f) Determine the maximum allowable volume of kick

g) Evaluate the annulus pressure, and safe drilling depth

h) Evaluate the performance of Driller‟s Method in animation

i) Generate kill sheet

j) Review the summary of the well control

k) Discussion and conclusion

3.4 Gantt chart

Below is the Gantt chart for FYP 2.

Table 1: Gantt chart for FYP2

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14	15
1	Project Work Continues	■	■	■	■	■	■	■	Mid-Semester Break								
2	Submission of Progress Report									●							
3	Project Work Continues									■	■	■	■	■			
4	Pre-EDX												●				
5	Submission of Draft Report													●			
6	Submission of Dissertation (soft bound)														●		
7	Submission of Technical Paper														●		
8	Oral Presentation															●	
9	Submission of Project Dissertation (Hard Bound)																●

● Suggested milestone

■ Process

CHAPTER 4

RESULTS AND DISCUSSION

The information and basic data that are used as follows:

Table 2: Well data

	Section 1 (Vertical Section)	Section 2 (ERD)
MD (ft)	1476.4	15652.9
TVD (ft)	1470.9	5257.1
Casing Size (in)	24	9 5/8
Open Hole Size (in)	16	8 ½
MW (ppg)	10.1	10.8
Initial Mud Gradient (psi/ft)	0.525	0.561
Rheology Model	Bingham Plastic	Bingham Plastic
Rheology Data	PV and YP	PV and YP
Temperature (˚F)	88.0	88.0
Plastic Viscosity (cp)	18.0	18.0
Yield Point (lbf/100 ft^2)	22.0	18.0
Kick Interval Gradient (psi/ft)	0.535	0.641
Kick Class	Kick While Drilling	Kick While Drilling
Influx Volume (bbl)	18.0	30.0
Kill Mud Gradient (psi/ft)	0.540	0.650
Circulation Flowrate (gpm)	900	620
Kill Rate (gpm)	450	350
SIDPP (psi)	100	300
SICP (psi)	300	500

Wellpath editor (wellbore trajectory).

- Kick off well with 3˚/100 ft, Azimuth at 61˚ at 1082.7 ft. Build angle from 0˚ to 78˚ from 1082.7 ft to 3608.9 ft at 61˚ Azimuth. Then hold at 78˚ Tangent at 61˚ Azimuth to well MD at 15652.9 ft.

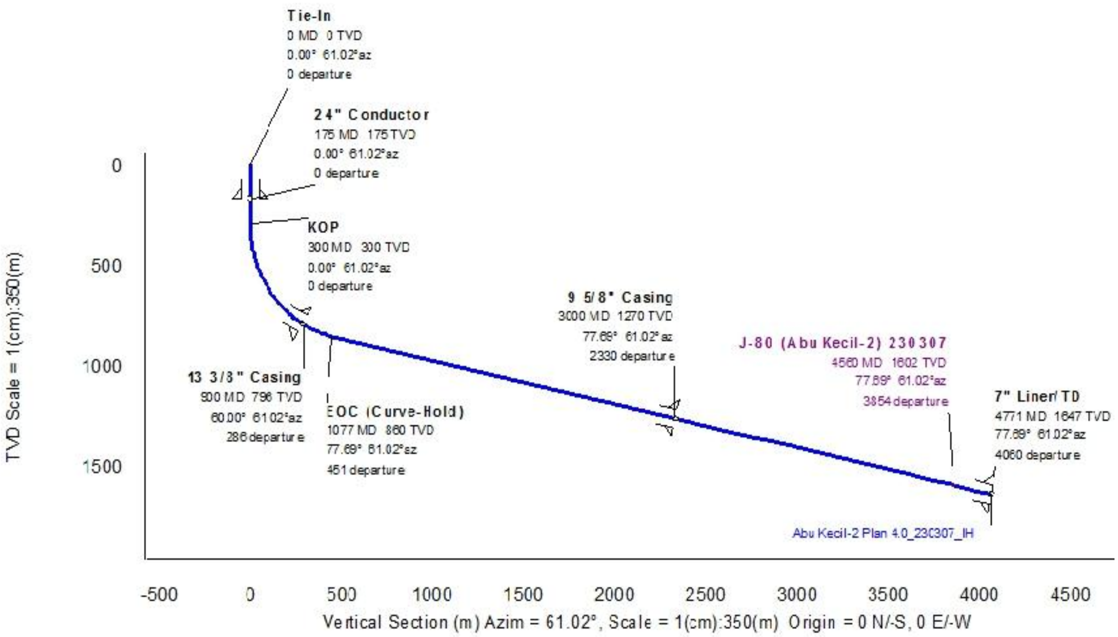

Figure 11: well trajectory

Pore pressure and fracture pressure.

Table 3: Pore pressure and fracture pressure

TVD (ft)	Pore Pressure (psi)	EMW (ppg)	Fracture Pressure (psi)	EMW (ppg)
338.9	147.68	8.38	236.15	13.40
574.2	250.20	8.38	400.09	13.40
2611.7	1138.06	8.38	1833.40	13.50
4166.9	1815.76	8.38	3076.82	14.20
4364.7	1901.97	8.38	3222.91	14.20
4459.9	1943.43	8.38	3293.16	14.20
4499.0	1960.48	8.38	3322.06	14.20
4538.6	1975.38	8.37	3351.31	14.20
4902.8	2131.34	8.36	3620.23	14.20
5155.4	2238.49	8.35	3806.77	14.20
5237.5	2271.38	8.34	3894.58	14.30
5257.1	2299.06	8.41	3881.88	14.20

4.1 Effect of varying total influx volume in kick tolerance and geometry of the wellbore

4.1.1 Introduction

For this investigation, well data was used as the base case for the typical ERD well profile. Assuming that varying total influx volume in kick tolerance would have the most effect on annulus pressure during kick occur. The experiment was performed with several simulation runs for different total influx volume with the ERD section and vertical section in the same well. All of the experiment was performed with gas is the type of influx.

Example of experiment:

Table 4: Range variables of total influx volume

	Section 1	Section 2
Total influx volume (bbl)	15, 30, 50	15, 30, 50

4.1.2 Results

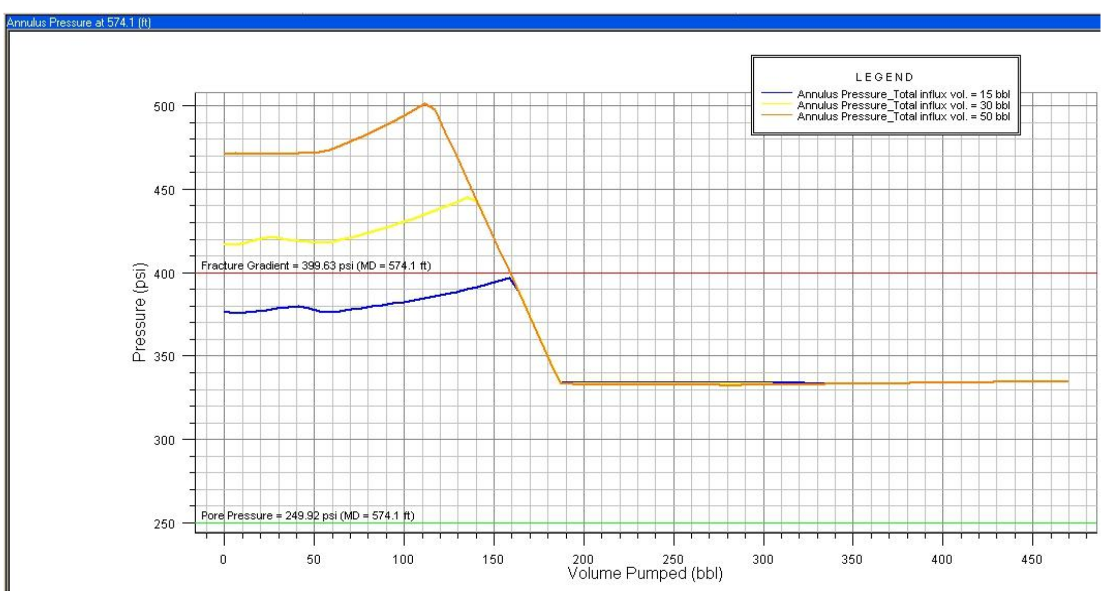

Figure 12: Annulus pressure for various total influx volume (Section 1)

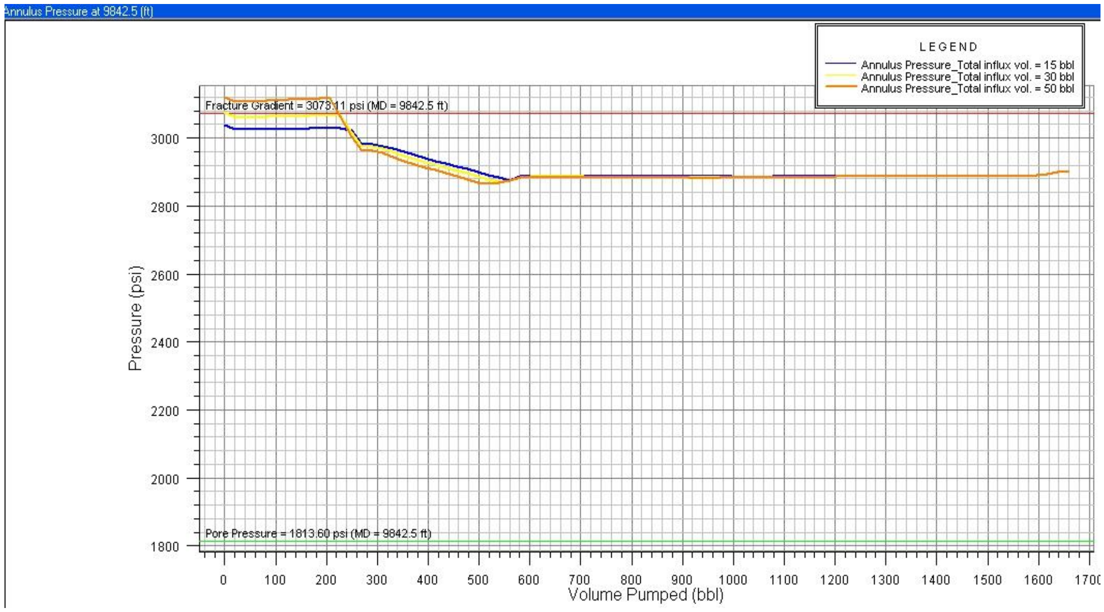

Figure 13: Annulus pressure for various total influx volume (Section 2)

4.1.3 Discussions

From Figures 11 and 12, the increasing in total influx volume causes an increase in the annulus pressure. Besides, the annulus pressure increase with TVD of the well is higher. For the Section 1, a 15 bbl influx volume is the only acceptable influx volume for the Section 1 because the annulus pressure is not exceeds the fracture pressure. The highest annulus pressure for 15 bbl kick is 397 psi and the fracture pressure is 399.62 psi. 30 bbl and 50 bbl are not acceptable because their pressure too high. However, the results show the annulus pressure of 30 bbl influx volume is not exceeds the fracture pressure for Section 2. It is because the Section 2 has longer open holes section and it is allowable more additional influx in the wellbore. The fracture pressure at MD 9842.5 ft is 3073.1 psi and annulus pressure for 50 bbl is 3120 psi.

The maximum allowable influx volumes for both sections are presented in Appendix, Figures 37 and 38.

4.2 Kill rate

4.2.1 Introduction

For this project, one of the objectives is to see the results from both WELLPLAN and theoretical calculations. The high kill rate must be performed in ERD well in order to remove gas kick from horizontal section. Table 6 shows the range variables of kill rate for this project.

Example of experiment:

Table 5: Range variables of kill rate

	Section 1	Section 2
Kill Rate (gpm)	300, 450, 500	210, 310, 350

4.2.2 Results

WELLPLAN, Section 1 (450 gpm).

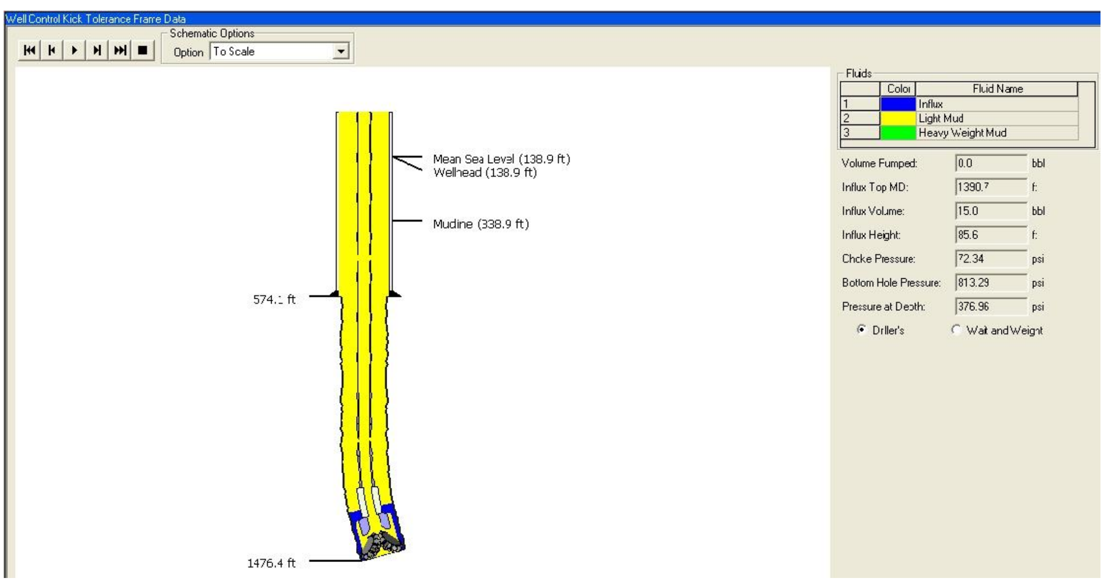

Figure 14: Animation of schematic before kill the well (Section 1)

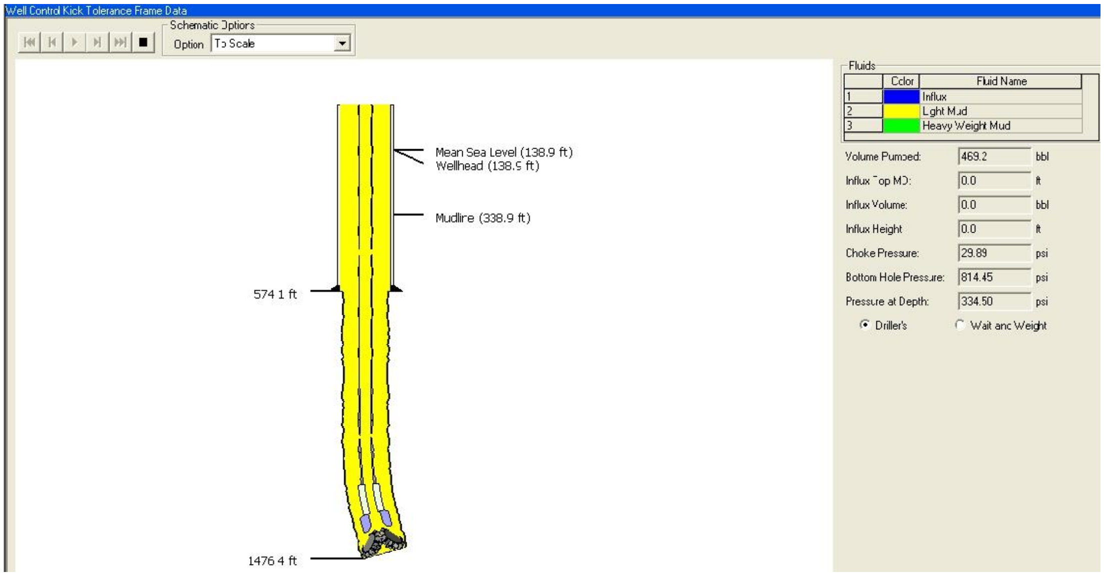

Figure 15: Animation of schematic after completely kill the well (Section 1)

WELLPLAN, Section 2 (350 gpm).

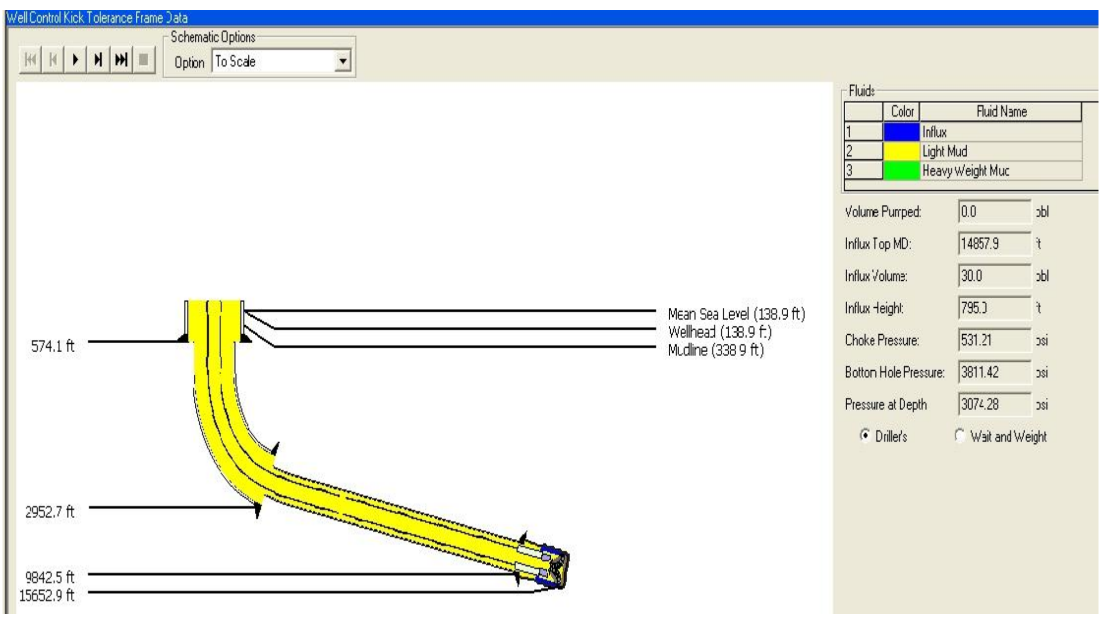

Figure 16: Animation of schematic before kill the well (Section 2)

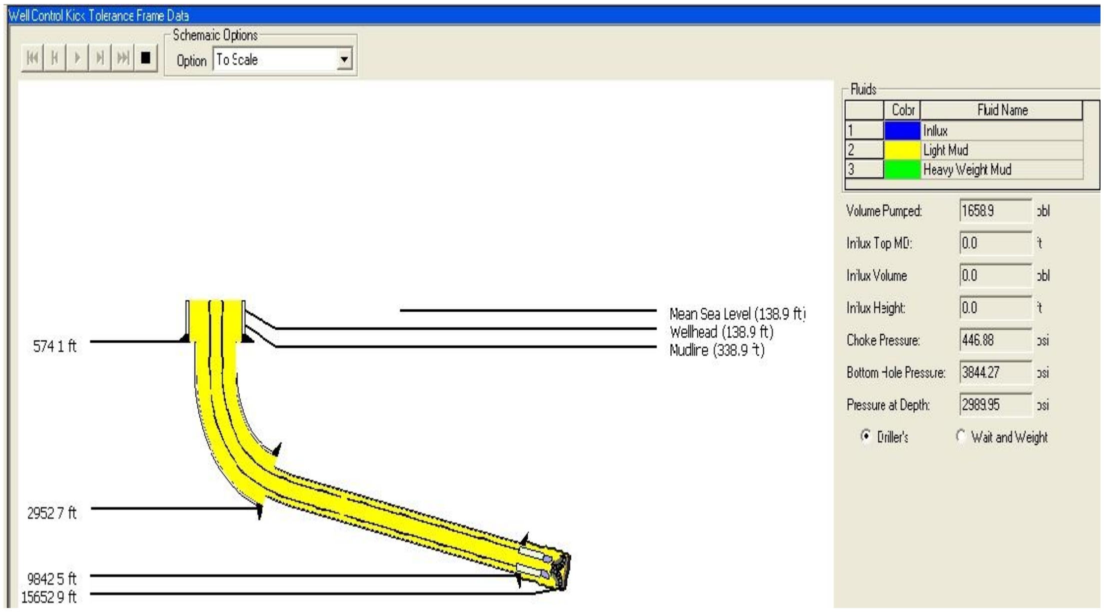

Figure 17: Animation of schematic after completely kill the well (Section 2)

4.2.3 Discussion

For the Section 1 and Section 2 in WELLPLAN, all the experiment kill rates are enough to completely remove the gas kick from the wellbore. From the researches that have been done by reading books and journals, the kill rate should be high rate for Section 2 to remove the gas kick. However, all the tested kill rates are enough to displace the kick. The influx volume and influx height are 15 bbl and 85.6 ft for Section 1 with 450 gpm kill rate. The required KMW to displaced gas volume is 469.2 bbl. Meanwhile in Section 2 with kill rate of 350 gpm, the influx height is 795 ft and 30 bbl of influx volume. The pumped volume kill mud is 1658.9 bbl to completely remove the gas kick. The differences in kill rate effects the P_{wf}. By increasing the Q, the P_{wf} will increase. Other kill rate results are presented in Appendix, Figures 27, 29, 31 and 33.

4.3 Kill Sheet

4.3.1 Introduction

WELLPLAN provides its own kill sheet to ease the user to review the summary of well control. The kill mud weight is calculated by the software.

4.3.2 Results

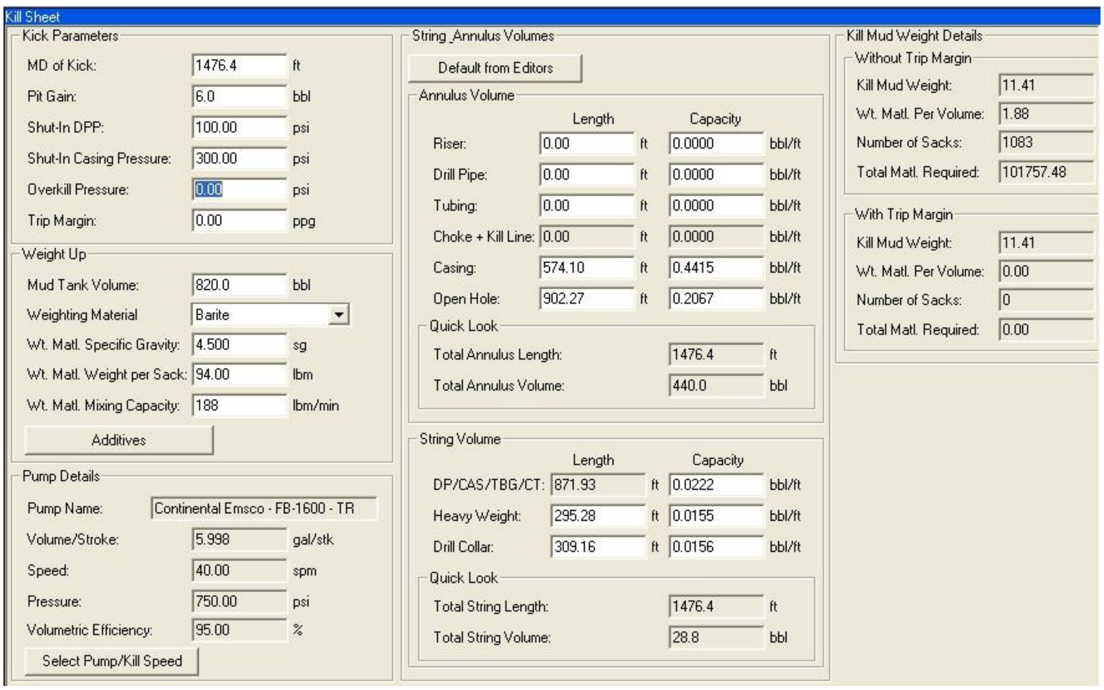

Figure 18: Kill sheet for Section 1

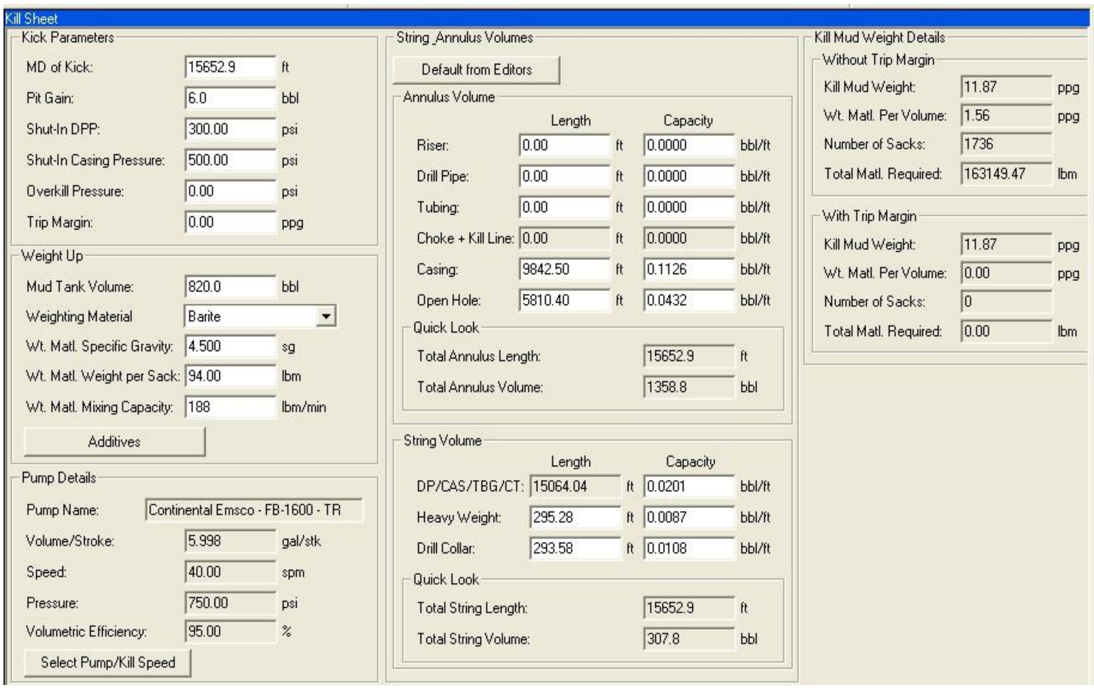

Figure 19: Kill sheet for Section 2

4.4.3 Discussion

The values in kick parameters, weight up and pump details are set to be constant for both sections. The string annulus volumes are specified by the software when click the „Default from Editors" button. The value of string annulus volumes are taken from the String Editor. Then the KMW details also are specified by the software.

The KMW for Section 1 is 11.41 ppg and the number of sacks required to pump into the well is 1083. If the assumption of SIDPP is high for example 300 psi, KMW will increase as in Appendix, Figure 35. Thus, the number of sacks and total material required also increase.

For the Section 2, the calculated KMW to kill the well is 11.87 ppg. The mud weight increases 1.07 ppg and the number of sacks required is 1736. The total material required to pump from surface to the target depth is 163149.47 lbm and the value of it depends on the number of sacks. Meanwhile the weight material per volume is depends on the KMW and MW.

4.4 Kill Graph and Well Control Summary

4.4.1 Introduction

Kill graph is one of the important things in well control. It shows the standpipe pressure as the kill mud is pumped down the string until it hits the annulus. Well control summary shows pumping schedule and pump stroke summary. The pump stroke can be used in well control operations to use drillpipe pressure schedules for maintaining the bottom-hole pressure at a proper value. During well control operations, the bottom-hole pressure must be maintained at a value slightly higher than the formation pressure during kill operations.

4.4.2 Results

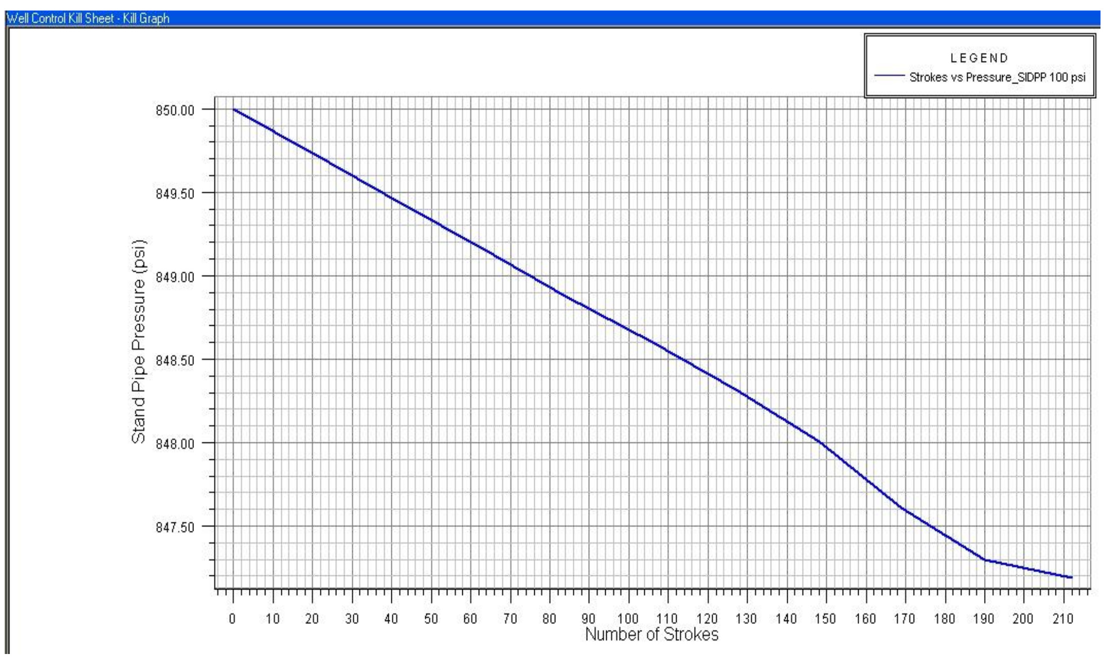

Figure 20: Kill graph for Section 1 with kill rate 450 gpm and 40 spm (Section 1)

Table 6: Pumping schedule (Section 1)

Measured Depth (MD) (ft)	True Vertical Depth (TVD) (ft)	Time (min)	No. of Strokes	Stand Pipe Pressure (psi)
0.0	0.0	0.0	0	850.00
129.7	129.7	0.5	21	849.72
259.3	259.3	1.1	42	849.44
389.0	389.0	1.6	63	849.16
518.6	518.6	2.1	84	848.88
648.3	648.3	2.7	106	848.60
777.9	777.9	3.2	127	848.32
922.8	922.8	3.7	148	848.01
1,107.9	1,107.9	4.2	169	847.61
1,292.3	1,291.0	4.8	190	847.30
1,476.4	1,470.8	5.3	212	847.19

Table 7: Pump strokes summary (Section 1)

	Strokes	Volume (bbl)	Time (min)
Fill String	212	28.8	5.3
Fill Open Hole	1375	186.5	34.4
Fill Casing	1868	253.5	46.7
Fill Annular Drill Pipe	0	0.0	0.0
Fill Annular Tubing	0	0.0	0.0
Fill Riser	0	0.0	0.0
Fill Choke / Kill Line	0	0.0	0.0
Fill Annulus	3243	440.0	81.1
Total	3455	468.8	86.4

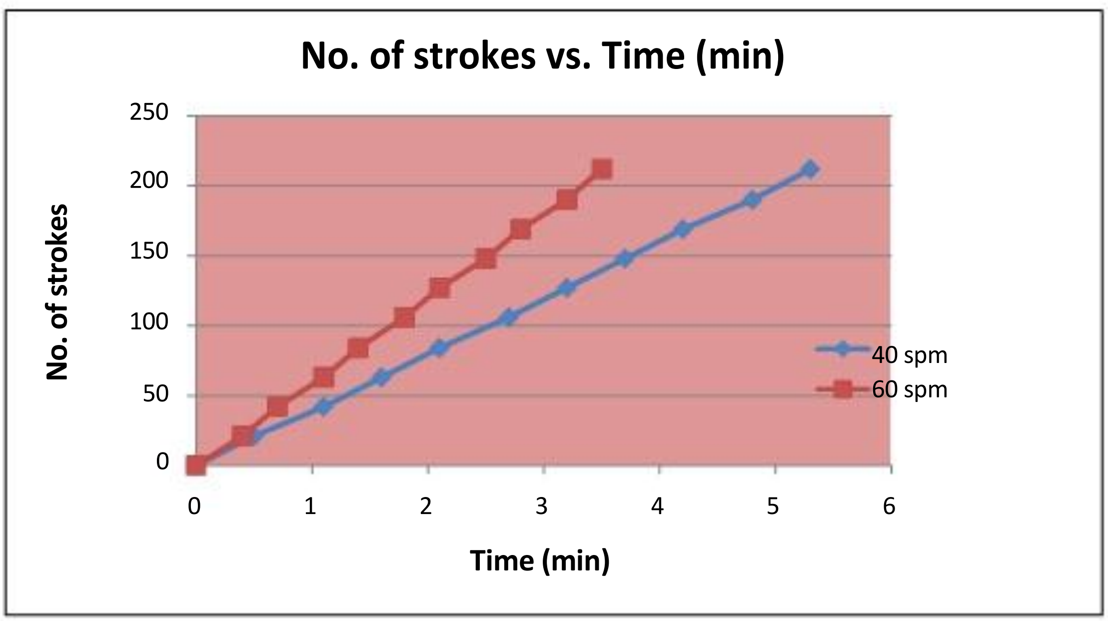

Figure 21: No. of strokes vs. Time (Section 1)

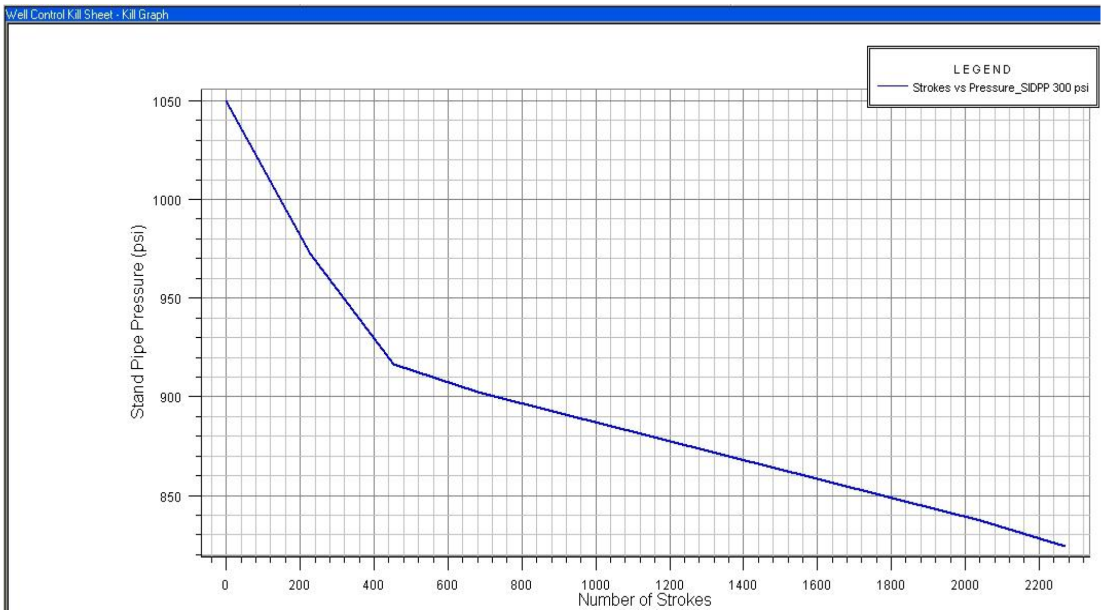

Figure 22: Kill graph for Section 2 with kill rate 350 gpm and 40 spm (Section 2)

Table 8: Pumping schedule (Section 2)

Measured Depth (MD) (ft)	True Vertical Depth (TVD) (ft)	Time (min)	No. of Strokes	Stand Pipe Pressure (psi)
0.0	0.0	0.0	0	1,050.00
1,535.1	1,527.3	5.7	226	972.50
3,070.3	2,667.8	11.3	453	916.48
4,605.4	3,049.5	17.0	680	902.57
6,140.6	3,376.8	22.7	907	891.68
7,675.7	3,704.1	28.4	1,134	880.79
9,210.8	4,031.4	34.0	1,361	869.90
10,746.0	4,358.7	39.7	1,588	859.01
12,281.1	4,686.0	45.4	1,815	848.12
13,816.3	5,013.3	51.1	2,042	837.23
15,652.9	5,404.9	56.7	2,269	824.20

Table 9: Pump strokes summary (Section 2)

	Strokes	Volume (bbl)	Time (min)
Fill String	2,269	307.8	56.7
Fill Open Hole	1,849	250.8	46.2
Fill Casing	8,167	1,107.9	204.2
Fill Annular Drill Pipe	0	0.0	0.0
Fill Annular Tubing	0	0.0	0.0
Fill Riser	0	0.0	0.0
Fill Choke / Kill Line	0	0.0	0.0
Fill Annulus	10,016	1,358.8	250.4
Total	12,285	1,666.6	307.1

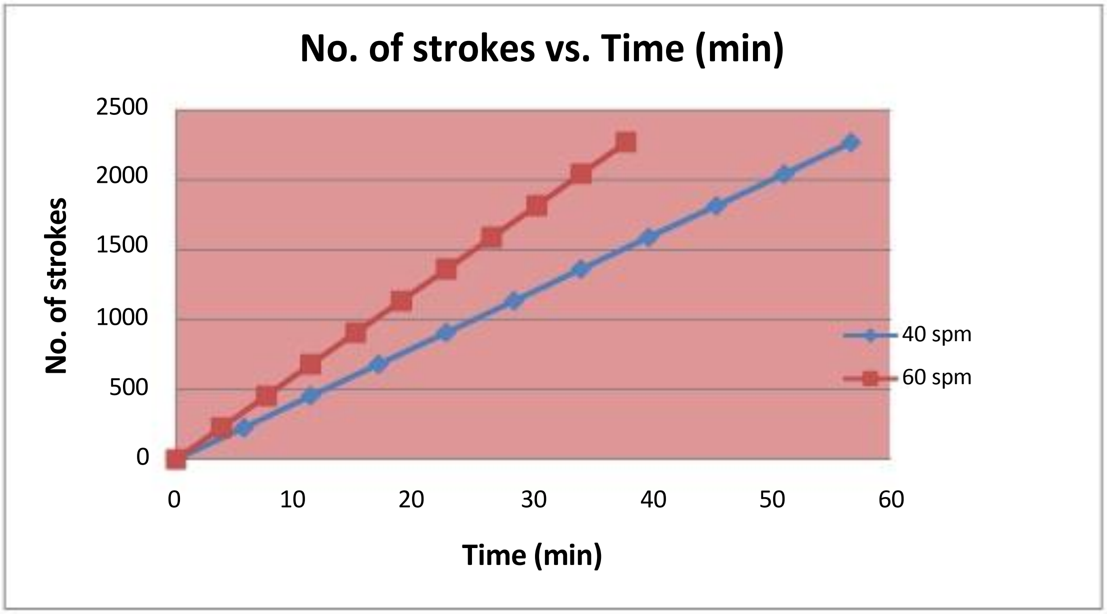

Figure 23: No. of strokes vs. Time (Section 2)

4.4.3 Discussion

From the above results, in order to kill the well for Section 1, 212 strokes needed to fill the KMW inside the drill string. The total strokes for the well control operations is 3455 and it takes 86.4 minutes. The standpipe pressure is start at 850.00 psi at 0 strokes and during the last stroke, the standpipe pressure reduce to 847.20 psi. The reduction of standpipe pressure is too small which is about 3 psi. The factor of this situation is because it takes only a few minutes just to transport the KMW to the end of the well. If the strokes per min high, time taken for the well control operations is less as presented in Figures 20 and 22.

Next, Figure 21 illustrate 2269 strokes are required in Section 2 to kill the well and it takes 56.7 minutes and 307.8 bbl from the surface to the target depth. Before starts kill the well, the standpipe pressure is 1050 psi and it reduces to 824.2 psi when the MW reaches the target depth. The total time for the well control operation is 307.1 minutes and the number of strokes is 12285 from the surface to the target depth and from the target depth to the surface. Besides, the total volumes of kill mud to pumped to whole well is 1666.6 bbl.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The conclusion of this study is the well control procedures in ERD wells are different from the conventional wells. For the kick detection, there are no difference between conventional wells and ERD wells. But for the killing kick, it is difference between both wells.

In ERD wells, the Driller"s Method is the preferred method to kill the well because the Engineer"s Method takes a long time to wait until the pressure stabilized. Kill procedures in conventional wells are usually 1/3 and ½ of the normal drilling rate. In ERD wells, the kill rate is high at the horizontal section then normal kill rate is performed between horizontal section and into the hold section, and in the hold section.

But for this study, the gas kick still can be displaced at the end of the well by using 1/3 or ½ of the circulation rate. One of the reasons is maybe the inclination angle of this well is not high.

From this study, the procedure of kill the well is as follows:

1. Performed "hard" shut-in of the well once a kick is detected and confirmed.
2. Read the SIDPP, SICP and pit gain when the pressures have stabilized.
3. Verify the KMW using the current the SIDPP and increase the density of the mud in the pits.
4. Start circulates by using the Driller"s Method.

5. Use high rate for a short time to displace the gas kick from the horizontal section of the wellbore.
6. When the choke pressure starts to increase to increase rapidly, the pumps have to slow down. Then continue with a kill rate which 1/3 or ½ of the normal circulation rate.
7. Continue holding the constant casing pressure until the strokes reach the no. of strokes that fill the drillstring.
8. Observe the drillpipe pressure and maintain constant until the KMW circulates the whole well which is referring to the total no. of strokes.
9. After complete the circulations, shut off the pump and close the well in.

WELLPLAN is really useful software in analyzing the drilling operations and it is friendly user. This software can improved the drilling performance through reduction of kicks, stuck pipe, lost circulation and blowouts for significant reductions in non-productive time. It will reduce the time to analyze the problem when using the WELLPLAN. By having proper well control procedures, we can avoid losses of valuable natural resources, increased drilling costs, environmental damages, increased regulations, injuries to personnel and the vast consequence is loss of life.

5.2 Recommendation

For the recommendation, the next step would be to investigate the factors that have effect on valve pressures and gas-return rates for different kick scenarios. The factors are the effect of kick size, water depth, circulation kill rate, holes size and also kick intensity. This research also can use the WELLPLAN software to run and get the better result.

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APPENDIX A

International Well Control Forum
Subsea BOP Deviated Well Kill Sheet (API Field Units)

DATE : ____________

NAME : ____________

FORMATION STRENGTH DATA:

SURFACE LEAK -OFF PRESSURE FROM FORMATION STRENGTH TEST (A) psi

MUD WEIGHT AT TEST (B) ppg

MAXIMUM ALLOWABLE MUD WEIGHT =

$$(B) + \frac{(A)}{\text{SHOE T.V. DEPTH} \times 0.052} = (C) \text{ ppg}$$

INITIAL MAASP =
((C) - CURRENT MUD WEIGHT) x SHOE T.V. DEPTH x 0.052
= ____ psi

PUMP NO. 1 DISPL.	PUMP NO. 2 DISPL.
bbls / stroke	bbls / stroke

SLOW PUMP RATE DATA:	(PL) DYNAMIC PRESSURE LOSS [psi]					
	PUMP NO. 1			PUMP NO. 2		
	Riser	Choke Line	Choke Line Friction	Riser	Choke Line	Choke Line Friction
SPM						
SPM						

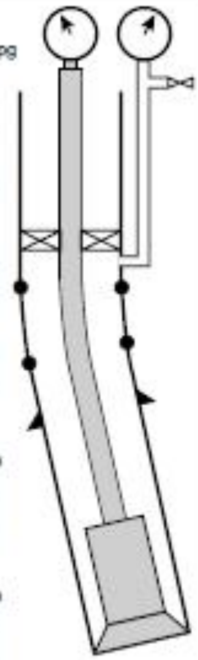
CURRENT DRILLING MUD:
WEIGHT ____ ppg

SUBSEA BOP DATA:
MARINE RISER LENGTH ____ ft
CHOKELINE LENGTH ____ ft

DEVIATION DATA:
KOP M.D. ____ ft
KOP T.V.D. ____ ft
EOB M.D. ____ ft
EOB T.V.D. ____ ft

CASING SHOE DATA:
SIZE ____ in
M. DEPTH ____ ft
T.V. DEPTH ____ ft

HOLE DATA:
SIZE ____ in
M. DEPTH ____ ft
T.V. DEPTH ____ ft



PRE-RECORDED VOLUME DATA:	LENGTH ft	CAPACITY bbls/ft	VOLUME bbls	PUMP STROKES Strokes	TIME minutes
DP - SURFACE TO KOP		x	=	(L) stks	
DP - KOP TO EOB		x	= +	(M) stks	
DP - EOB TO BHA		x	= +	(N1) stks	
HEVI WALL DRILL PIPE		x	= +	(N2) stks	
DRILL COLLAR		x	= +	(N3) stks	
DRILL STRING VOLUME			(D) bbls	stks	min
DC x OPEN HOLE		x	=		
DP / HWDP x OPEN HOLE		x	= +		
OPEN HOLE VOLUME			(F) bbls	stks	min
DP x CASING		x	= (G) +	stks	min
CHOKELINE		x	= (H) +	stks	min
TOTAL ANNULUS / CHOKELINE VOLUME			(F+G+H) = (I) bbls	stks	min
TOTAL WELL SYSTEM VOLUME			(D+I) = (J) bbls	stks	min
ACTIVE SURFACE VOLUME			(K) bbls	stks	
TOTAL ACTIVE FLUID SYSTEM			(J+K) bbls	stks	
MARINE RISER x DP		x	= bbls	stks	

Dr No SSD 04/01
(Field Units)
27-01-2000

Figure 23: Kill sheet sample 1

International Well Control Forum

Subsea BOP Kill Sheet - Deviated Well (API Field Units)

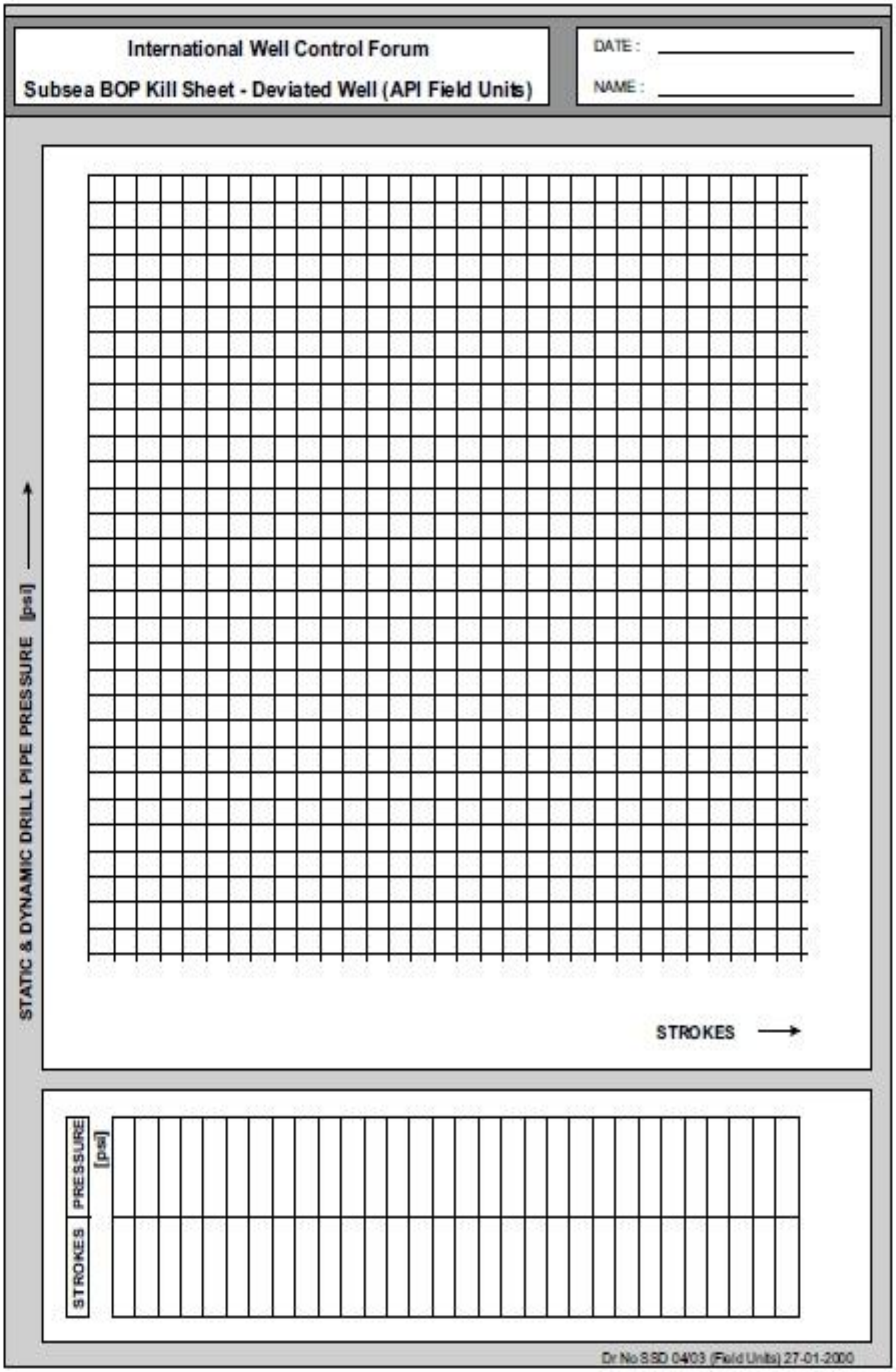
DATE : ________________

NAME : ________________

KICK DATA:	SIDPP [ ] psi SICP [ ] psi PIT GAIN [ ] bbl
KILL MUD WEIGHT KMW	CURRENT MUD WEIGHT + $\frac{\text{SIDPP}}{\text{TVD x 0.052}}$ ______ + $\frac{\text{\_\_\_\_\_\_}}{\text{X 0.052}}$ = ______ ppg
INITIAL CIRC. PRESSURE ICP	DYNAMIC PRESSURE LOSS + SIDPP ______ + ______ = ______ psi
INITIAL DYNAMIC CASING PRESS AT KILL PUMP RATE	SICP - CHOKE LINE FRICTION = ______ - ______ = ______ psi
FINAL CIRCULATING PRESSURE FCP	$\frac{\text{KILL MUD WEIGHT}}{\text{CURRENT MUD WEIGHT}}$ x DYNAMIC PRESSURE LOSS ______ x ______ = ______ psi
DYNAMIC PRESSURE LOSS AT KOP (O)	PL + [(FCP-PL) x $\frac{\text{KOPMD}}{\text{TDMD}}$] = ______ + [(______-______) x ______] = ______ psi
REMAINING SIDPP AT KOP (P)	SIDPP - [(KMW - CMW) x KOPTVD x 0.052] = ______ - [(______-______) x 0.052 x ______] = ______ psi
CIRCULATING PRESS. AT KOP (KOP CP)	(O) + (P) = ______ + ______ = ______ psi
DYNAMIC PRESS. LOSS AT EOB (R)	PL + [(FCP-PL) x $\frac{\text{EOBMD}}{\text{TDMD}}$] = ______ + [(______-______) x ______] = ______ psi
REMAINING SIDPP AT EOB (S)	SIDPP - [(KMW - CMW) x EOBTVD x 0.052] = ______ - [(______-______) x 0.052 x ______] = ______ psi
CIRCULATING PRESS. AT EOB (EOB CP)	(R) + (S) = ______ + ______ = ______ psi
(T) = ICP - KOP CP = ______ - ______ = ______ psi	$\frac{\text{(T) x 100}}{\text{(L)}}$ = $\frac{\text{X 100}}{\text{\_\_\_\_\_\_}}$ = ______ $\frac{\text{psi}}{\text{100 strokes}}$
(U) = KOP CP - EOB CP = ______ - ______ = ______ psi	$\frac{\text{(U) x 100}}{\text{(M)}}$ = $\frac{\text{X 100}}{\text{\_\_\_\_\_\_}}$ = ______ $\frac{\text{psi}}{\text{100 strokes}}$
(W) = EOB CP - FCP = ______ - ______ = ______ psi	$\frac{\text{(W) x 100}}{\text{(N1+N2+N3)}}$ = $\frac{\text{X 100}}{\text{\_\_\_\_\_\_}}$ = ______ $\frac{\text{psi}}{\text{100 strokes}}$

Dr.No.SSD 04/02 (Field Units) 27.01.2000

Figure 24: Kill sheet sample 2


International Well Control Forum

Subsea BOP Kill Sheet - Deviated Well (API Field Units)

DATE : ____________

NAME : ____________

STATIC & DYNAMIC DRILL PIPE PRESSURE [psi]

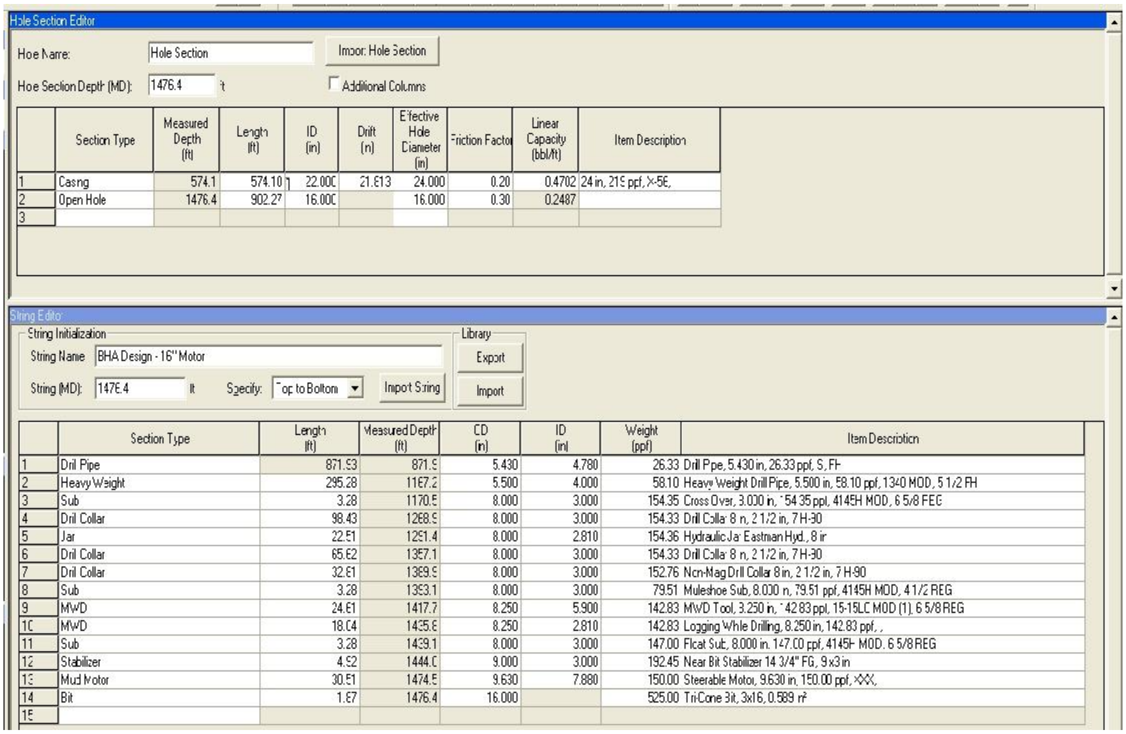
STROKES

PRESSURE [psi]

STROKES

Dr No SSD 04/03 (Field Units) 27-01-2000

Figure 25: Kill sheet sample 3



Hole Section Editor

Hole Name: Hole Section

Hole Section Depth (MD): 1476.4 ft

Additional Columns

	Section Type	Measured Depth (ft)	Length (ft)	ID (in)	Drift (in)	Effective Hole Diameter (in)	Friction Factor	Linear Capacity (bbl/ft)	Item Description
1	Casing	574.1	574.10	22.000	21.813	24.000	0.20	0.4702	24 in, 219 ppf, X-56,
2	Open Hole	1476.4	902.27	16.000		16.000	0.30	0.2487	
3									

String Editor

String Initialization

String Name: BHA Design - 16" Motor

String (MD): 1476.4 ft

Specify: Top to Bottom

Import String

Library: Export, Import

	Section Type	Length (ft)	Measured Depth (ft)	OD (in)	ID (in)	Weight (ppf)	Item Description
1	Drill Pipe	871.93	871.9	5.430	4.780	26.33	Drill Pipe, 5.430 in, 26.33 ppf, S, FH
2	Heavy Weight	295.28	1167.2	5.500	4.000	58.10	Heavy Weight Drill Pipe, 5.500 in, 58.10 ppf, 1340 MOD, 5 1/2 FH
3	Sub	3.28	1170.5	8.000	3.000	154.35	Cross Over, 3.000 in, 154.35 ppf, 4145H MOD, 6 5/8 REG
4	Drill Collar	98.43	1268.9	8.000	3.000	154.33	Drill Collar 8 in, 2 1/2 in, 7 H-90
5	Jar	22.51	1291.4	8.000	2.810	154.36	Hydraulic Jar Eastman Hyd., 8 in
6	Drill Collar	65.62	1357.1	8.000	3.000	154.33	Drill Collar 8 in, 2 1/2 in, 7 H-90
7	Drill Collar	32.81	1389.9	8.000	3.000	152.76	Non-Mag Drill Collar 8 in, 2 1/2 in, 7 H-90
8	Sub	3.28	1393.1	8.000	3.000	79.51	Muleshoe Sub, 8.000 in, 79.51 ppf, 4145H MOD, 4 1/2 REG
9	MWD	24.61	1417.7	8.250	5.900	142.83	MWD Tool, 3.250 in, 142.83 ppf, 15-15LC MOD (1), 6 5/8 REG
10	MWD	18.04	1435.8	8.250	2.810	142.83	Logging While Drilling, 8.250 in, 142.83 ppf, ,
11	Sub	3.28	1439.1	8.000	3.000	147.00	Float Sub, 8.000 in, 147.00 ppf, 4145H MOD, 6 5/8 REG
12	Stabilizer	4.92	1444.0	9.000	3.000	192.45	Near Bit Stabilizer 14 3/4" FG, 9x3 in
13	Mud Motor	30.51	1474.5	9.630	7.880	150.00	Steerable Motor, 9.630 in, 150.00 ppf, XXX,
14	Bit	1.67	1476.4	16.000		525.00	Tri-Cone Bit, 3x16, 0.589 in²
15							

Figure 26: Hole section and string editor

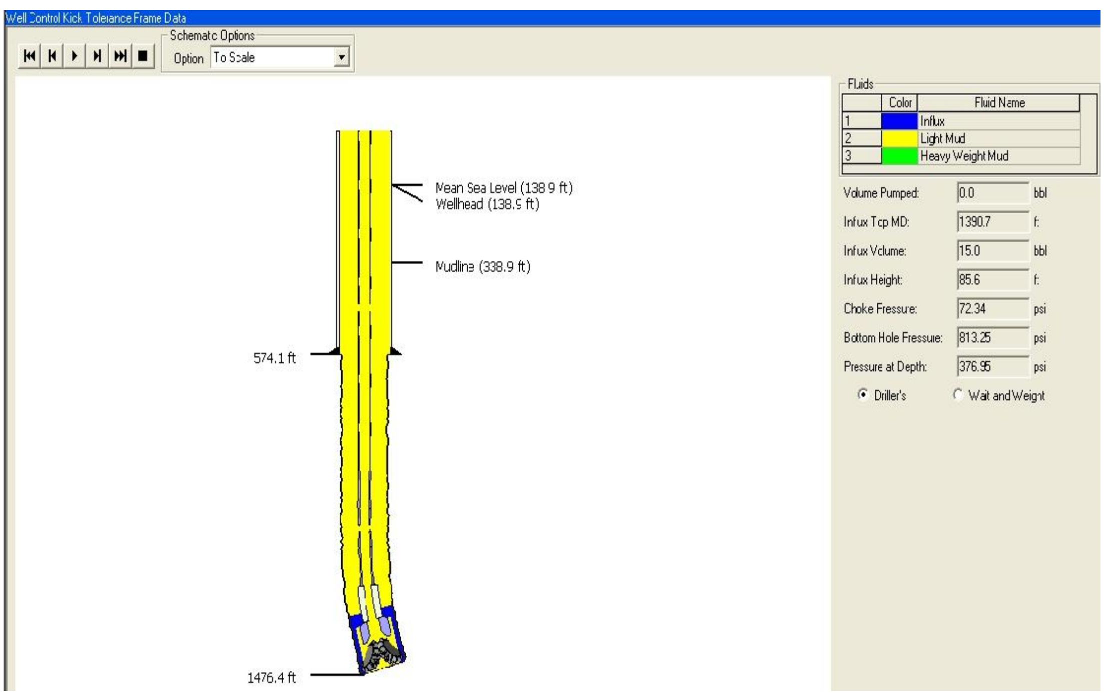


Figure 27: Animation of schematic before kill the well, kill rate 300 gpm (Section 1)

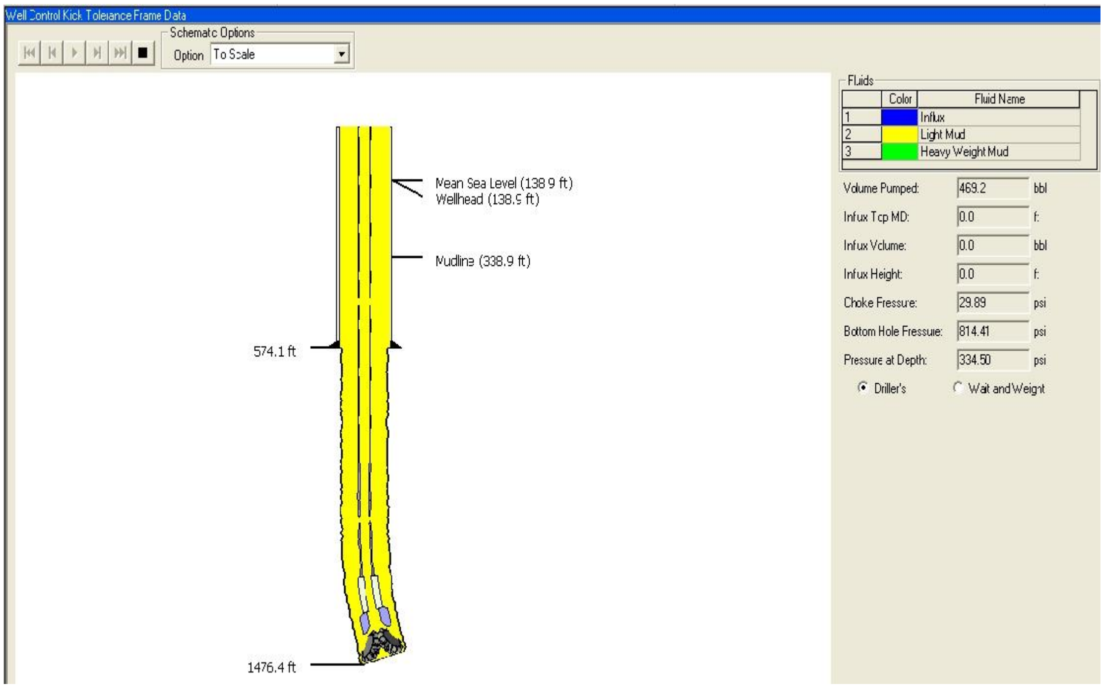


Figure 28: Animation of schematic after completely kill the well, kill rate 300 gpm (Section 1)

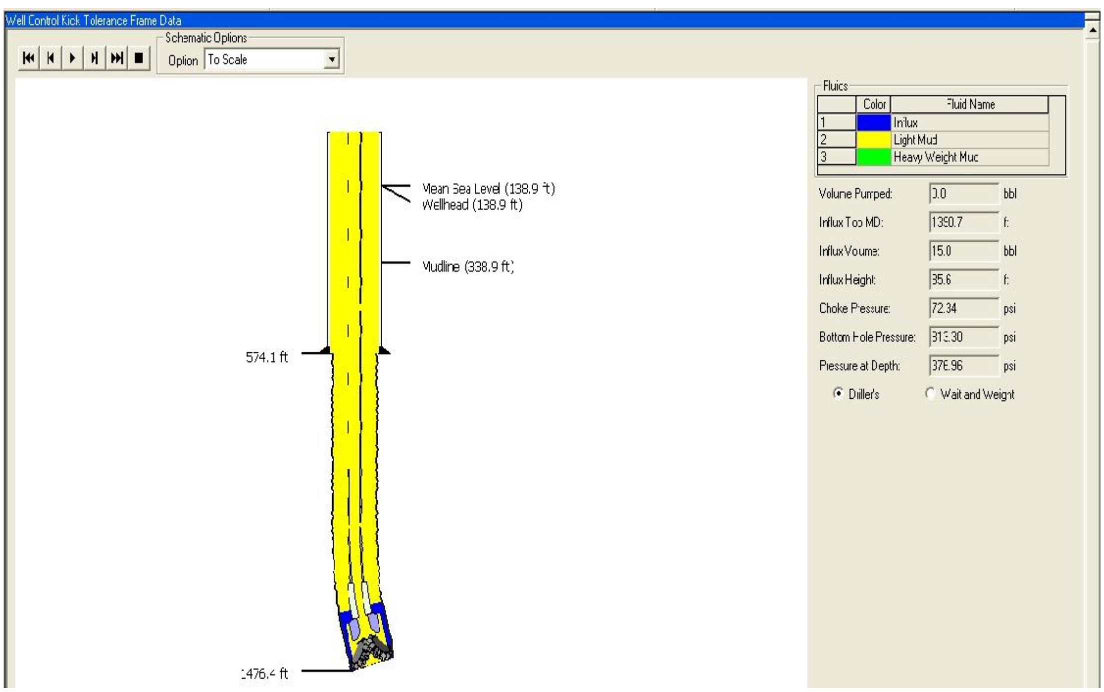


Figure 29: Animation of schematic before kill the well, kill rate 500 gpm (Section 1)

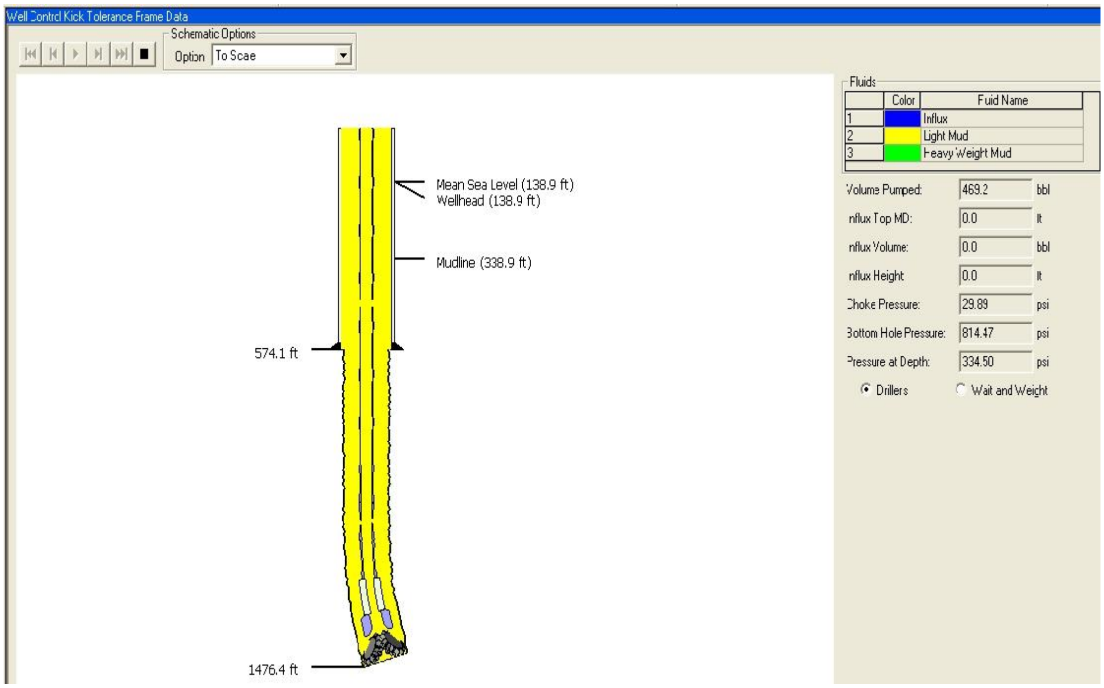


Figure 30: Animation of schematic after completely kill the well, kill rate 500 gpm (Section 1)

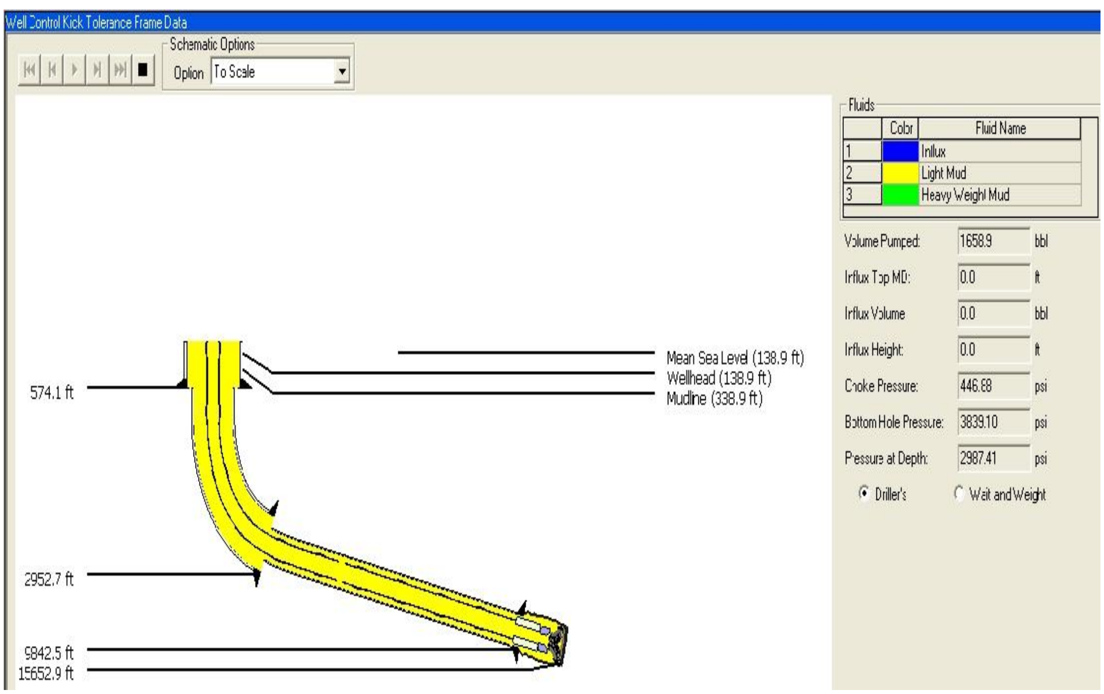


Figure 31: Animation of schematic before kill the well, kill rate 310 gpm (Section 2)

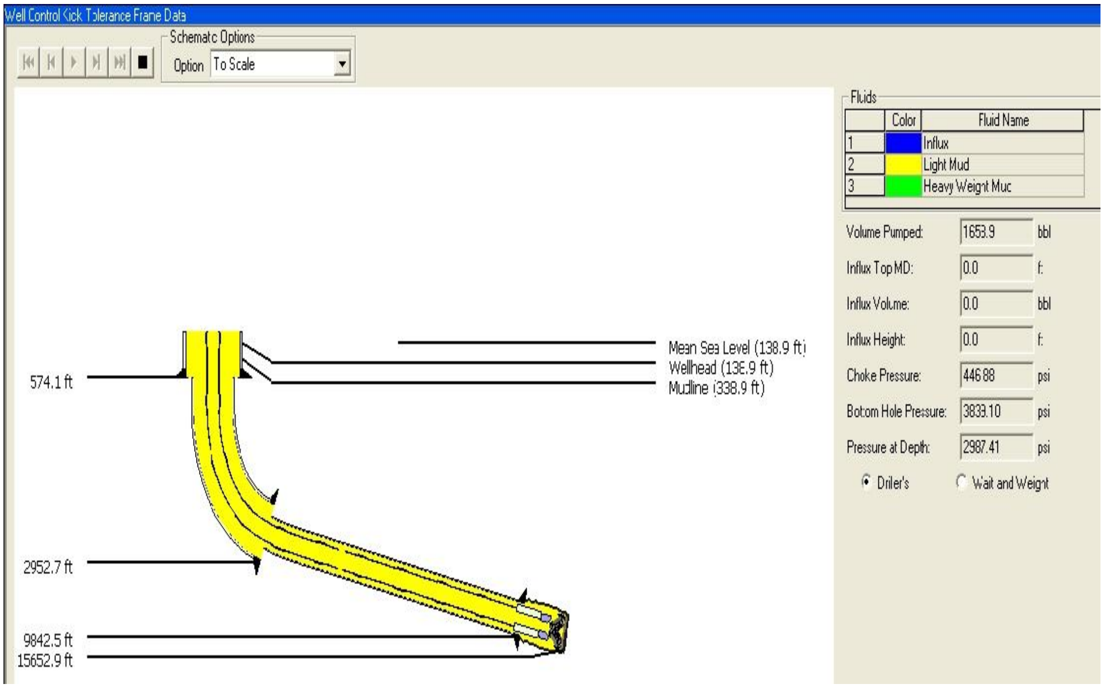


Figure 32: Animation of schematic after completely kill the well, kill rate 310 gpm (Section 2)

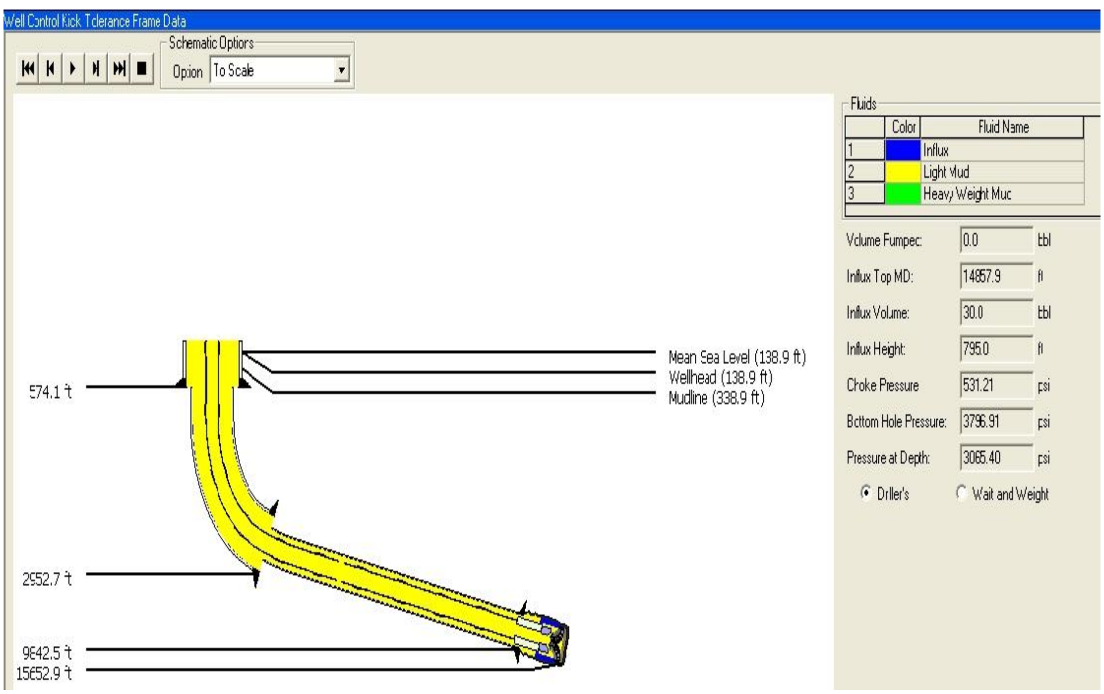


Figure 33: Animation of schematic before kill the well, kill rate 210 gpm (Section 2)

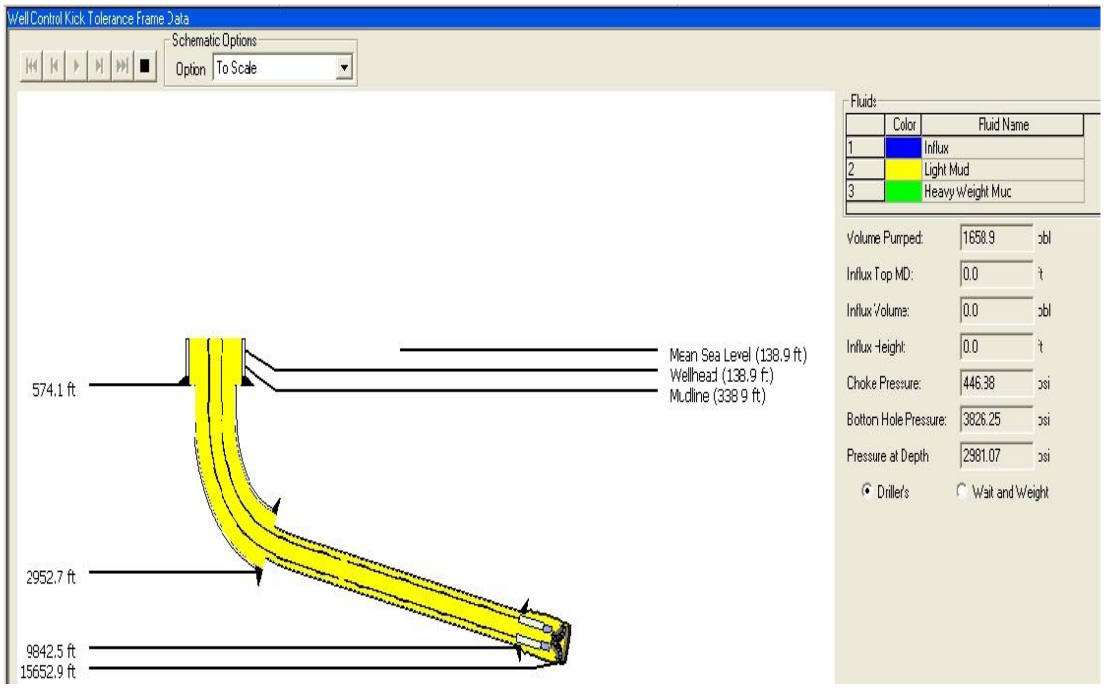


Figure 34: Animation of schematic after completely kill the well, kill rate 210 gpm (Section 2)

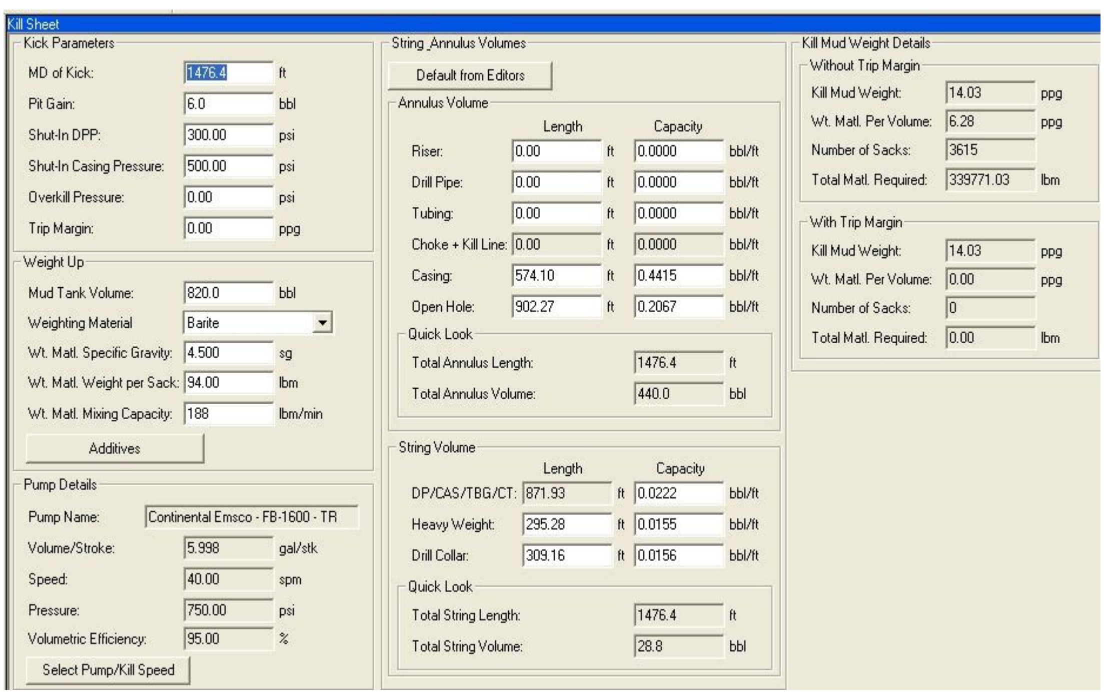
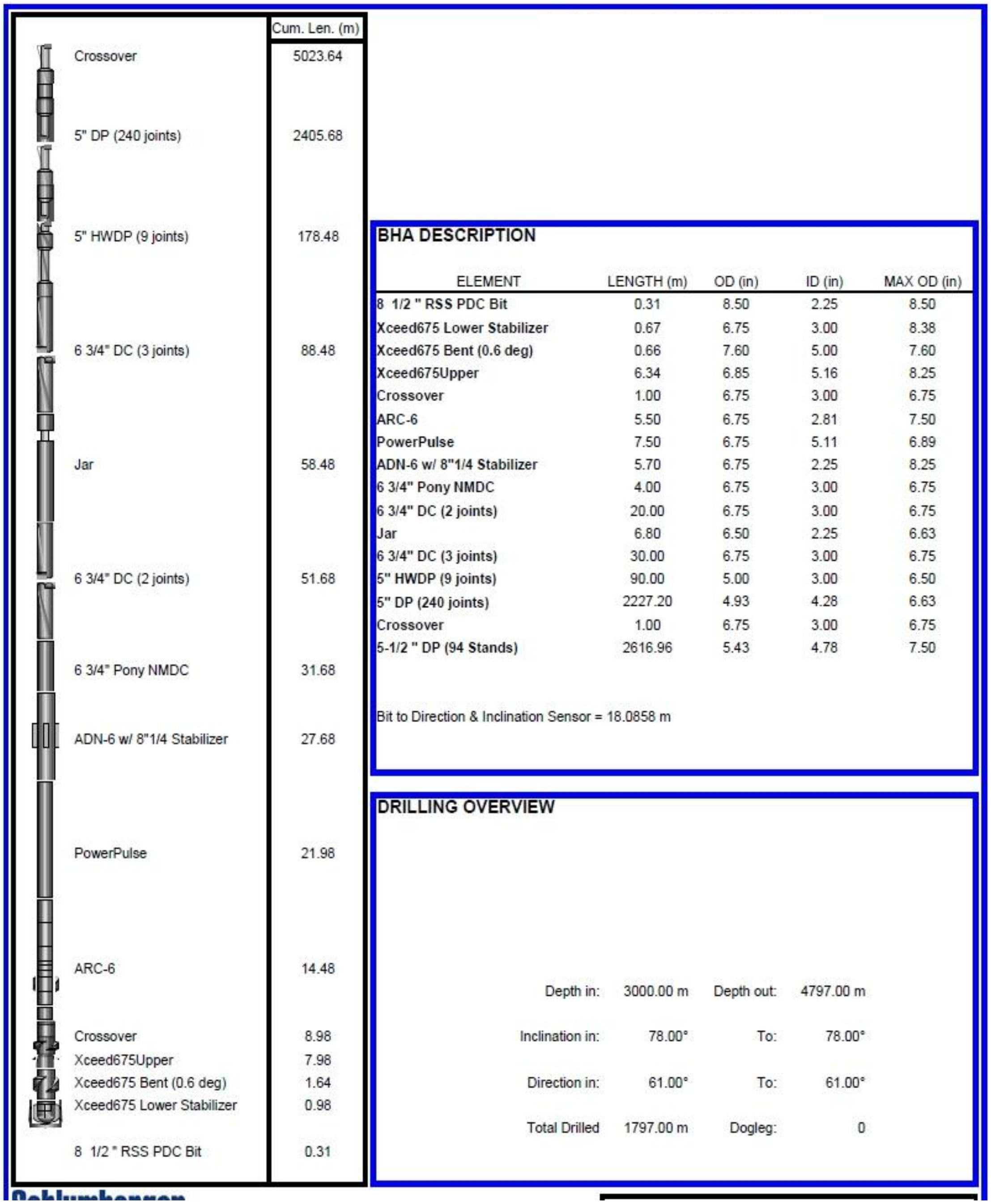


Figure 35: Kill sheet with SIDPP 300 psi (Section 1)



BHA DESCRIPTION

ELEMENT	LENGTH (m)	OD (in)	ID (in)	MAX OD (in)
8 1/2 " RSS PDC Bit	0.31	8.50	2.25	8.50
Xceed675 Lower Stabilizer	0.67	6.75	3.00	8.38
Xceed675 Bent (0.6 deg)	0.66	7.60	5.00	7.60
Xceed675Upper	6.34	6.85	5.16	8.25
Crossover	1.00	6.75	3.00	6.75
ARC-6	5.50	6.75	2.81	7.50
PowerPulse	7.50	6.75	5.11	6.89
ADN-6 w/ 8"1/4 Stabilizer	5.70	6.75	2.25	8.25
6 3/4" Pony NMDC	4.00	6.75	3.00	6.75
6 3/4" DC (2 joints)	20.00	6.75	3.00	6.75
Jar	6.80	6.50	2.25	6.63
6 3/4" DC (3 joints)	30.00	6.75	3.00	6.75
5" HWDP (9 joints)	90.00	5.00	3.00	6.50
5" DP (240 joints)	2227.20	4.93	4.28	6.63
Crossover	1.00	6.75	3.00	6.75
5-1/2 " DP (94 Stands)	2616.96	5.43	4.78	7.50

Bit to Direction & Inclination Sensor = 18.0858 m

DRILLING OVERVIEW

Depth in:	3000.00 m	Depth out:	4797.00 m
Inclination in:	78.00°	To:	78.00°
Direction in:	61.00°	To:	61.00°
Total Drilled	1797.00 m	Dogleg:	0

Figure 36: BHA design for MD 15652.9 ft

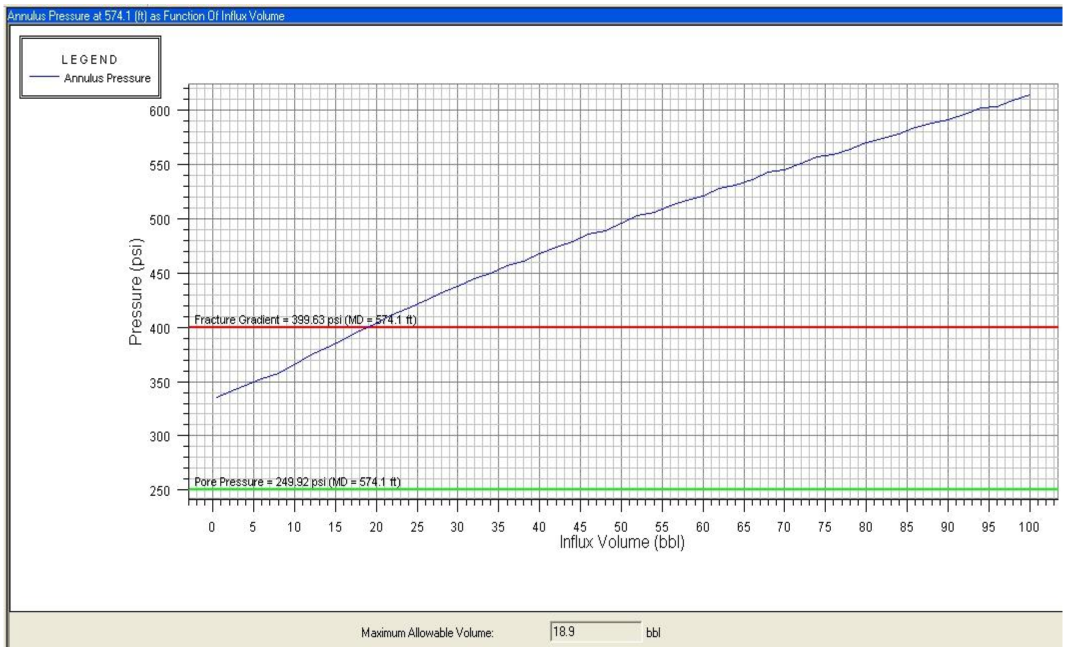


Figure 37: Maximum allowable volume (Section 1)

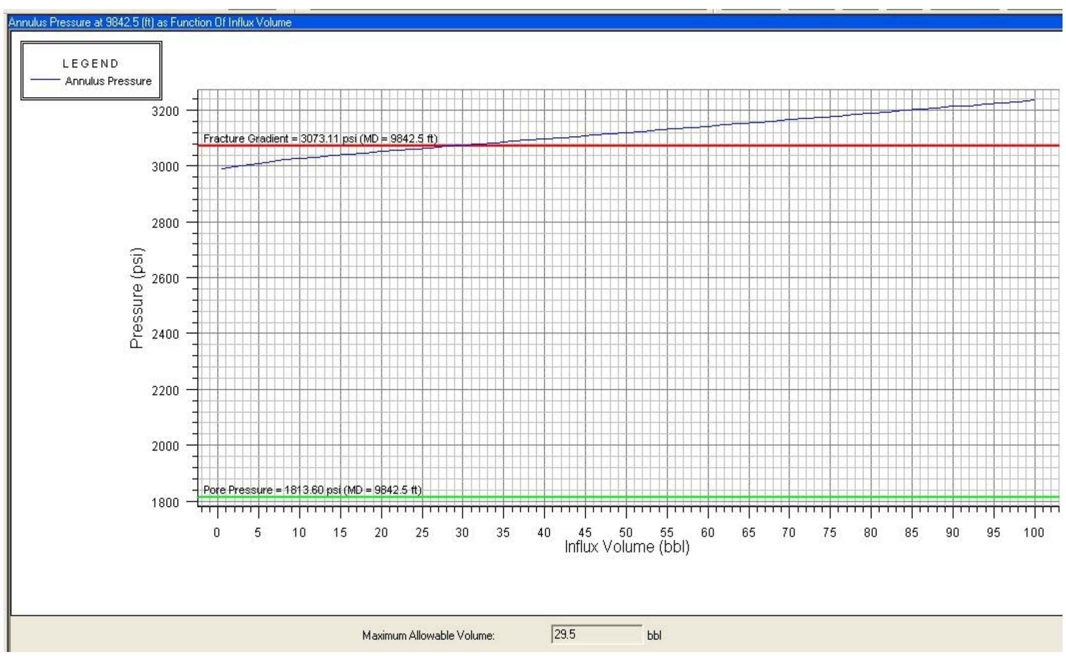


Figure 38: Maximum allowable volume (Section 2)