SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY

COLLEGE OF PETROLEUME ENGINEERING & TECHNOLOGY

Department of Petroleum Engineering

Side-track Trajectory Design Optimization in Congested Cluster

(Case Study a Pad Containing Seven Wells, Keyi-Field, Block6)

تصميم امثل مسار جانبي لبئر وسط عدد من الابار المتقاربه

(تطبيق حقلي لموقع يحتوي علي سبعة ابار, حقل Keyi, مربع-6)

Submitted in Partial Fulfillment of the Requirements of the Degree of B.Tech. in Petroleum Engineering

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October-2018

بسم الله الرحمن الرحيم

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

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Date / / 2018

الإستـهلال

قال تعالى:

﴿ اقْرَأْ بِاسْمِ رَبِّكَ الَّذِي خَلَقَ (1) خَلَقَ الْإِنْسَانَ مِنْ عَلَقٍ (2) اقْرَأْ وَرَبُّكَ الْأَكْرَمُ (3) الَّذِي
عَلَّمَ بِالْقَلَمِ (4) عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ (5)﴾

صدق الله العظيم
سورة العلق

DEDICATION

This study is wholeheartedly dedicated to our parents, who have been our source of inspiration and gave us strength when we thought of given up, who continually provide their moral, spiritual, emotional, and financial support.

To our brothers, sisters, relatives, mentor, friends, and classmates who shared their words of advice and encouragement to finish this study.

And lastly, we dedicated this research to the Almighty God, thank you for the guidance, strength, power of mind, protection and skills and for given us a healthy life.

AKNOWLEGMENT

We would like to express our sincere appreciation to our supervisor Eng.Fatima Ahmed Altigani her guidance, inspiration, and assistance, in addition for her wisdom and authoritative knowledge. That has upper hand in accomplishing the research in this current view.

Many thanks also to Dr.Yousif Bagadi, Eng. Mohanned Khairy, and Eng. Mohamed Abdelkhalig for giving us valuable advices and suggestion on this project.

Special thanks to Eng. Mohamed Idris who guide us through entire stages of this project, with the methodology of Designing, performing analysis by utilizing different techniques, design optimization, And provide us with required data.

We thank all people for their help directly and indirectly to complete this project.

Abstract

To introduce efficiency and cost savings in drilling operations, clients in Sudan have started to focus on Cluster Wells drilling, which is basically the same concept as platform drilling in offshore environment. Multiple wells will be drilled from the same pad structure, which will help clients save rig move time & cost, reduce surface infrastructure and will also help reduce the land acquisition costs. However, as this the first time wells will be drilled in such close proximity, this project thus becomes important for the long-term sustainability of cluster drilling campaigns in Sudan. the Design and Technical Challenges in our case study for pad containing seven wells are 15 meter Center to Center distance (High collision risk), Drilled vertical well in the same pad (Offset Well), Poor survey data for Vertical well, No Gyro Survey available in Sudan, and Difficulties in directional control due to low inclination issue (9 to 20) deg.

This project has studied Possibility of Sidetrack trajectory Design in such high dense wells area. COMPASS software has been used for Designing the Pad containing seven wells, side track trajectory from one of the wells (Subject Well) in the same Pad, perform collision risk analysis with regards to the adjacent wells on the same Pad (offset Wells) .

Three Side-Track Designing Scenarios has been performed, in first scenario well if kicked-off from 480m, with 2.5 deg/30 m toward 330 deg Azimuth, and turn gradually to 2.76 deg Azimuth. In second scenario well is kicked-off from 530 m, with 3deg/30m toward 100 deg azimuth and turn gradually to 338 deg Azimuth. And in the last scenario well is kicked-off from 950m, with 3deg/30m toward 270deg Azimuth while turning gradually toward 17deg Azimuth. Two scenarios were rejected because based on anti-collision risk analysis tools they were not satisfying design requirements (10-15m), and both scenario were showing high collision risk with offset wells. The third scenario has been selected as optimum Side-track design.

التجريد

للحصول علي افضل كفاءة وتوفير التكاليف في عمليات الحفر ، بدأت الشركات المستثمره في مجال النفط في السودان بالتركيز علي حفر عدد من الابار من منصة حفر واحده (Cluster Wells) ، وهي في الأساس نظرية مشابهة لمفهوم الحفر في المنصات البحرية (Offshore Platform). حيث يتم حفر عدد من الآبار من نفس المنصة اونفس الموقع ، مما يساعد على: توفير وقت وتكلفة ترحيل الحفارة (Rig Move)، تقليل المنشاءات لمراحل ما بعد الحفر (خطوط الانابيب, محطات المعالجه,.......الخ) ، كما يساعد في تقليل المساحة المطلوبة لعمليات الحفر والمعالجه وبالتالي تقليل التكلفه . نظراً لأن هذه الآبار سيتم حفرها لأول مرة بهذا القرب ، فإن هذا المشروع يصبح مهما لتطبيق هذه التقنيه في السودان على المدى الطويل. التحديات الفنية والتصميمية في هذه الدراسة هي : المسافات المتقاربة بين الابار 10- 15 متر من المركز الي المركز (خطر الاصطدام العالي) ، حفر بئر راسية في نفس المنصة (Offset Wells) مع ضعف بيانات المسح لهذه البئر ، لايوجد مسح بإستخام Gyro في السودان ، والصعوبات في المحافظه علي المسار بسبب انخفاض زاوية انحراف البئر (9 إلى 20) درجة.

هذا المشروع يدرس إمكانية تصميم مسار جانبي لبئر في منطقة ذات كثافة عالية بالابار، تم استخدام برنامج COMPASS لتصميم المنصة التي تحتوي على سبعة آبار، تصميم مسارجانبي من أحد الآبار (Subject Well) علي نفس المنصة، إجراء تحليل مخاطر الاصطدام فيما يتعلق بالآبار المجاورة على نفس المنصة (Offset Wells) باستخدام أربعة طرق للتحليل (anti-collision risk analysis tools) وهي: Standard anti-collision Report', Travelling Cylinder (TC) Plot ، Spider Plot (SP) وLadder Plot (LP) .

تم تنفيذ ثلاثة سيناريوهات تصميم للمسار الجانبي، في السيناريو الأول للبئر تكون بداية الانحراف من العمق 480متر بمعدل 2.5 درجة /30 متر، باتجاه 330 درجة (Azimuth) والدوران تدريجيًا إلى 2.76 درجة (Azimuth) ، في السيناريو الثاني للبئر تكون بداية الانحراف من العمق 530متر بمعدل 3 درجات /30 متر، باتجاه 100 درجة (Azimuth) والدوران تدريجيًا إلى 338 درجة (Azimuth) ، في السيناريو الاخير تكون بداية الانحراف من العمق 950 متر بمعدل 3 درجات /30 متر، باتجاه 270 درجة (Azimuth) ، والدوران تدريجيًا إلى 17 درجة (Azimuth) ، بناء على تحليل السيناريوهات السابقه باستخدام طرق التحليل (anti-collision risk (analysis tools تم اختيار السيناريو الاخير كافضل تصميم للمسار الجانبي (Optimum side-track design).

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Nomenclature

KOP	kick Off Pint
F	An expansion factor
MWD	Measurements While Drilling
BHA	Bottom Hole Assembly
TVD	Total Vertical Depth
UTM	Universal Transverse Mercator
MD	Measure Depth
DLS	dogleg Severity
RF	Ratio Factor
ISCWSA	Industry Steering Committee for Wellbore Survey Accuracy
EMS	Error Model Specifically
EOU	Ellipsoids Of Uncertainty
OSF	Oriented Separation Factors
ADP	Allowable Deviation From Plan
MAS	Minimum Allowable Separation
TC	Traveling Cylinder
FDP	Field Development Plan
GL	Ground Level
RKB	Rotary Kelly Bushing
TWT	Two-Way Traveltime
WGS	World Geodetic System
BUR	Build Up Rate
SP	Spider plot
LP	Ladder Plot

Chapter One
Introduction

1.1 Introduction

Oil and gas operators look to increase efficiency and improve profit margins, multiple-well pad (Cluster) drilling has become much more widespread. Pad sites make it possible to implement simultaneous operations and batch drilling solutions to minimize the cost and time associated with drilling and completing wells, and then moving them onto production. However, for all the benefits that pad drilling and simultaneous operations can generate for oil and gas companies, they also present unique challenges. While operators using multi-well pad drilling are seeing cost reductions on the order of 15-30 percent per well, they also are facing additional risks related to both property and people. Operators and contractors alike should be aware of these risks, as well as understand the best practices for managing exposures. While many risks involved with multi-well pad drilling are similar to those on single-well sites, the potential for catastrophic loss can be much greater.

1.1.1 Sidetrack Definition

Sidetracking is the drilling of a new lateral from an existing well that has poor or no productivity due to mechanical damage to the well or depleted hydrocarbons at that particular site. A sidetracking operation may be done intentionally or may occur accidentally. Intentional sidetracks might bypass an unusable section of the original wellbore or explore a geologic feature nearby. In the bypass case, the secondary wellbore is usually drilled substantially parallel to the original well, which may be inaccessible due to an irretrievable fish, junk in the hole, or a collapsed wellbore.

A secondary wellbore drilled away from the original hole. It is possible to have multiple sidetracks, each of which might be drilled for a different reason (e.g. multilateral).

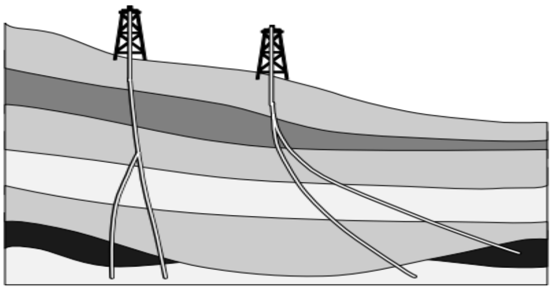


Figure (1.1): Side tracking (Mike Smith, 1996)

1.2 History Overview

Clients in Sudan have started to focus on Cluster Wells drilling in 2008, Petro-Energy E&P Co.Ltd (PEEP), Was the first who Kicked-off this project in Sudan, Block-6, Keyi-Field.

The idea basically the same concept as platform drilling in offshore environment. Multiple wells will be drilled from the same pad structure, which will help clients save rig move time & cost, reduce surface infrastructure and will also help reduce the land acquisition costs. Figure (1.2). However, as this the first time wells drilled in such close proximity, the Design and Technical Challenges in this project were 15 meter Center to Center distance (High collision risk), Drilled vertical well in the same pad (Offset Well), Poor survey data for Vertical well, No Gyro Survey available in Sudan, and Difficulties in directional control due to low inclination issue (9 to 20) deg.

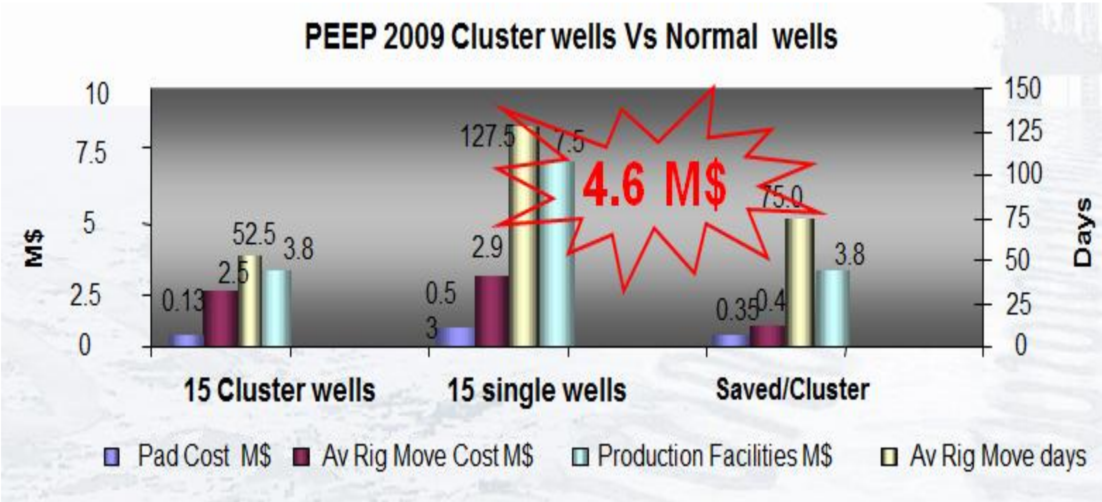


Figure (1.2): PEEP Cluster vs. Normal Well Cost Analysis (M.Idris).

The purpose of this project is to undertake the study of Sidetrack trajectory Design. The pad contained seven Wells including Keyi-24 which the subject side tracked well is selected as case study. Three side track scenarios with different kick off point (KOP), and different trajectories will be prepared. Risks analysis will be carried out for every proposed side track plan by utilizing the hazard analysis and risk control to list all expected risks and propose the proper mitigation actions. The plan that meets the Client center to center distance requirement (10-15m) will be selected as optimum plan.

1.3 Problem Statement

Design and collision risk with the nearby wells are the main challenge Since this the first time wells will be drilled in such close proximity, the challenges are Close proximity (10-15 meter Center to Center), Poor survey data for Vertical well Drilled by Client and Surveyed with Totco-Surveying tool which has high uncertainty, and No Gyro Survey (accurate surveying tool) available in Sudan.

1.4 Objectives

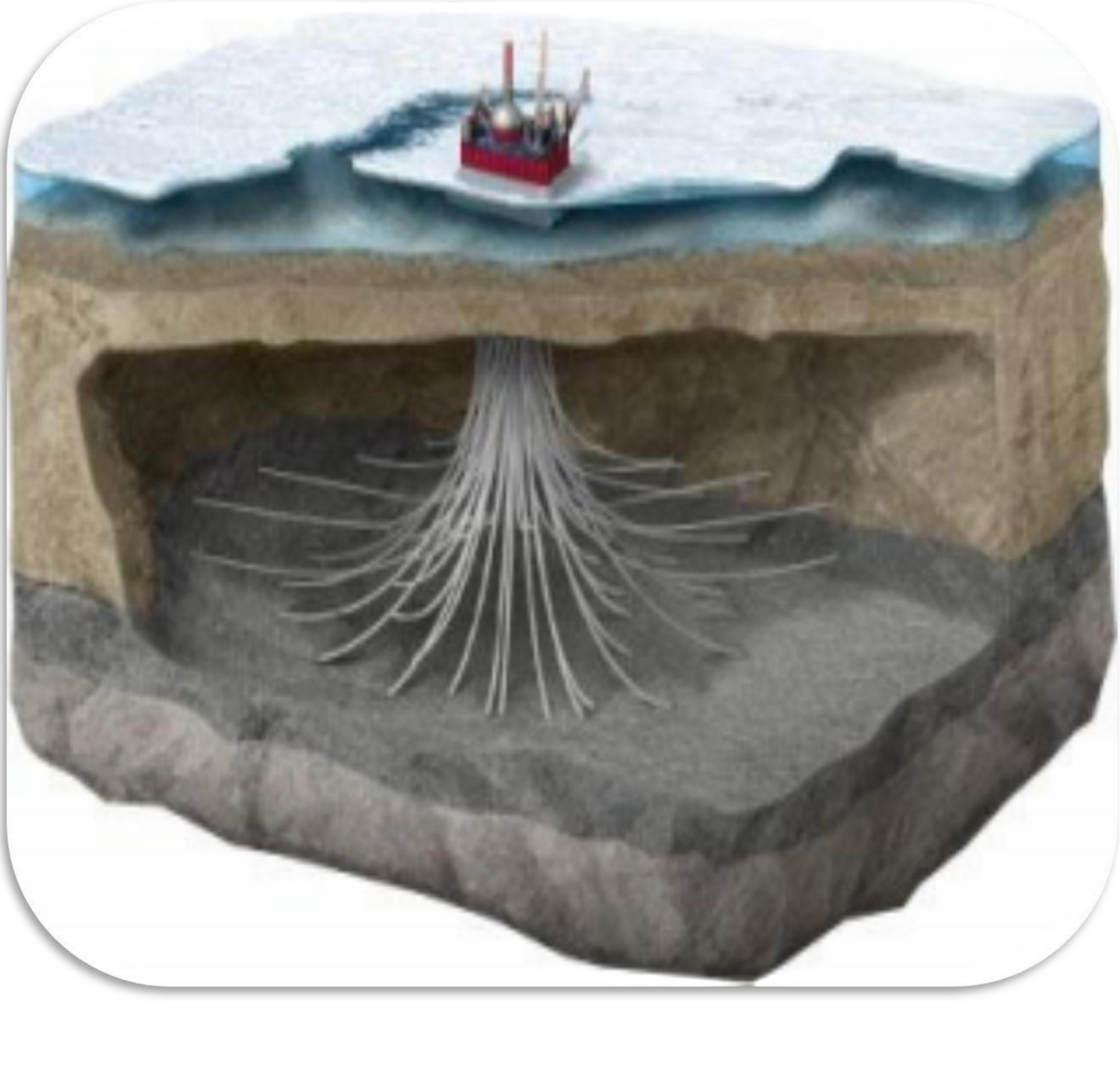
- ❖ Perform the trajectory design for the Pad which contains seven wells.
- ❖ Select Keyi-24 as subject well to perform the side track Design with different Scenarios.
- ❖ Perform design and collision risks analysis for each scenario using different monitoring tools.
- ❖ Select optimum side track design that meets center to center requirements (10-15m) based on above analysis.

1.5 Project Lay Out:

- ❖ **Chapter two:** This chapter presents the literature review and theoretical background.
- ❖ **Chapter three:** This chapter presents the methodology for designing side track in Congested cluster environment.
- ❖ **Chapter Four:** This chapter presents the results and discussion of designing side track with three different scenarios, collision Risk analysis for each scenario using different monitoring tools, and select optimum design that is meets center to center requirements (10-15m).
- ❖ **Chapter Five:** This chapter presents the conclusions and recommendations.

Chapter TWO

Literature Review & Theoretical Background



Chapter Two

This chapter will present brief description of Directional Well Trajectory planning Concepts, side track trajectory design, Survey Calculation methods and Anti-collision risk analysis tools, and techniques, and Keyi-24 background

2.1 Literature Review:

J. E. Walstrom, R. P. Harvey and H. D. Eddy (Oct 1972) discussed a comparison of various directional survey models based on averaging, they conclude that the basic calculations for any model are to determine the values for increments of coordinates for each station interval from the incomplete data available, the terminal angle tangential method should be abandoned because it is grossly susceptible to error.

Nitin Sharma et al (October 2009) They discussed orientation to avoid collision risks and optimization of directional drilling, Anti-collision management using traveling cylinder plot and spider plot, The authors have clearly demonstrated the use and the importance of anti-collision management with traveling cylinder plot, they have further emphasized the no-go line criteria on traveling cylinder plot, which gives users a proactive approach to make any changes in directional plans. This flexibility enabled from the traveling cylinder diagram permits optimum directional drilling without posing an unacceptable financial risk for the participants.

Zhichuan Guan et al (2010) they discussed the development tendency of anti-collision technology in the future and put forward the concept of active anti-collision. They also list programs which probably solve the anti-collision problem, Active anti-collision technology program will solve the problem: The concept of active anti-collision technology in this anti-collision technology implementations emit a signal from drilling wells or other drilled well then received signal in the same well or other and adopt anti-avoidance measures by analyzing the attenuation of signals and direction, Anti-collision techniques rely on acoustic detection by placing three or more acoustic sensors into the well detect bit vibrations energy, according to the energy variation of the bit to determine the actual distance well into the trend.

J .Bang, and T.Torkildsen (2011) Studied Wellbore Anti-Collision Safety Separation Distances Must Be Increased Due To Degraded Positioning Accuracy In Northern Areas, Uncertainty analysis incorporating a broad range of wellbore profiles and several magnetic and gyroscopic surveying instruments has been carried out . The results show that F!2/!1(An expansion factor) can range from 1.35 to above 2.0 , when moving from 60°N (North Sea region) to 75°N (Barents Sea region). If expansion factors of these magnitudes are ignored, the collision risk typically increases by a factor of 10 to 50, respectively. These numbers show that it is of vital importance to apply the correct latitude dependency in wellbore surveying error models, when planning drilling activities in arctic regions.

Margherita, D, Mirco, N, and Dino, P (2011) they developed a density based clustering method for moving objects trajectories, they considers generic sequences together with a conceptual gradation over the sequence elements used to compute both the cluster representatives and the distance between two sequences, they also adapted two classical distance-based clustering methods to trajectories, trajectories of objects are given by means of a finite set of observations, i.e. a finite subset of points taken from the real continuous trajectory, there may exist time segments where the clustering structure of our moving objects dataset is clearer than just considering the whole trajectories.

S.J. Sawaryn, A.L. Jamieson and A.E. McGregor (2013) represented a new computationally efficient method titled “separation by expansion” is presented for the exact determination of the osculating condition of two survey-error ellipses, this new method enables effective use of available space between the two wells while satisfying the geometrical and probabilistic constraints associated with the collision risk between them, methods are presented for the expansion of either ellipse one or both. The single-sided expansion offers further potential to optimize the use of the space around the wells.

Rizwan Muneer1 et al. (2015) They studied effect of kick-off point on build-up rate In directional drilling, and discussing Kick-off depth selection is made preferably in soft or soft to medium formation to have a successful kick-off, proper utilization of offset well data, deployment of latest drilling tools related to drilling directional wells, and a successful directional well plan in all the aspects increases the probability to have an economical and a usable well which is according to the requirement of production and reservoir engineer ,In directional drilling KOP is proportional to BUR and it should be selected in soft formation at shallow.

Yingbiao Liu et al. (2017) constructed Optimum Drilling Design of Cluster Well in Jimsar Well Block, they studied Optimum design of factory-like well site platform According to the wellhead position, well hole axis trend, drilling target and distribution of well control area, the platform with 43 wells is divided into three different control areas to avoid the occurrence of cross orbit in the different control areas, and to reduce the overall risk of anti-collision, they designed The platform as double rows platform with 5m wellhead spacing and 60m rows spacing, The minimum distance of the well trajectory is designed greater than 5m and the separation coefficients is designed greater than 1.5. The design can ensure the safe drilling along the downhole trajectory.

2.2 Theoretical Background

2.2.1 Well Planning

Introduction

Well planning defines the trajectory, or curve, of the proposed well path. The path is planned from the surface location to the target.

During drilling, the directional driller uses the well plan to accurately drill the wellbore and reach the target.

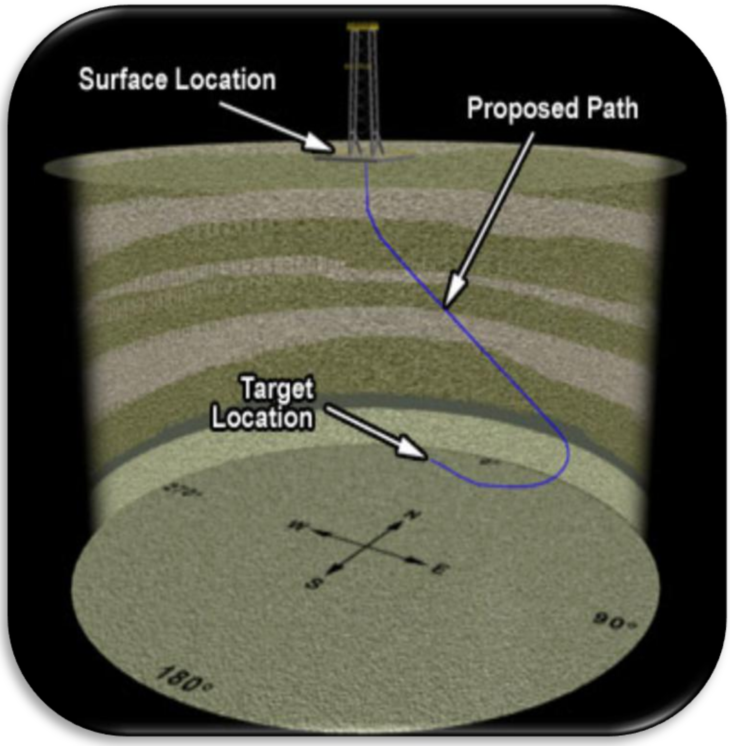


Figure (2.1): Well Plan

As the wellbore is drilled, down hole surveys are taken to make sure the trajectory defined by the well profile is being followed. The proposed path must be followed to make sure the actual path of the wellbore intersects the target at the correct angle and in the correct direction (Harry, H., & Varnado, S.G. October 1983).

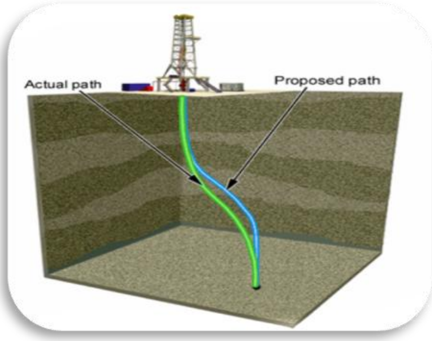


Figure (2.2): Wellbore

2.2.1.1 Down hole Survey Measurements

To track the progress of the wellbore, the MWD tool takes down hole surveys at regular intervals (feet or meters) as determined by the client. Each survey produces two measurements, inclination and direction, at a given depth. These measurements are input to calculations that provide the coordinates (true vertical depth, vertical section, etc.) of the BHA in the wellbore.

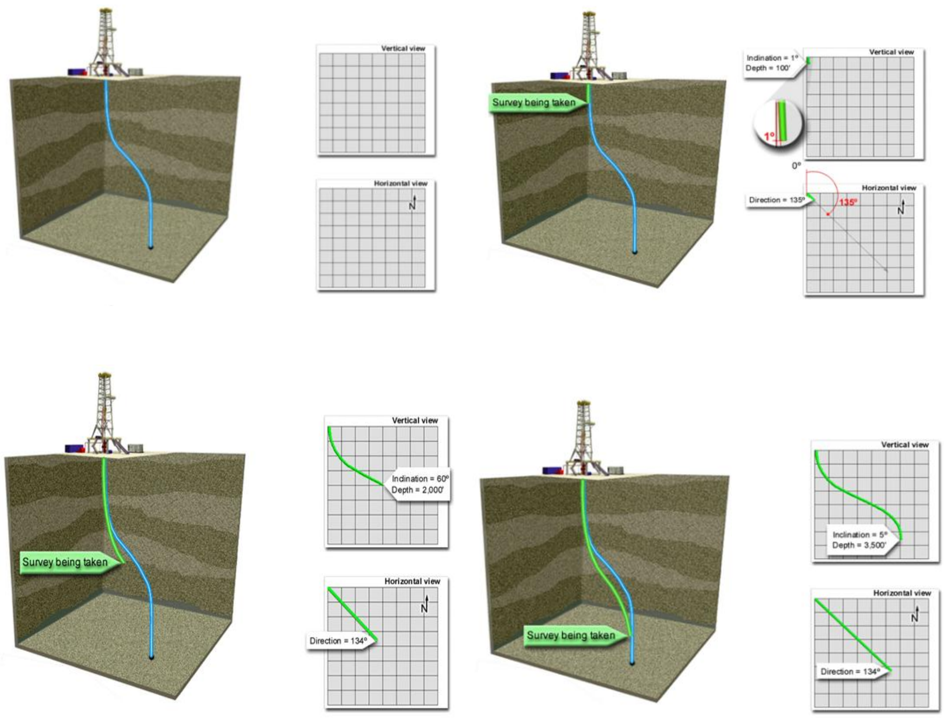


Figure (2.3): Down Hole Surveys

We must make sure that each down hole survey is accurate. If the surveys are not correct, it could be an indication of an error in the MWD survey tool, or that the survey procedure was not correctly followed. In either case, bad survey data can cause the directional driller to eventually miss the objective (as indicated by the red wellbore), which could be very costly to the client (Anurag, K., Prof. Avinash, K. July-2016.).

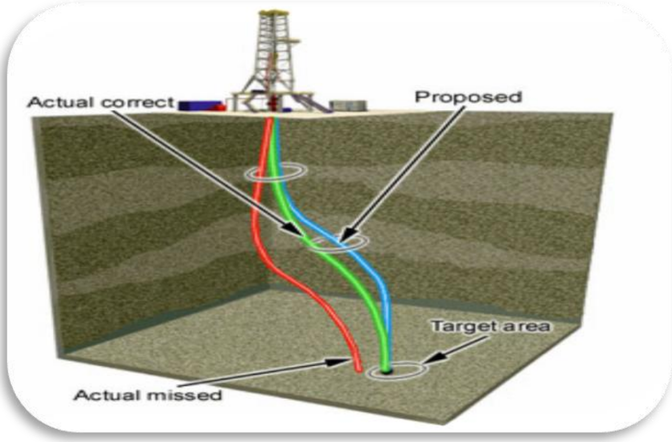


Figure (2.4): Bad surveys

2.2.1.2 Well Planning Terminology

To analyze the accuracy of down hole survey data, we must understand the well planning process and well plan terminology.

Well planning is done by Directional company well planner and not by the field engineer. The client provides the well planner with a surface coordinate and one or more bottom hole coordinates. From these coordinates, the well planner generates a well plan that lays out the most efficient and the smoothest path to drill through. The proposed path must pass through the bottom hole coordinates.

- **Surface Location:** The start of the wellbore. The coordinates of the surface location represent the geographical position where the well is started.

- **Kickoff Point:** A point in the wellbore at a given vertical depth below the surface location where the well is to be deviated away from vertical. It is deviated in a given direction up to a given inclination and at a given build rate. The selection of the kickoff point is made by considering the geometrical well path and the geological characteristics of the formation. Buildup rate is the increase in wellbore inclination over an interval of 100 feet
- **Well Profile:** The planned trajectory of the wellbore from surface location to target. The profile is designed to minimize dogleg severity and BHA torque and drag. Dogleg severity is a measure of the amount of change of inclination and/or direction of a wellbore. It is usually expressed in degrees per 100 feet or degrees per 30 meters. The smaller the dogleg severity, the less BHA torque and drag that can develop during drilling. BHA torque and drag need to be minimized to prevent damage to the drill string and to prevent the drill string from getting stuck.
- **Target Area:** A defined area at a prescribed vertical depth and location, which will be intersected by the wellbore. Target size is the size or acceptable limits of the target area. To make sure the objectives of the well are met when making well planning and drilling decisions, a properly defined target is essential. The cost of drilling a well is largely dependent on the accuracy required. Therefore, identifying the limits of the target before the well is begun is very important.
- **Horizontal Displacement:** Horizontal displacement is the distance between the surface location and the current survey when the wellbore is projected onto the horizontal view.
- **Vertical Section:** The vertical section is the length of the projection of the horizontal displacement onto the vertical plane of

projection. A vertical plane of projection is defined by its direction (azimuth) and scaled with vertical depth. If the current survey falls on the vertical plane of projection, then horizontal displacement and vertical section are equal.

- **Leaselines and Boundaries:** In many cases, the wellbore's location is described with respect to property lines or boundaries. Frequently, drilling rights are leased to oil companies. In these cases, the property boundaries are referred to as base lines. Any point within a property can be defined in terms of the distance from any two adjoining boundaries. (Inglis, T. A. 1987).

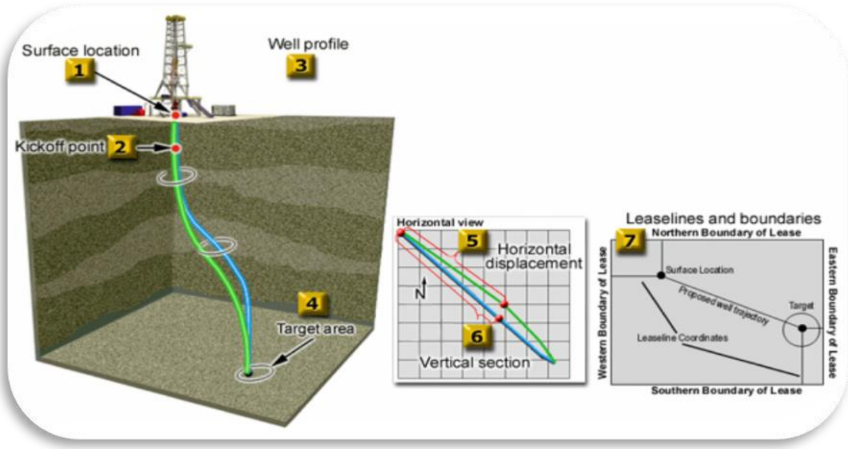


Figure (2.5): Well Planning Terminology

2.2.1.3 Map Coordinate Systems

To plan a well, the surface and target locations must be defined as coordinates on a map. A map is a flat depiction of points on the globe. A grid system is placed on top of the map projection. The grid system allows any location on earth to be expressed as Cartesian coordinates. The coordinates are the distances from the two intersecting lines on the grid that define the grid origin. In the figure (2.6), the coordinates of point A are latitude 6 degrees 40 minutes and 30 seconds North (6° 40' 30” N) and longitude 17 degrees 58 minutes and 45 seconds East (17° 58' 45” E). (Prof. Keith, C. 2008).

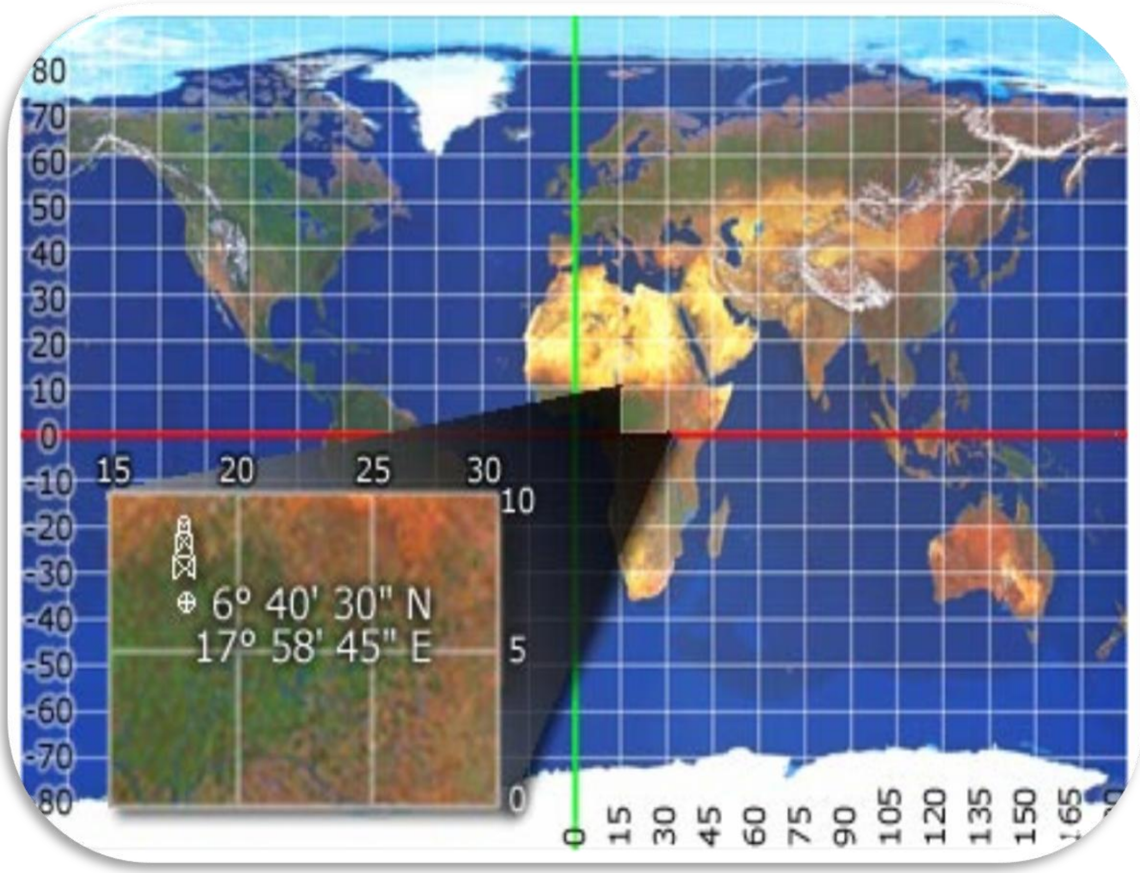


Figure (2.6): Cartesian Coordinates

2.2.1.4 Types of Grid Systems

There are many types of coordinate systems. Each one produces a unique set of coordinates for any location on a map.

- Geographic coordinates.
- UTM coordinates.
- Lambert coordinates.
- Legal coordinates.
- Local coordinates.

In this project will be using the (UTM) as per design requirement.

2.2.1.4.1 Universal Transverse Mercator (UTM) Coordinates

The UTM Projection Universal Transverse Mercator (UTM) coordinates are commonly used in oilfields throughout the world. They are derived from a cylindrical map projection, with the cylinder rotated, or transversed, 90°. This means that the cylinder is tangent to the globe along a specific central meridian. As a result, the axis of the cylinder runs parallel to the Equator.

Areas close to the central meridian are true to scale. For this reason, UTM systems are used for areas that have a relatively long north-south extent and short east-west extent.

Figure (2.7): Transverse Cylindrical Projection

UTM Zones: The UTM projection is divided into 60 zones equal north-south zones. Each zone has its own central meridian, which is its north-south reference line. There is a cylindrical projection for each zone with the cylinder being tangent to the central meridian of the specific zone. Therefore, each zone is 6° wide, and the globe is made up of 60 projections (6° x 60 = 360°). The zones cover the total north-south distance between 84° North and 80° South. The UTM projection is too distorted to be used for the Polar Regions. The zones are numbered from 1 to 60. Zone 1 is at the 180° meridian. The zones are numbered consecutively from west to east (Rabia H)

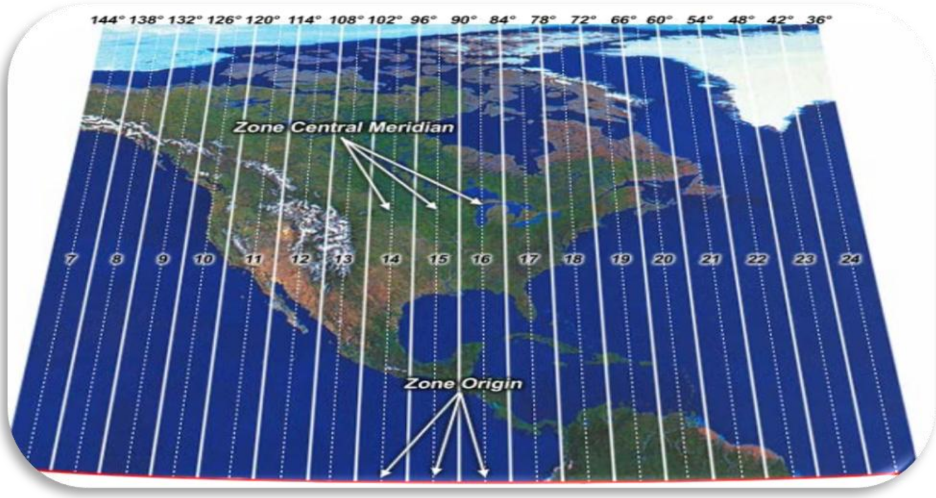


Figure (2.8): UTM Zones and Central Meridians

2.2.1.5 Directional Well Profiles

To plan a directional well, the well's geometric profile must be defined in the vertical section view and the plan view. The well profile identifies the depths and angles at which drilling will proceed. most common directional well profiles: slant, s-type, and horizontal (Anurag, K., Prof. Avinash, K. 2016).

2.2.1.5.1 Profile of a Slant Well

The simplest directional well is a slant well, also called a J-type well. A slant well consists of three basic sections: a vertical section, a build section, and a tangent section. Slant wells are often called build-and-hold wells because they consist of a build section followed by a tangent section where inclination is held constant until the target is reached.

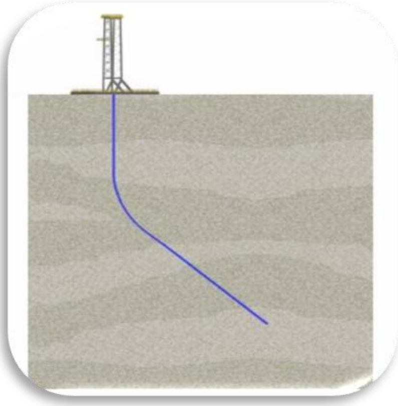


Figure (2.9): Slant Well

2.2.1.5.2 Profile of an S-type Well

The S-type well has the same sections as a slant well with the addition of a drop section. In an S-type well, inclination decreases between the tangent section and the target.

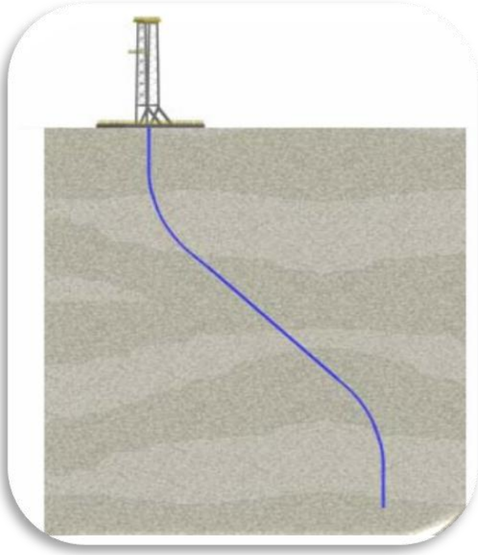


Figure (2.10): S-Type Well

2.2.1.5.3 Profile of a Standard Horizontal Well

The most common type of horizontal well has a vertical section, a tangent section, and two build sections, one before and one after the tangent section. In the second build section, the angle builds towards horizontal. The horizontal section, also known as the drainhole, is at or close to 90° inclination.

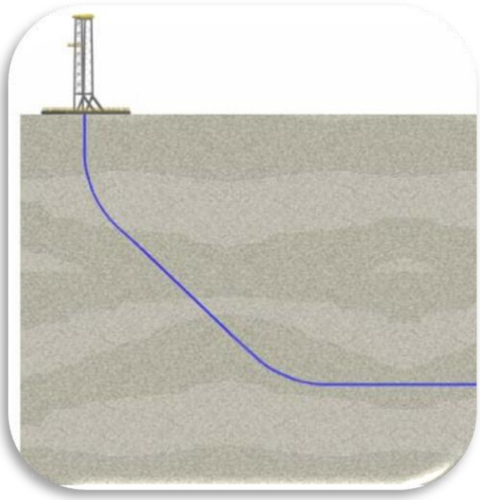


Figure (2.11): Horizontal Well

2.2.1.6 Well Plan Inputs

The well planner needs three pieces of information to plan a well:

- ✓ **The surface location** (UTM, Lambert, or geographical) where drilling will begin.
- ✓ **The target location** (UTM, Lambert, or geographical) where drilling will end.
- ✓ **and the true vertical depth of the target.** True vertical depth is the depth measured vertically from the surface to a point on the well path.

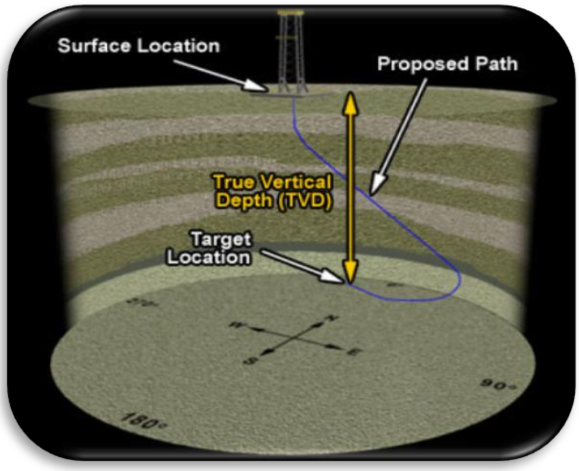


Figure (2.12): Plan Inputs

The planning process produces two views of the proposed wellbore. Plan view, and vertical section view.

Plan View: the well path is projected onto the horizontal plane. The Plan View is a bird's eye view, as if you are above the well looking straight down at it. The Plan View is sometimes referred to as the Horizontal Projection.

The graphic below shows a 3D well projected onto the Plan View.

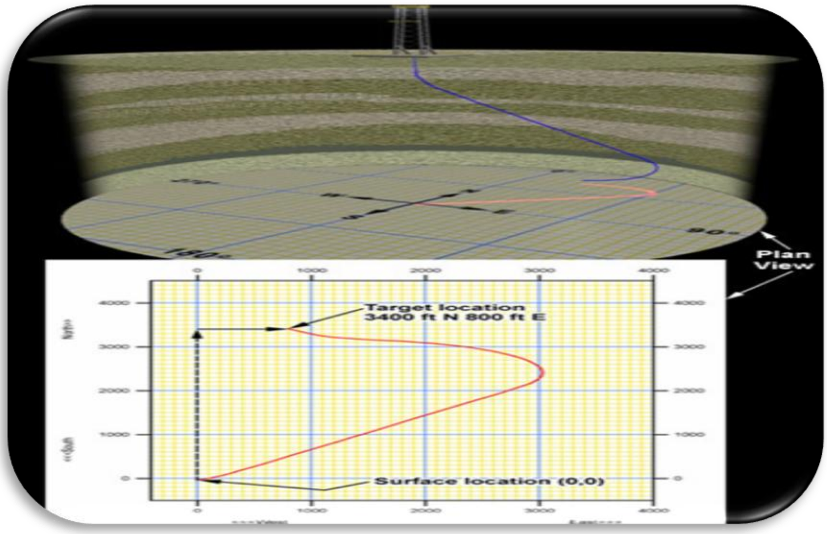


Figure (2.13): Plan View

Plan View Coordinates: In the Plan View, every point on the well path is defined by its north-south and east-west distance from the surface location. North-south coordinates lie on the y-axis, and east-west coordinates lie on the x-axis. The surface location is given the coordinates 0,0. According to the Plan View in the figure (2.14), the target is 3,400 feet north and 800 feet east of the surface location. The coordinates of the target location would be written as 3400 ft N 800 ft E. The north-south coordinate is always written first.

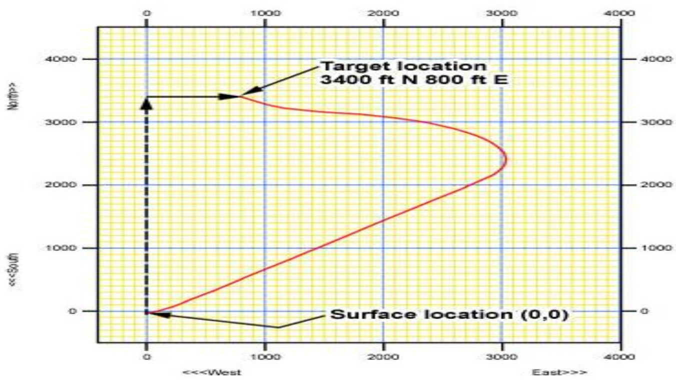


Figure (2.14): Plan View Coordinates

Vertical Section View: The well planner also creates a vertical view of the well path. The view is called the Vertical Section View. When you look at the Vertical Section View, it is as if you are looking at the well from the side. The figure (2.15) shows a 3D well projected onto the Vertical Section View. (Inglis, T. A. 1987).

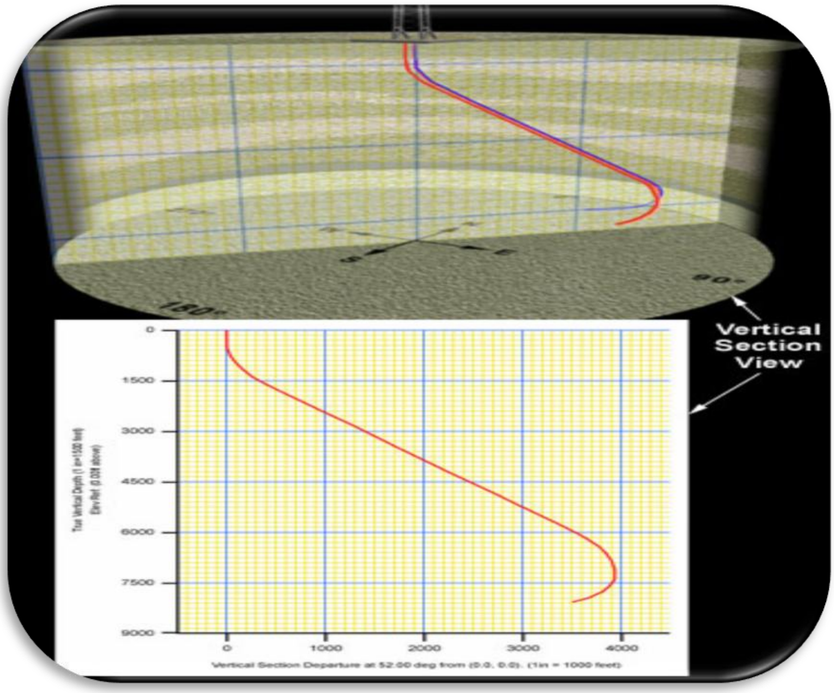


Figure (2.15): Vertical Section View

2.2.1.7 Expected Measurements

The well plan map provides the expected measurements at hypothetical points along the wellbore. When a downhole survey is taken, We need to compares the expected measurements to the actual downhole measurements. The directional driller plots the actual points on the well plan map. (LIU, Y., GUAN, Z., & LIANG, H., et al. 2010).

2.2.1.7.1 Expected Measured Depth: The expected measured depth is the length of the wellbore from the surface location to the survey point.

2.2.1.7.2 Expected Inclination: The expected inclination is the angle between the wellbore and the vertical at the survey point.

2.2.1.7.3 Expected Direction (Azimuth): The expected direction is the angle between the horizontal projection of the wellbore and true North at the survey point (LIU, Y., GUAN, Z., & LIANG, H., et al. 2010).

2.2.1.8 Monitoring Bottom hole Position

During drilling, we need to monitor bottom hole position to make sure the wellbore is on course and the target will be reached.

Monitoring involves taking survey measurements and calculating bottom hole coordinates at regular intervals. These intervals are commonly referred to as survey stations as shown in the graphic below. The following survey data is gathered at each station. (Williamson, H. Dec. 2000).

2.2.1.8.1 Survey Data

- Borehole inclination as measured by the survey tool
- Borehole azimuth direction as measured by the survey tool
- Measured depth as tracked by Depth Control

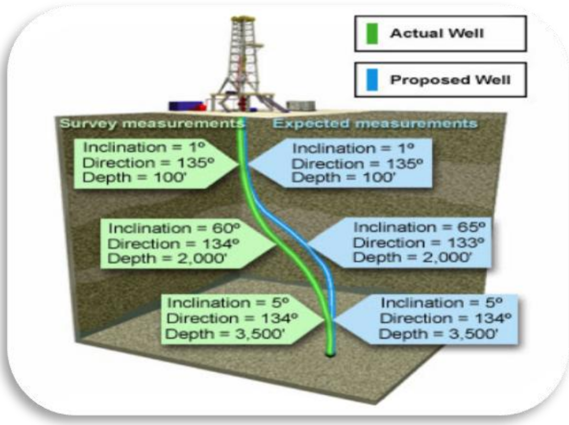


Figure (2.16): Survey and Expected Measurements

2.2.1.8.2 Bottom hole Coordinates

The directional driller calculates bottom hole coordinates from the survey measurements taken at each survey station. The bottom hole N/S and E/W coordinates can be plotted in the Plan View, and the TVD and vertical section coordinates can be plotted in the Vertical Section View. We can track the progress of the actual well by comparing actual bottom hole coordinates to the proposed coordinates of the well path as shown in the graphic below.

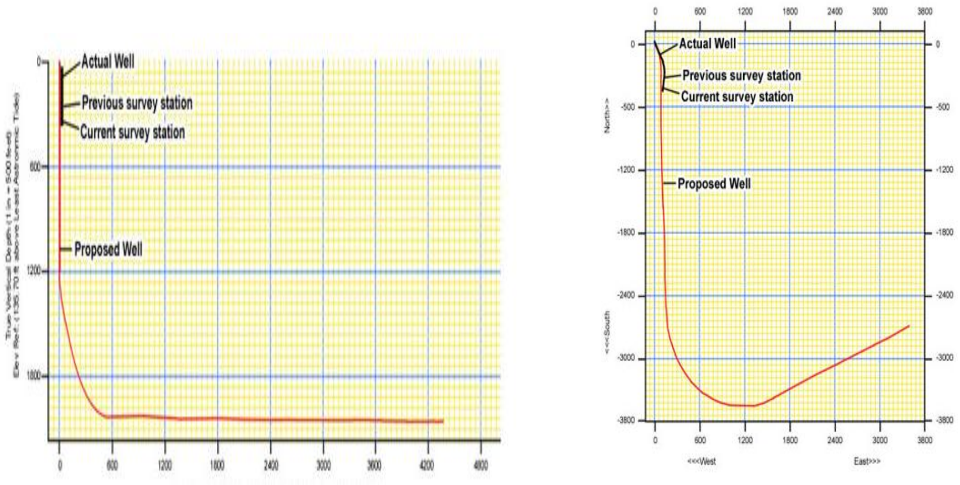


Figure (2.17): Bottom hole Coordinates

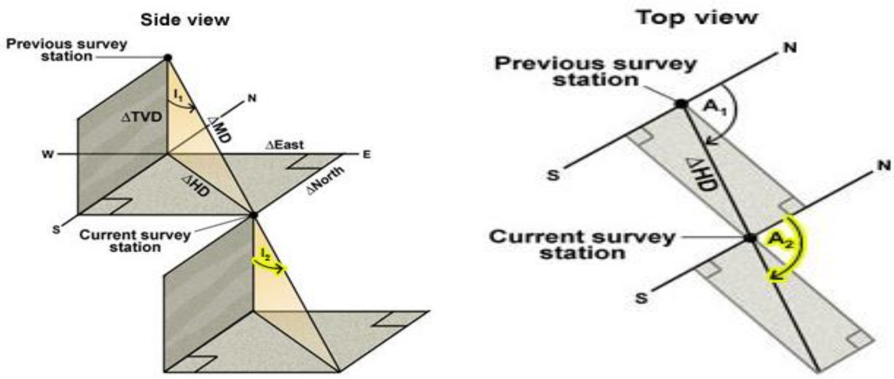
2.2.2 Survey Calculation Methods

There are five calculation methods:

- Tangential
- Balanced tangential
- Average angle
- Radius of curvature
- Minimum curvature

2.2.2.1 Tangential Method

This is the oldest and least accurate method because it assumes that inclination and azimuth are held constant from the previous to the current survey station. It only uses the inclination and direction at the current survey station. This method does NOT provide realistic results for surveys taken in curved sections of the wellbore. However, it can be used for quick calculations using a handheld calculator when inclination and azimuth do not change much, or over short distances (Dr.Mark, H,. Horizontal Drilling Workshop).



Tangential Method Side View **Tangential Method Top View**

Figure (2.18): Tangential Method

Tangential Calculations:

The tangential method uses the following calculations:

$$\Delta North = \Delta MD \sin \mathrm{I}_2 \cos \mathrm{A}_2 \qquad (2.1)$$

$$\Delta East = \Delta MD \sin \mathrm{I}_2 \sin \mathrm{A}_2 \qquad (2.2)$$

$$\Delta TVD = \Delta MD \cos \mathrm{I}_2 \qquad (2.3)$$

$$\Delta HD = \Delta MD \sin \mathrm{I}_2 \qquad (2.4)$$

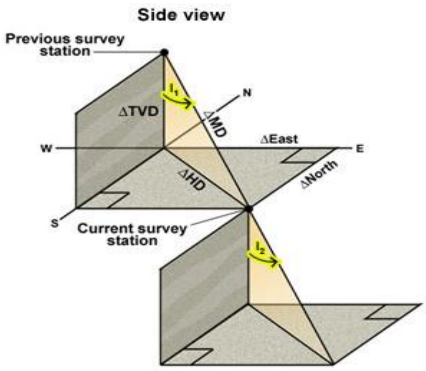
ΔNorth and ΔEast calculations can be simplified as follows:

$$\Delta North = \Delta HD \cdot \cos A_2 \quad (2.5)$$

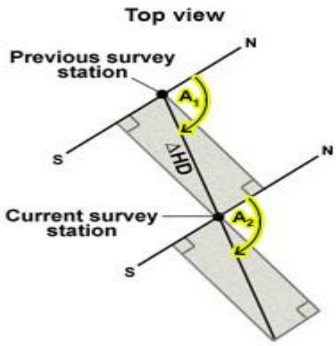
$$\Delta East = \Delta HD \cdot \sin A_2 \quad (2.6)$$

2.2.2.2 Balanced Tangential Method

Balanced tangential is another form of the tangential method. It produces a closer approximation of the bottomhole position because it uses both previous and current survey data. It also calculates dogleg severity (DLS). The length of the wellbore between the two survey stations (Δ MD) is divided into two equal line segments (Dr.Mark, H,. Horizontal Drilling Workshop).



Balanced Tangential Method Side View



Balanced Tangential Method Top View

Figure (2.19): Balanced Tangential Method

Balanced Tangential Calculations:

The balanced tangential method uses the following calculations:

$$\Delta North = \frac{\Delta MD}{2}(\sin I_1 \cos A_1 + \sin I_2 \cos A_2) \quad (2.7)$$

$$\Delta East = \frac{\Delta MD}{2}(\sin I_1 \sin A_1 + \sin I_2 \sin A_2) \quad (2.8)$$

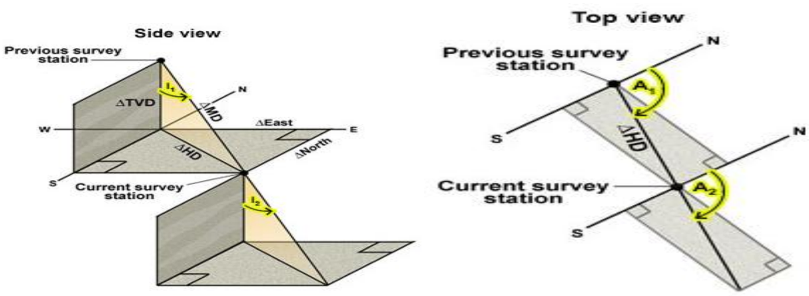
$$\Delta TVD = \frac{\Delta MD}{2}(\cos I_1 + \cos I_2) \qquad (2.9)$$

$$\Delta HD = \frac{\Delta MD}{2}(\sin I_1 + \sin I_2) \qquad (2.10)$$

$$DLS = \left[\frac{d}{\Delta MD}\right] \cos^{-1} [(\sin I_1 \sin I_2)(\sin A_1 \sin A_2 + \cos A_1 \cos A_2) + (\cos I_1 \cos I_2)] \qquad (2.11)$$

2.2.2.3 Average Angle Method

The average angle method averages the angles of inclination and direction at the current and previous survey stations. Averaging the angles is NOT the most accurate method. However, it can be used with a handheld calculator to make quick calculations over short distances (Dr.Mark, H,. Horizontal Drilling Workshop).



Angle Method Side View **Angle Method Top View**

Figure (2.20): Average Angle Method

Average Angle Calculations:

The average angle method uses the following calculations:

$$\Delta North = \Delta MD \sin\frac{I_1+I_2}{2} \cos\frac{A_1+A2}{2} \qquad (2.12)$$

$$\Delta East = \Delta MD \sin\frac{I_1+I_2}{2} \sin\frac{A_1+A_2}{2} \qquad (2.13)$$

$$\Delta TVD = \Delta MD \cos\frac{I_1+I_2}{2} \qquad (2.14)$$

$$\Delta HD = \Delta MD \sin\frac{I_1+I_2}{2} \qquad (2.15)$$

$$\Delta \text{Vertical Section} = \Delta HD \times \cos\left[\frac{A_1+A_2}{2} - \text{Target Direction}\right] \qquad (2.16)$$

2.2.2.4 Radius of Curvature Method

The radius of curvature method calculates bottom hole position more accurately than the average angle method because it fits the previous and current survey stations onto the surface of a cylinder. In effect, the wellbore is projected onto a vertical and horizontal plane. These projections produce coordinates that more closely approximate locations in the Plan View and Vertical Section View.

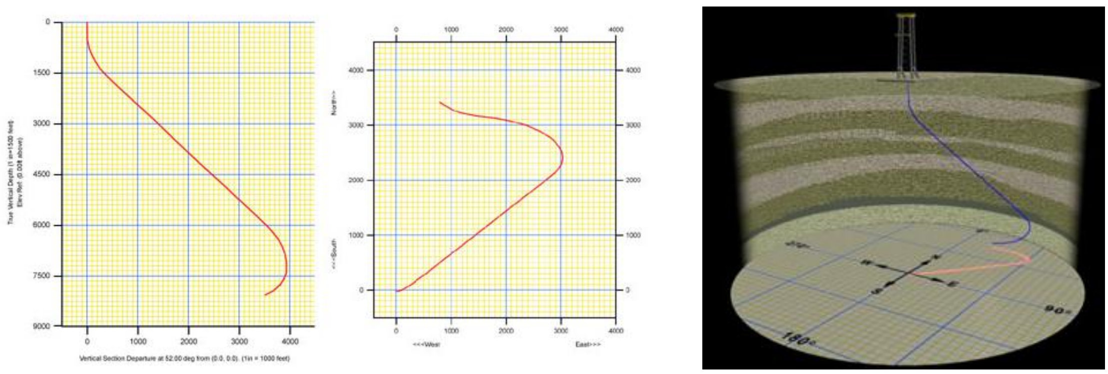


Figure (2.21): Radius of Curvature Method

Vertical Projection: To create the vertical projection, a vertical slice through the previous and current survey stations is unwrapped. This produces an arc of length ΔMD. The radius of this arc is used to calculate ΔTVD and ΔHD (Dr.Mark, H,. Horizontal Drilling Workshop).

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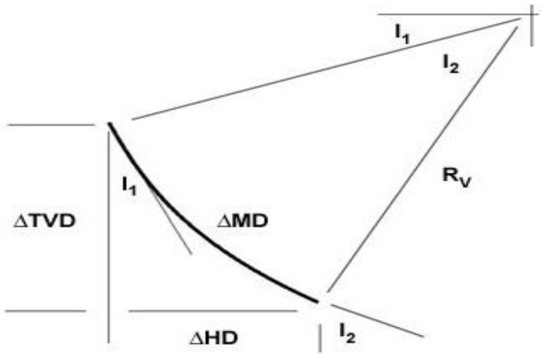


Figure (2.22): Vertical Projection

The radius of arc ΔMD is calculated as follows:

$$R_V = \frac{[180 \times \Delta MD]}{\pi(I_1 - I_2)} \quad (2.17)$$

Using RV, ΔTVD and ΔHD can be determined.

$$\Delta TVD = R_V (\sin I_2 - \sin I_1) \quad (2.18)$$

$$\Delta HD = R_V (\cos I_1 - \cos I_2) \quad (2.19)$$

Horizontal Projection: To create the horizontal projection, a horizontal slice through the previous and current survey stations is unwrapped. This produces an arc of length ΔHD. (The length of ΔHD was calculated previously in the vertical projection.) The radius of this arc is used to calculate ΔNorth and ΔEast.

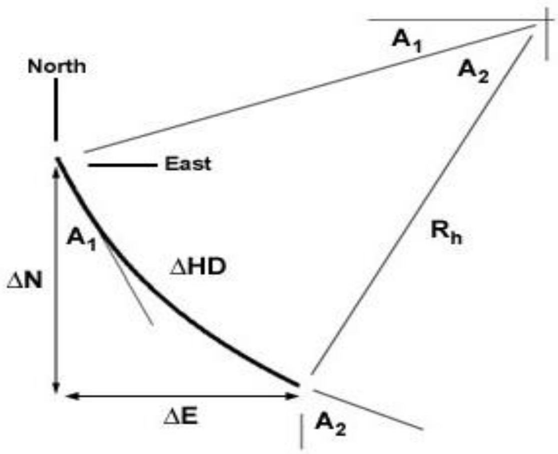


Figure (2.23): Horizontal Projection

The radius of arc ΔHD is calculated as follows:

$$R_h=\frac{[180\text{-}\Delta MD]}{\pi(A_2\text{-}A_1)} \tag{2.20}$$

Then, ΔNorth and ΔEast can be determined.

$$\Delta North=R_h(\sin A_2-\sin A_1) \tag{2.21}$$

$$\Delta East = R_h (\cos A_1 - \cos A_2) \tag{2.22}$$

2.2.2.5 Minimum Curvature Method

The minimum curvature method is also called the circular arc method. It is the accuracy in determining bottom hole position. Minimum curvature fits a spherical arc onto two survey points. The inclination and azimuth at each survey point are defined as space vectors. These vectors are smoothed onto the wellbore using a ratio factor. The ratio factor is defined by the curvature of the section of the wellbore where the path curves through changes in inclination and/or azimuth. This curvature is called a dogleg. In the graphic below, angle DL represents the dogleg.

Industry standard and the preferred method for horizontal wells because of its

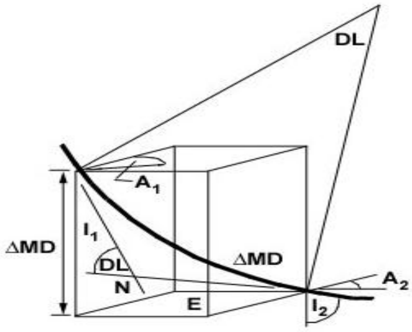


Figure (2.24): Minimum Curvature Method

Dogleg and Ratio Factor

The straight-line segments that define angles I_1, I_2, A_1, and A_2 are smoothed onto the curve using the ratio factor, RF, which includes the value for DL (Dr.Mark, H,. Horizontal Drilling Workshop).

Dogleg is calculated using the following formula:

DL = cos-1 [cos(I_2 - I_1) - sin I_1 sin I_2 (1 - cos (A_2 - A_1))] (2.23)

There are two forms of the RF calculation, as shown below. For small angles, where DL < 0.0001, it is customary to set RF = 1. DL is in degrees.

$$RF=\frac{360}{DL*\pi}\tan\frac{DL}{2} \text{ or } RF=\frac{360}{DL*\pi}*\frac{1-\cos DL}{\sin DL} \qquad (2.24)$$

Minimum Curvature Calculations:

Using RF, ΔNorth, ΔEast, ΔTVD, ΔHD and DLS are calculated as follows:

$$\Delta North=\frac{\Delta MD}{2}*(\sin I_1 \cos A_1+\sin I_2 \cos A_2)*RF \qquad (2.25)$$

$$\Delta East=\frac{\Delta MD}{2}*(\sin I_1 \sin A_1+\sin I_2 \sin A_2)*RF \qquad (2.26)$$

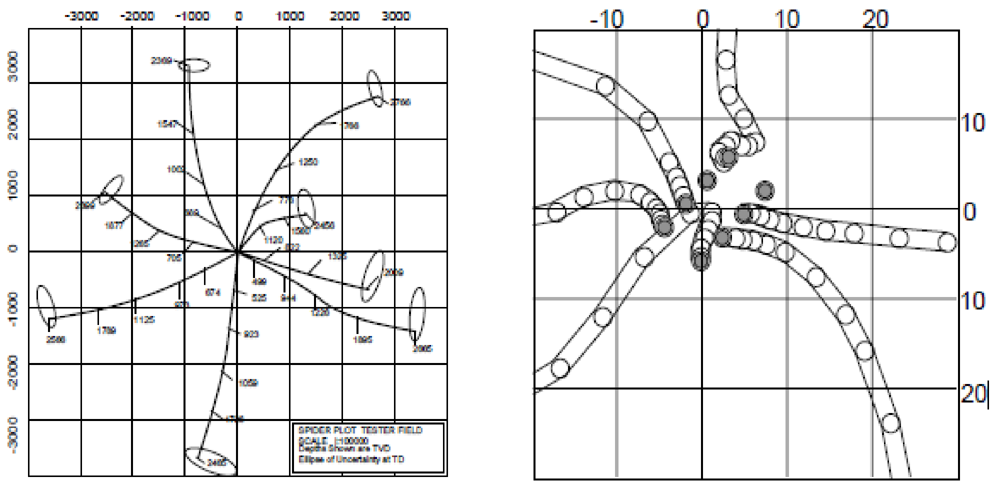
$$\Delta TVD=\frac{\Delta MD}{2}*(\cos I_1+\cos I_2)*RF \qquad (2.27)$$

$$\Delta HD=\sqrt{\Delta North^2+\Delta East^2} \qquad (2.28)$$

$$DLS=\frac{d}{\Delta MD}\cos^{-1}\left[\cos\Delta I-(\sin I_1 \sin I_2)\left(1-\cos\Delta A\right)\right] \qquad (2.29)$$

2.2.3 Anti-collision and Advanced Well Planning

Anti-collision Considerations: Collision with neighboring wells can be a problem when drilling multiple boreholes from one surface location. This is especially true when adjacent wells are producing and a collision could result in an extremely dangerous situation. Anti-collision planning begins with accurate surveys of the position of the subject well and all existing wells in its vicinity as well as a complete set of proposed well plans for future wells to be drilled in the vicinity. The surveys and well plans are used to carefully map the relationship of the proposed new well to all existing wells and any proposed future wells. These maps, sometimes referred to as “Spider" Plots are usually of the horizontal projection. The Spider-plots are normally small scale to provide an overall view of the field, and large scale to permit careful analysis of a given part of the field, such as the surface location. The Spider-plot can be used for tracing a planned trajectory and visually analyzing the threat of collision with other wells (Andrew, G., Brooks, & Harry, W. 1999).



Spider plot, small scale

Spider plot, large scale

Figure (2.25): Spider-plots

2.2.3.1 Definitive Survey Database

In order to satisfy the standard anti-collision procedures, verification of the definitive survey database is a key element. Each borehole, sidetrack, fish, or abandoned well must have a separate top to bottom definitive survey that uniquely describes the well path position from start to finish. In the ideal case, the drilling engineer would be performing all survey management services for the client, and so would have total control, and thus direct responsibility for database quality control. Extra care had to be taken to ensure that it was complete, and that the correct error models were assigned to each and every borehole. Only when this is done can the surveys be marked as definitive. During drilling, the definitive survey database must contain the most up-to-date as-drilled surveys at all times, until the final definitive survey is complete. On the rig it is the directional drillers' responsibility to oversee survey quality and to send regular updates to the DEC of the well site surveys that have been acquired.

2.2.3.2 Survey Error Model

The survey error model in software are :

- Cone of error.
- ISCWSA (Widely used).
- Systematic Ellipse.

The survey error model used in this project :

ISCWSA Survey Error Model: The Industry Steering Committee for Wellbore Survey Accuracy has built a survey instrument error model specifically for solid state magnetic instruments (e.g. MWD & EMS). The model is based on a paper published by H.Williamson "Accuracy Prediction for Directional MWD" (SPE56702). The model vastly extends the work started with the systematic error model and incorporates the experience of the many participating parties. In COMPASS, including a format for defining error terms has extended the model. The error terms for this type of survey instrument should be entered in the grid. The error value and weighting formula is be entered as well as the vector direction and treatment at survey tie-on.

A row in the grid may be for an individual source of error that can be from instrument reading, depth measurement, instrument barrel-hole/collar alignment and external reference and interference terms (Grindrod, S. Sept. 2007).

2.2.3.3 Ellipses of Uncertainty (EOU)

The systems employed for surveying directional wells have a specified level of accuracy. Some surveying systems are more accurate than others, but they are all prone to some degree of inherent error. In addition to the accuracy of the measuring device, the surveys are also subject to errors resulting from the surveying environment, such as magnetic interference, which may not be detected at the surface. An ellipse can be drawn (actually an ellipsoid, since for anti-collision purposes it is a 3-D body) that represents the encompassing volume that gives the most likely position of the well path at a given level of statistical confidence. This effectively quantifies the errors associated with either a magnetic or gyro compass, and those due to misalignment of the tool in the hole, depth measurement, and inclination. (C Chia, 2002).

2.2.3.4 Separation Factors (SF)

The separation factor is defined as the ratio of the center-to-center distance between wells, and the sum of the radii (major semi-axis) of the ellipsoids of uncertainty, around the subject and offset wells being scanned at any given point. An allowance is also included for the hole diameters as shown below.

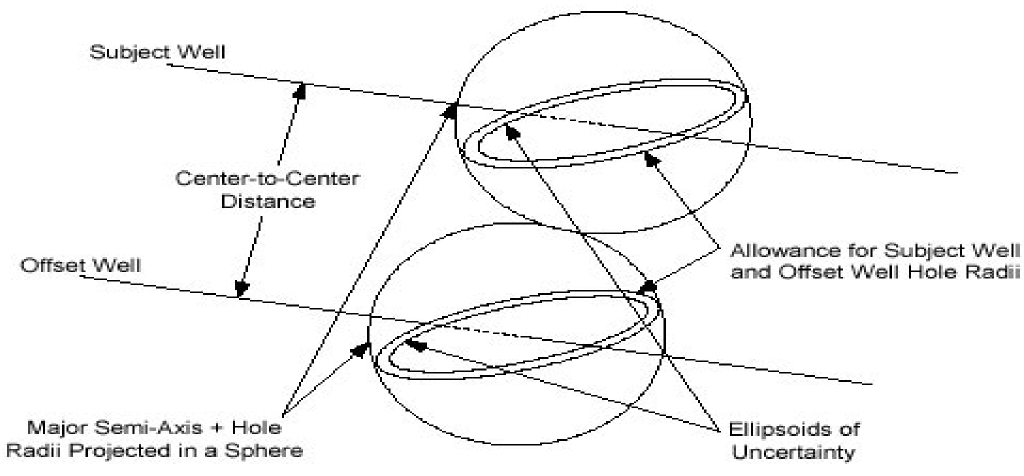


Figure (2.26): Separation Factor = 1. Separation factor based on Semi Major Axis of EOU

Well collision risk has traditionally been managed by considering the clearance between spheres that contain the EOU's where the sphere's radius is defined by the size of the semi major axis. However, using this simplistic approach, it is possible to have two collision scenarios with the same separation factor, but which have very different probabilities of collision because the individual orientation and shape of the EOU's are not accounted for. This can result in overly conservative well planning, which can at times be unnecessarily restrictive. For this reason, oriented separation factors are used. Oriented separation factors (OSF) are defined to take into account the geometry of the EOU's so that all scenarios with the same safety factor (separation factor) have the same probability of collision. Obviously, if a well is drillable using normal separation factors, then it will also be drillable using oriented separation factors. However, the reverse of this statement may not be true (J .Bang , and T.Torkildsen 2011).

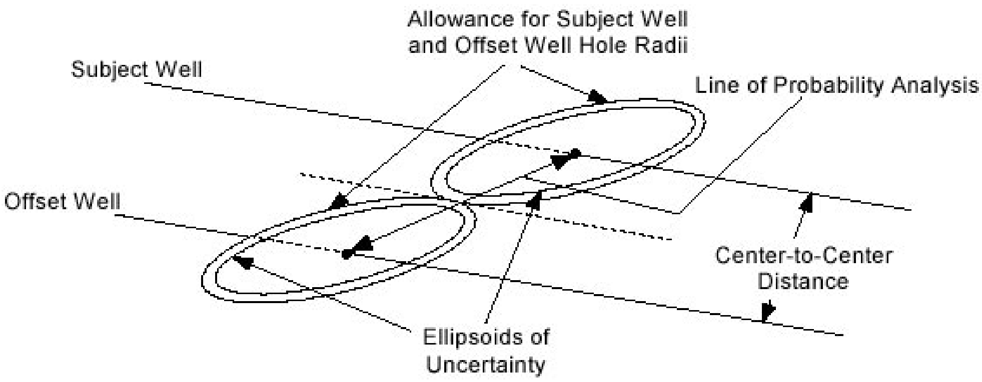


Figure (2.27): Oriented separation factor = 1. Oriented separation factors reduce overly conservative planning

2.2.3.5 Center-to Center Distance

The center-to-center distance is defined as the distance between the subject well (well being planned) and the offset well being scanned. This definition is only valid when either the 3–D Least Distance or Normal Plane scanning methods are used.

2.2.3.6 Allowable Deviation From Plan (ADP)

The allowable deviation from plan (ADP) can be thought of as a "drilling tunnel" that is created as a result of the avoidance of any close approach violation identified by the use of oriented separation factors. It is therefore represented as the radial distance from the plan at any point, to which the driller may be allowed to depart from the plan during the drilling process for the purposes of drilling efficiency, without violation of the "drill ahead" anti-collision rules (Technical, T., Astier, B., Baron, G., Boe, J.C., & Peuvedic, J.L.P. 1990).

2.2.3.7 Minimum Allowable Separation

The minimum allowable separation (MAS) is defined as the minimum center-to-center distance, with allowance for hole size, between subject and offset wells that is allowable without violation of the drill ahead anti-collision rules.

The allowable deviation from plan and the minimum allowable separation should sum to give the actual center-to-center distance observed under all normal drilling circumstances, when allowance has been made for the respective hole diameters.

2.2.3.8 Alert Zones

Separation factors between subject and offset wells are used to identify close approach situations. Alert zones are defined to help the user quickly identify which wells are in the closest proximity to a planned well, and therefore most likely to be the cause of proximity issues during the execution of the plan. Note that alert zones only identify potential problems. Detailed anti-collision scans need to be used to fully analyze potential problems. There are three levels of alerts:

2.2.3.8.1 Buffer Risk Alert (OSF < 5)

this is the first alert condition. When the separation factor between two wells is less than 5, a detailed anti-collision scan must be included in the well design file. This report contains sufficient information to closely examine the proximity condition of nearby wells that have failed the alert zone condition. Surveys should also be projected at least one stand ahead of the bit in this situation

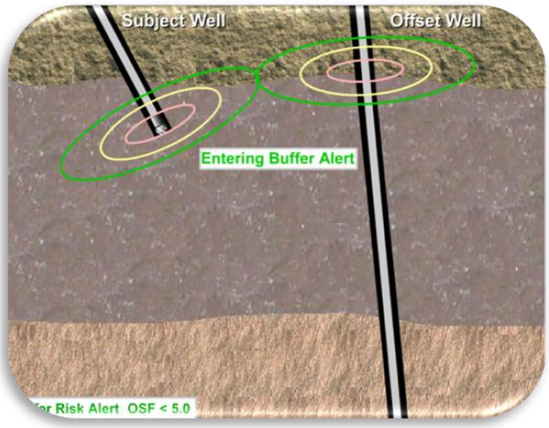


Figure (2.28): Buffer Risk Alert (OSF < 5)

2.2.3.8.2 Minor Risk Alert (OSF < 1.5)

A minor risk well is an offset well which falls within an oriented separation factor of less than 1.5, but greater than 1.0. This OSF represents the limit of the “drill ahead” separation threshold. When approaching a minor risk tolerance line, it is a good practice to project ahead of the bit by at least one surveying interval. Drilling with separation factor of less than 1.5 requires a written exemption from both line management and the client.

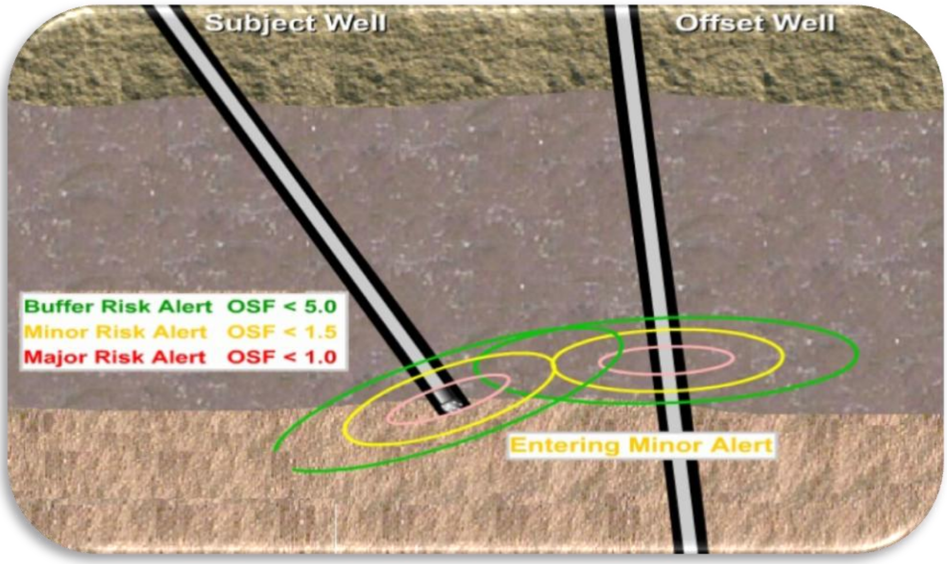


Figure (2.29): Buffer Risk Alert (OSF <1.5)

2.2.3.8.3 Major Risk Alert (OSF <1.0)

A major risk well has an OSF of less than 1.0. This represents the point at which the DD must stop all drilling operations. The well must be replanned to improve the separation factor beyond a minor risk status, and or replanned to attain minor risk status, and subjecting the minor risk well to an exemption process agreed upon with the client. Remember that any separation factor of 1.0 or less means that you have effectively collided with a well.

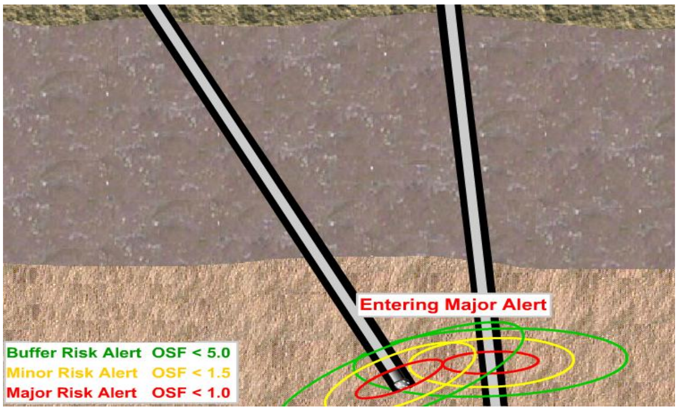


Figure (2.30): Buffer Risk Alert (OSF < 1.0)

2.2.3.9 Surface Hole Anti-collision

The most common well collision problems are found at the surface hole. This is especially true where slot separation provides minimal clearance from other wells drilled from the same template. In addition to this, it is also an area where the separation factor method is technically weak.

For example, at the well head, where positional uncertainty is small, you can have a large separation factor between two wells that are in reality only a few feet away from each other. By the time the traditional rules have been violated (less than 1.5 separation factor), it may be too late to avoid a collision. For this reason, a mandatory surface hole anti-collision rule exists.

This rule states that for wells sharing the same physical drilling template, the minimum separation between the subject well and all offset wells will be no less than 80 % of the allowable deviation from plan (ADP) at the well reference point at all times. This is referred to as the minimum separation rule. The following diagrams highlight this particular case, and the other two possible scenarios. (Thorogood, J.L. & Sawaryn, S.J., 1991).

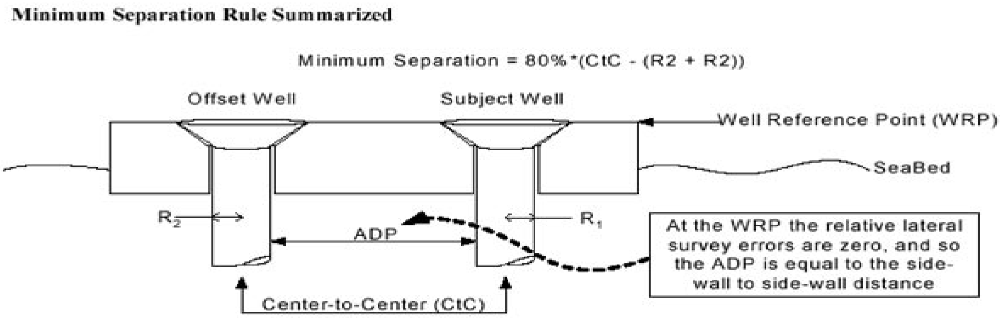


Figure (2.31): Wells Sharing the same template. Minimum separation = 80% of ADP at Well Reference Point

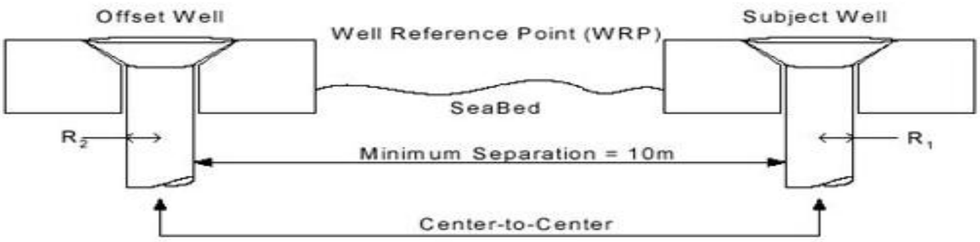


Figure (2.32): Wells not sharing the same template or pad. Minimum separation = 30 ft (10 m)

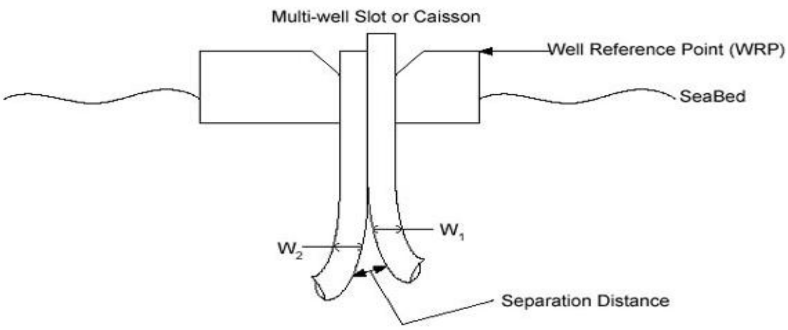


Figure (2.33): Wells sharing the same slot. Anti-collision monitoring required until separation = 30 ft (10 m) and OSF = 1.5

2.2.3.10 Global Anti-collision Scan

A global scan is the initial scan made in the anti-collision scanning process. It is strictly made on the surface location of the wells under consideration. Subsurface survey data is not considered at this point. The scan radius must be set to 80,000 ft (24,000 meters). This distance is chosen to consider the worst case scenario of two 40,000 ft horizontal wells drilled directly towards each other, which is considered to be the limit of today's current drilling technology. If no other wells are found in this scan, then the planned well can be considered as being a single well. The scan for this well has indicated the presence of no other offset well heads other than the existing 24 slots associated with the platform. (C Chia, 2002)

2.2.3.11 Scanning Methods

Two different scanning methods for anti-collision analysis: “3D Least Distance” and “Normal Plane.” When scan reports are examined for interpretation, it is vital that you know which method was used, and also how the method works. The theory behind each one is introduced in this section.

It should be noted that both scanning methods suffer from different weaknesses, and therefore both methods must be used during the anti-collision scanning process in order to fully investigate the potential for collision.

2.2.3.11.1 3D Least Distance

The 3D least distance method of proximity scanning calculates the nearest distance to each offset well by stepping down the subject well at specified intervals. At each step, this analysis scans the offset well to determine a plane that is normal (right angles) to the offset well survey, and that intersects the subject well at the interval point. Mathematically, this is the shortest distance between the subject well and the offset well from each of the respective subject well scanning points. Therefore, under normal circumstances it will produce the most appropriate solutions

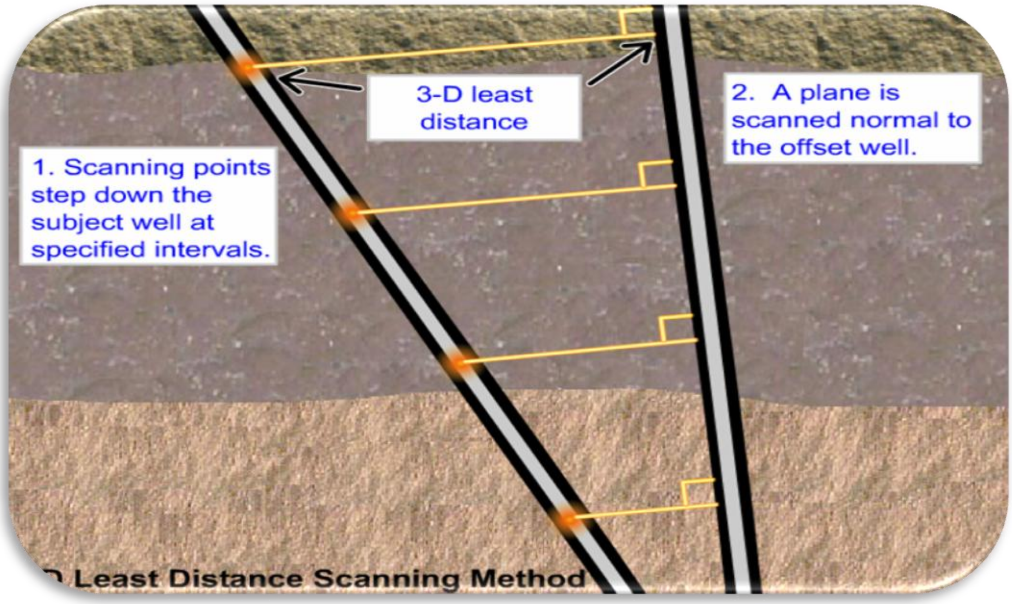


Figure (2.34): 3D Least Distance

2.2.3.11.2 Normal Plane

The normal plane method of proximity calculation steps down each offset well at the specified intervals. This stepping down of each offset well is done to ensure that the proximity of the entire offset well is analyzed, and to ensure the scanning of any potential perpendicularly approaching wellbore. At each step down the offset well, this method scans the subject well to determine where a plane normal to the subject well intersects the offset well at the respective scanning point. This method is also the only acceptable option for producing traveling cylinder plots

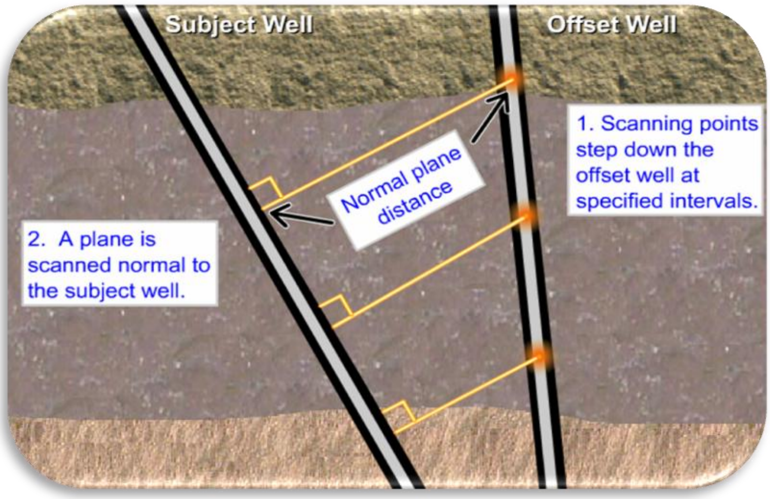


Figure (2.35): Normal Plan

2.2.3.12 Summary Anti-collision Scan

The anti-collision summary scan report is obtained by the drilling engineer by using the Close Approach software application. It is required to be completed separately for each survey program part and included in the well design file. The summary report details the following information between the subject well plan and offset trajectories:

- Center-to-center distance between subject and offset borehole
- Ellipse of uncertainty size (semi major and semi minor axis radius)
- Separation factor between subject and offset borehole
- Separation factor alert zone (as per anti-collision rules)
- Anti-collision rule violation status

For each offset trajectory, scanned information is displayed for the surface location (0 ft MD), the closest point of inflection, the smallest separation factor, depths any alert zones are entered and exited, and information at TD of the subject well. In addition to this information, the heading of the report also includes the scanning method used (3D Least Distance or Normal Plane), the scanning interval used (the depth interval between scans), and the date the scan was completed.

The purpose of the summary report is to demonstrate that all wells exceed the alert zone separation criteria (OSF = 5), and therefore the anti-collision scan is complete for these wells. In the case where the proximity of any offset well triggers any of the alert zones, or crosses the minor or major risk thresholds, a detailed anti-collision scan report is required to be completed. The following figure shows a portion of the scan completed for the North Penguin 101 platform, the subject well being Slot M. This will be examined in more detail. (C Chia, 2002)

2.2.3.13 Traveling Cylinder Plots

The main advantage of the traveling cylinder plot over any other type of graphical plot is its ability to clearly and accurately displays the required drilling tolerances, or “drilling tunnel.” For any point on a nearby well that is displayed on the traveling cylinder plot, a line may be drawn from it that represents the minimum distance from that point to which the well being drilled can approach without violating the anti-collision rule in force. The traveling cylinder (TC) plot or circle travels along the planned well path and indicates on its surface the distance and direction to offset wells. It is much like a coke can that moves along the well path. The top of the can is a map showing the radial distance to the other wells while drilling. The center of the can is fixed to the planned well's trajectory. As the can travels down the well path, any offset wellbore entering the cylinder (approaching closer than the given radius of the cylinder) is plotted and displayed graphically.

The Widely used standard is to use the normal plane scanning method and reference the cylinder to North. No other scanning methods can be used, as they distort the true distance to offset wells. To be useful, depths need to be indicated on all offset surveys entering the cylinder. The depths that appear correspond to the measured depth of the subject well, and not the measured depth of the offset wells. This means you can use the plot to see how close you are to offset wells for any given depth of the subject well. The preparation of the TC plots, their scale ranges, and depth labels requires some experience in order to provide something that is of practical use to the directional driller. The directional driller should be personally involved in the creation and review of the plots. This ensures that they will be correctly interpreted and used at the well site. In most cases, more than one TC plot will be prepared for a well plan

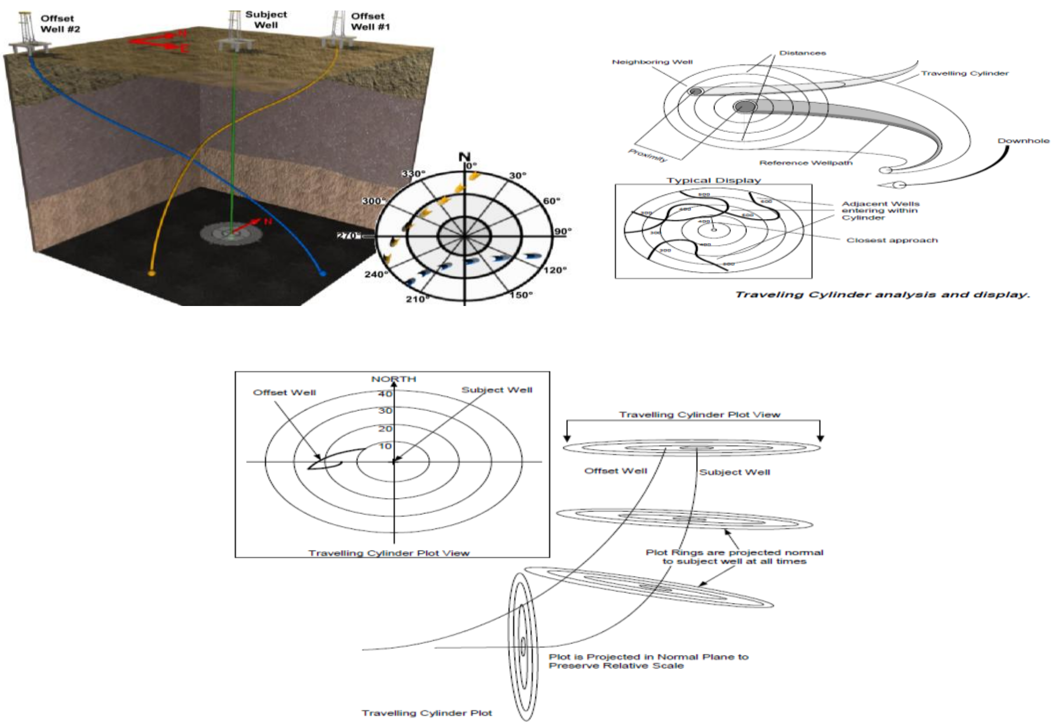


Figure (2.36): Traveling Cylinder Plot

In addition to displaying the position and distance to any offset wellbores, the traveling cylinder plots are also used to display areas that the directional driller must not enter. These lines are known as the no go zones and are displayed as circles around the offset wells. The distance from the center of the plot to the edge of the no go zone represents the allowable deviation from the plan. The no go zone therefore, is a combination of the separation factor, positional uncertainty, and hole radii of both the subject and offset well in question, at any given depth. The standard is to base the dimension of the no go zones on the minor risk rule (OSF = 1.5). (Thorogood, Sawaryn,. Thorogood, J. L. & Sawaryn, S. J. 1991).

2.2.3.14 Anti-collision Monitoring Plan

Every well design file must include the client, or project specific anti-collision monitoring program for which the well design has been provided. Where such a program does not exist, or its existence is in doubt, then the well design file should include a detailed anti-collision monitoring program. This program includes details of the conditions and circumstances under which the program shall be executed and anti-collision monitoring carried out. It should also describe the roles and responsibilities of all parties involved in anti-collision monitoring, and the resource requirements to ensure successful execution of the program. As the directional driller at the wellsite, it is your responsibility to maintain and update the definitive survey database. You must conduct anti-collision calculations, including oriented separation factors (OSF's), as new surveys become available to correctly execute the specified surveying program. You must also confirm onsite survey quality control requirements, corrections, reference data, and their use by survey engineers. It is good practice to check that independent survey and position calculations performed by surveyors correlate with the local definitive database. The content of the anti-collision monitoring program for this well will be discussed further as you progress through the drilling stage. (C Chia, 2002)

2.2.3.15 Implications of a Minor Risk Well

Some policy for a minor risk well states that a minor risk well has a separation factor of less than 1.5 and greater than 1.0. In this case, the interfering well should be shut in and the subject well (your well) resurveyed with a more accurate survey tool to increase the OSF above 1.5, or invoke Risk Based Anti-collision Procedures and plan to drill ahead with line manager approval and client written exemption. This would have been the case if the problem had occurred while we were drilling. In this case, we still have time to change the drilling plans to avoid this situation entirely. we have two options:

- **Gyro Surveys**. Although the drop gyro has failed, you still have another opportunity to run a gyro inside casing prior to starting the next section. This would be a north seeking multi shot conveyed on wireline. The error model associated with type of instrument (SLB_NSG+MSHOT) has a similar accuracy to the battery multishot that failed.
- **Change the Well Plan.** The trajectory of the well can be redesigned so that the OSF is increased to over 1.5 at all times. This is relatively easy to do and may be completed by the drilling engineer in a short time period. This action also requires line management and client approval.

2.2.4 Key-24, Keyi-Field, Background

According to the Keyi FDP indepth study, development wells were proposed to be drill to reach **60000BOPD** of **phase Ⅲ** production. **KEYI-24** is one of the Keyi development deviate wells in Keyi Main Block. The proposed formation tops was predicted from adjacent well Keyi-3, where Ghazal and Zarqa reservoirs are the target formation to exploit oil from this well then switch it to water injection well.

2.2.4.1 Basic Information

Well Name is Keyi-24 (FDP Name is INJ-2), Abbreviation Keyi-24, Classification is Development Well, Well Type is Producer and Injection, Basin is Fula Sub-Basin, Block 6, Structure is Keyi Main Block, Reference Well is Keyi-3, Objectives are Ghazal and Zarqa Formation.

2.2.4.2 Directional Well Location:

Table (2.1): Keyi-24 (FDP Name INJ-2)

Reservoir	**Zarqa_Oil**	**Type**		
		Surface	**KOP**	**Target**
Grid Coordinators	**X**	637825.60	637825.60	637822.23
	Y	1254182.58	1254182.58	1254338.05
	GL	521.0		
	KB	530.2		
Depth	**TVDSS(m)**		-669.8	-1174.8

2.2.4.3 Formation Tops

The proposed formation tops are predicted from adjacent well (Keyi-3), and also pay zones are expected from Ghazal and Zarqa reservoir.

Table (2.2): Keyi-24 Formation Prognosis

Formation	Rock Type	Lithol. Column	TWT (ms)	Proposed TVD (m-KB)	Thick (m)	Remark
Tendi – Senna	shale with sand		384	572	480	**Problem cause: Mud making, loss circulation, serious caving.**
Amal Sand	sandstone		796	1052	223	Pure unconsolidated, medium to very coarse Sandstone. **loss circulation, serious caving.**
Baraka Sand/Sh	sandstone with shale		946	1275 (MD: 1275)	134	Gray, soft, minor firm, sticky, blocky Claystone with interbedded unconsolidated fine to coarse Sandstone. **Problem cause: tight interval, caving.**
Ghazal-Zarqa Shale/Ss *	shale with sandstone		1047	1409 (MD:1414)	330	
Aradeiba	shale with sand		1283	1739 (MD: 1769)	41	Pure gray and minor brown, firm, blocky Claystone with interbedded poor consolidated, very fine to medium Sandstone. **Problem cause: tight interval, caving.**
Proposed TD			1311	1780 **(MD:1812)**		

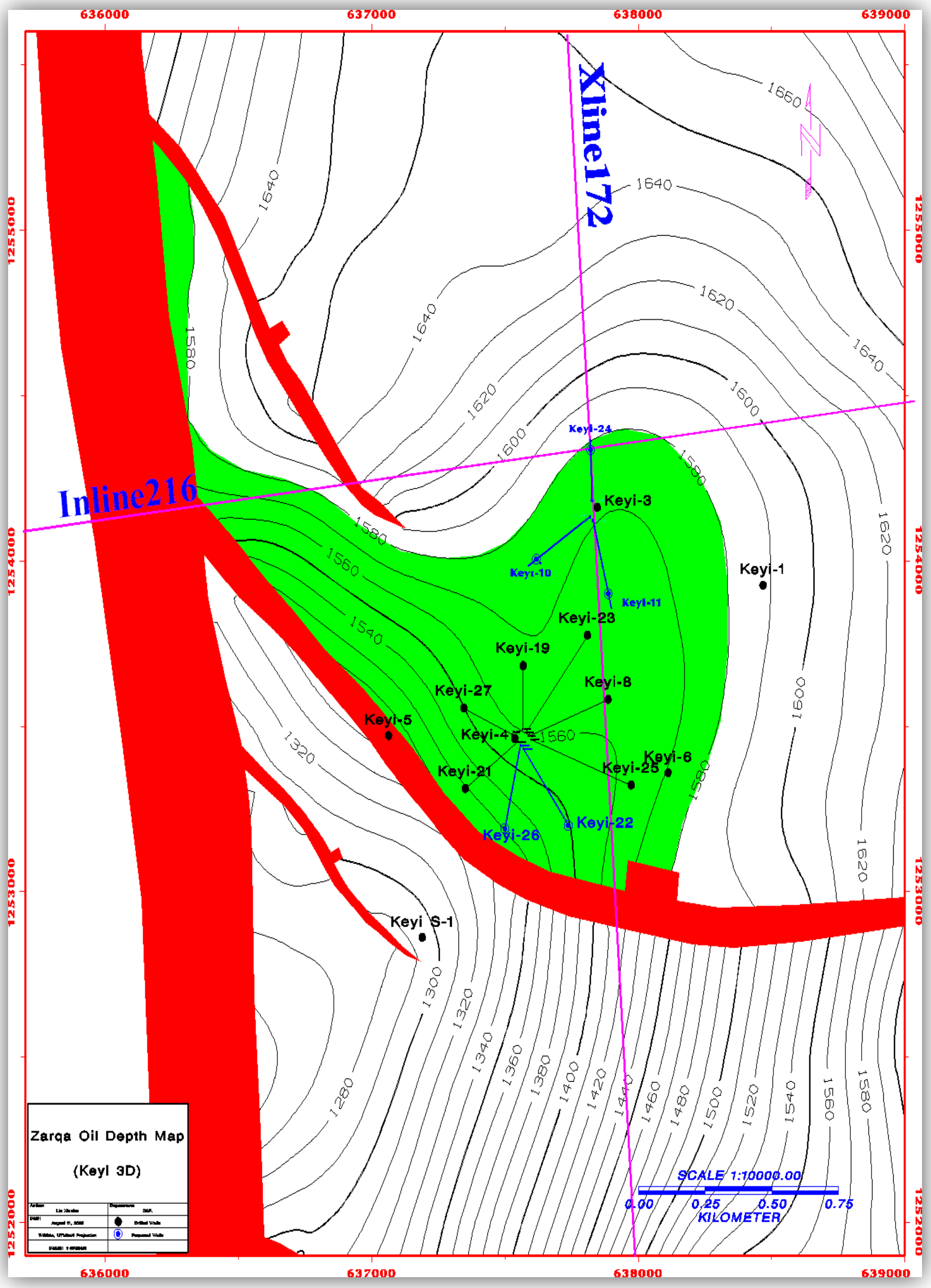


Figure (2.37): Proposed Location of Well Keyi-24 on Zarqa Oil Depth Map

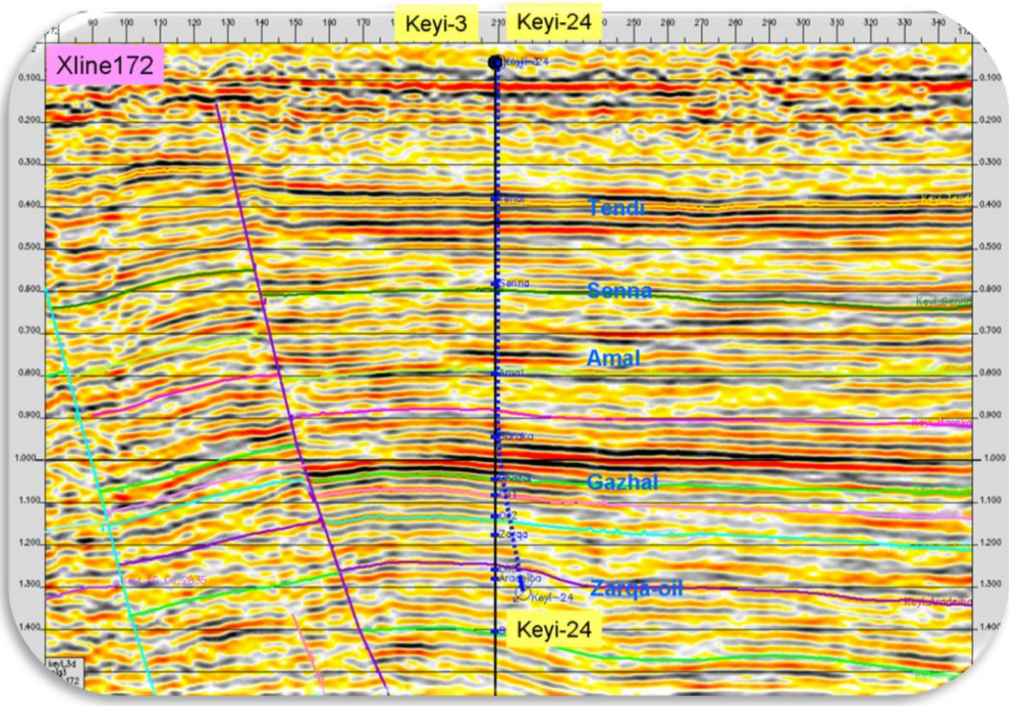


Figure (2.38): Crossline_172 of Well Keyi-24

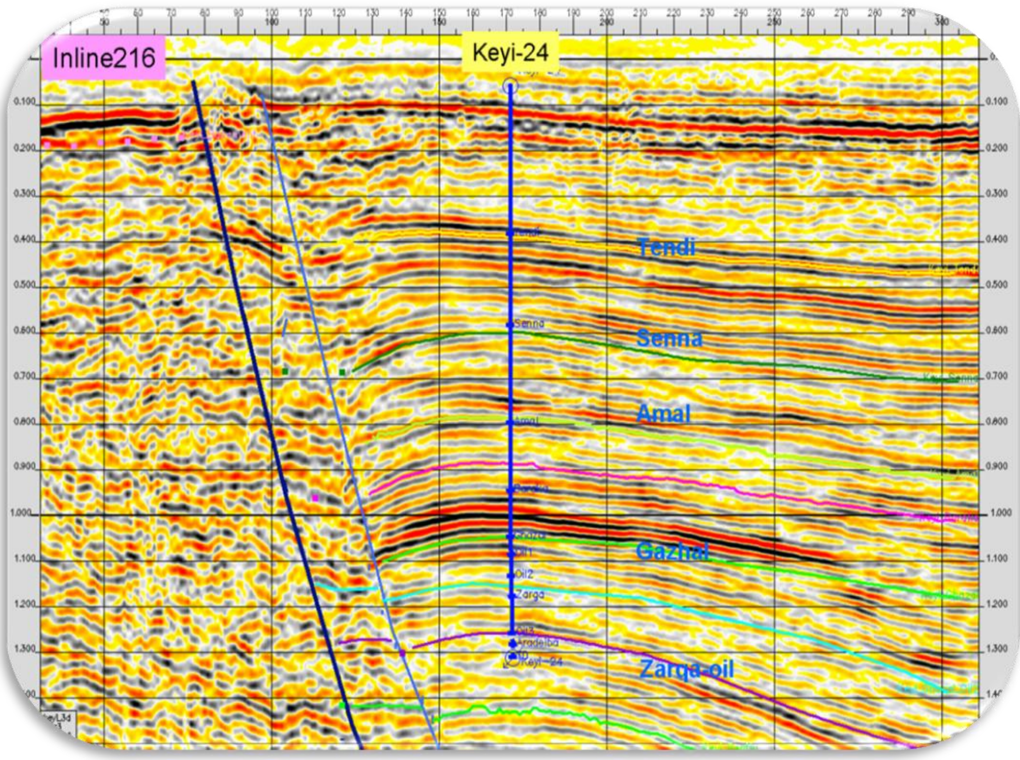


Figure (2.39): Inline_216 of Well Keyi-24

Chapter Three

Methodology

Chapter Three

Methodology

This chapter presents the Procedures that have been followed for the design, analysis, and design optimization for side-track in congested Cluster Environment using COMPASS SOFTWRE.

3.1 COMPASS SOFTWARE:

The Computerized Planning and Analysis Survey System (COMPASS) one of LANDMWRK Software Packages. It is a comprehensive software tool designed for use in directional well design by either oil companies or directional contractors. COMPASS is a tool that enables us to quickly and accurately plan wells and identify potential problems at the earliest possible stage.

All of the features for complex well trajectory design, monitoring and analysis are included. The list of features include survey and planning methods, torque-drag optimization, anti-collision plotting with traveling cylinder and ellipse of uncertainty.

COMPASS consists of three main function areas (Survey, Planning, Anti-collision), as well as an extensive plotting tool.

3.1.1 Survey

The Survey module calculates a Wellbore's trajectory. Compass considers a survey to be a set of observations made with a single survey tool in the same tool run. Data can be entered in a spreadsheet or imported and processed using industry-standard calculation methods. The resulting survey files can be edited, printed or analyzed. Surveys may be spliced together to form a definitive 'best path' using a tool interval editor. Special provisions are made for Inertial and Inclination only surveys. Survey provides an advanced "project ahead" from survey station to target, formation or well plan. Two methods enable you to assess survey data for incorrectly entered survey data or bad readings from the survey tool. Input Validation will isolate bad survey data as soon as it is entered. Varying Curvature isolates incorrect survey station data by highlighting their inconsistency. Survey analysis graphs are available that produce comparison plots of survey and plan data for a number of different variables.

COMPASS survey data can be referenced to any number of user-defined datum and can include a number of canned or custom formatted report layouts that you can send to an ASCII file. You can also export survey data to a raw survey file or output it to a number of canned or custom export file formats.

3.1.2 Planning

Use the Plan Editor to design the shape of proposed wellbores. The Planning environment has an interactive editing worksheet allowing the user to build up the well trajectory in sections. There are many different plan sections available for each section and they can be based on 2 or 3 dimensional Slant or S Shaped profiles or 3 dimensional dogleg/toolface or build/turn curves. Alternatively the plan can be imported or entered directly into the spreadsheet line by line. At each stage of well planning, the user can see the Wellbore graphics dynamically update as changes are made. The user may re-visit, insert or delete any section of a plan and the whole plan will be recomputed.

The Wellbore optimizer integrates torque drag analysis into the planning module. It will determine the best combination of trajectory design parameters that lead to the minimum cost, anti-collision or torque and drag solution. Planned designs which are 'un-drillable' by colliding with other Wellbores or exceeding the drill strings tension, torque, buckling, side force or fatigue limits are indicated.

3.1.3 Anti-collision

Anti-collision can be used to check the separation of surveyed and planned Wellbores from offset wells. Anti-collision provides spider plots, ladder plots, traveling cylinder, and printouts of well proximity scans. Any anti-collision scans may be run interactively with planning, surveying or projecting ahead. All anti-collision calculations are integrated with Wellbore uncertainties that are shown on graphs or reported as separation ratios. Warnings may be configured to alert the user when the Wellbores converge within a minimum ratio or distance specified by company policy.

3.2 Side-Track Design and Analysis

In this part we will go through designing and collision risk analysis stages which include:

- Offset Wells design
- Side track trajectory design
- Anti-collision risk Analysis using different monitoring tools

3.2.1 Offset Well Design

The offset well design is the first step in such congested well Environment which allows monitoring the proximity to the Subject well in later stage of side-track planning Process.

3.2.1.1 Data Required:

- General information's for each offset well (name, type,….etc.)
- Surface location coordinates (UTM).
- Target Coordinates (UTM).
- Depth reference information (RKP).
- Survey Program (MWD).
- Quality checked (QC'ed) Surveys for each offset well need to be entered.

3.2.2 Side track trajectory design

Data required:

- Mapping information's:
  - Geodetic System (UTM).
  - Geodetic datum (WGS 1984 (WGS 1984)).
  - Map Zone 35N (24E to 30E).
- Well Surface Location Coordinates:
  - Northing/Easting.
- Kick-off point (KOP):
  - Depth (m).
- Build Up Rate (BUR):
  - in deg/30m.
- Target Coordinates:
  - Northing/Easting.
- Target True Vertical Depth (TVD):
  - Depth (m).

3.2.2.1 Survey Calculation Methods

In this Project we will select Minimum Curvature method since it is the industry standard and the preferred method because of its accuracy in determining bottom hole position.

Minimum curvature fits a spherical arc onto two survey points. The inclination and azimuth at each survey point are defined as space vectors. These vectors are smoothed onto the wellbore using a ratio factor. The ratio factor is defined by the curvature of the section of the wellbore where the path curves through changes in inclination and/or azimuth. This curvature is called a dogleg.

In the graphic below, angle DL represents the dogleg.

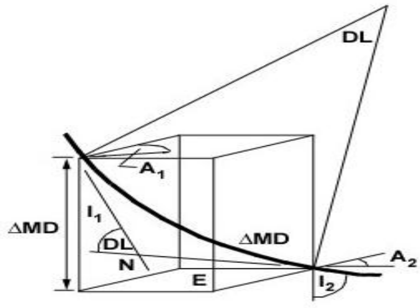


Figure (3.1): Minimum Curvature

Dogleg and Ratio Factor

The straight-line segments that define angles I_1, I_2, A_1, and A_2 are smoothed onto the curve using the ratio factor, RF, which includes the value for DL. Dogleg is calculated using the following formula:
$DL = \cos^{-1} [\cos(I_2 - I_1) - \sin I_1 \sin I_2 (1 - \cos (A_2 - A_1))]$ (3.1)

There are two forms of the RF calculation, as shown below. For small angles, where $DL < 0.0001$, it is customary to set RF = 1. DL is in degrees.

$$RF=\frac{360}{DL*\pi}\tan\frac{DL}{2} \text{ or } RF=\frac{360}{DL*\pi}*\frac{1-\cos DL}{\sin DL} \quad (3.2)$$

Minimum Curvature Calculations:

Using RF, ΔNorth, ΔEast, ΔTVD, ΔHD and DLS are calculated as follows:

$$\Delta North=\frac{\Delta MD}{2}*(\sin I_1 \cos A_1+\sin I_2 \cos A_2)*RF \quad (3.3)$$

$$\Delta East=\frac{\Delta MD}{2}*(\sin I_1 \sin A_1+\sin I_2 \sin A_2)*RF \quad (3.4)$$

$$\Delta TVD = \frac{\Delta MD}{2} * (\cos I_1 + \cos I_2) * RF \quad (3.5)$$

$$\Delta HD = \sqrt{\Delta North^2 + \Delta East^2} \quad (3.6)$$

$$DLS = \frac{d}{\Delta MD} \cos^{-1}\left[\cos \Delta I - (\sin I_1 \sin I_2)(1 - \cos \Delta A)\right] \quad (3.7)$$

3.2.2.2 Relative Accuracy of the Different Methods

A comparison of the relative accuracy of the five calculation methods is shown in the table below. A theoretical well in a due North direction is assumed. The MD is from 0 to 2000 ft; build rate is 3°/100 ft, with survey stations every 100 ft. Actual TVD is 1653.99 ft and HD is 954.93 ft.

Table (3.1): Relative Accuracy of the Different Methods

Calculation Method	Error on TVD (ft)	Error on HD (ft)
Tangential	-25.38	+43.09
Balanced Tangential	-0.38	-0.21
Average angle	+0.19	+0.11
Radius of curvature	0.00	0.00
Minimum Curvature	0.00	0.00

3.2.3 Collision risk Analysis:

After side track has been designed, collision risk with offset wells need to be analyzed carefully using different monitoring tools. Based on the analysis the design will be corrected till optimum design is met as per center to center distance (10-15 meters) required. Following steps will be carried out:

3.2.3.1 Anti-collision setting in compass:

This is very important step when we come to analysis stage, proper setting in anti-collision panel has to be set as following:

- Determine the survey error model will be used by the compass based on what is agreed with client, in our case is (ISCWSA).
- Determine the scan Method, will be using (Closest approach 3D).
- Warning type is (Error Ratio).
- Warning Levels:
  - Level 1, Separation factor is 1
  - Level 2, Separation factor is 1.25
  - Level 3, Separation factor is 1.5

3.2.3.2 Collision Risk monitoring outputs:

To perform the anti-collision risk analysis will use the following outputs from COMPASS:

- Anti-collision Risk Summary Report.
- Spider plot (SP) view.
- Travelling Cylinder (TC) View.
- Ladder Plot (LP) View.

Chapter Four

Results and Discussion

Chapter Four

Results and Discussion

4.1 Pad Design

4.1.1 Cluster Wells Design

Keyi Field has been selected as case study. The Pad Contained Seven wells including **Keyi-24** which the subject side tracked well. The Surveys of the 6 offset Wells **(all wells are *J-Type*)** had been QC'ed before upload them into **COPMASS** as blew:

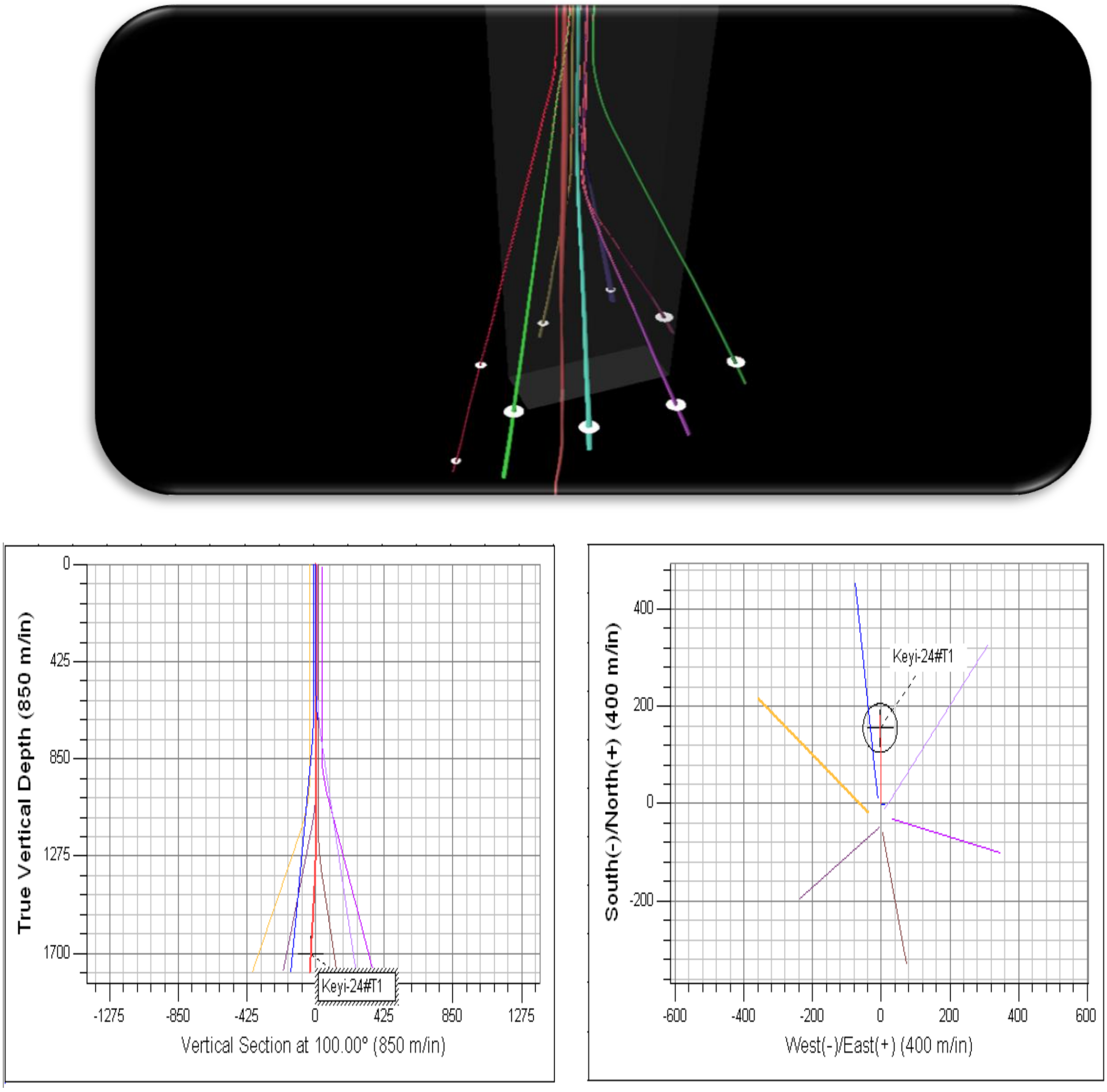
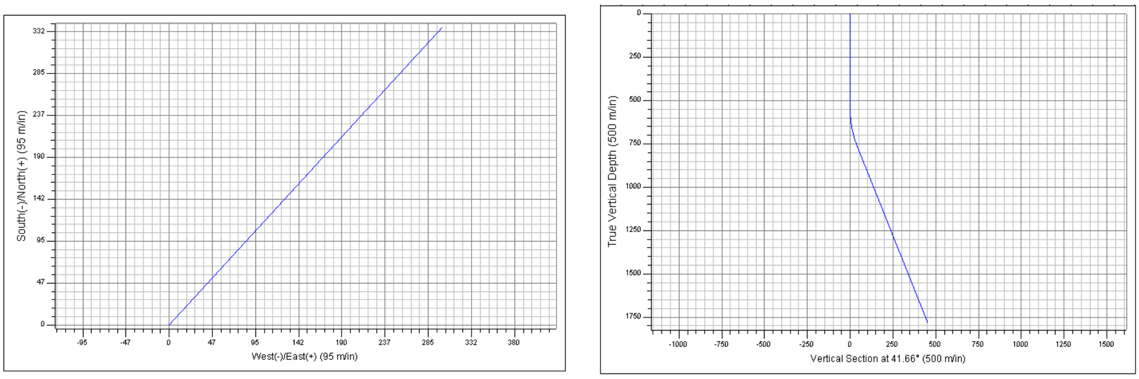


Figure (4.1): Keyi Cluster Wells

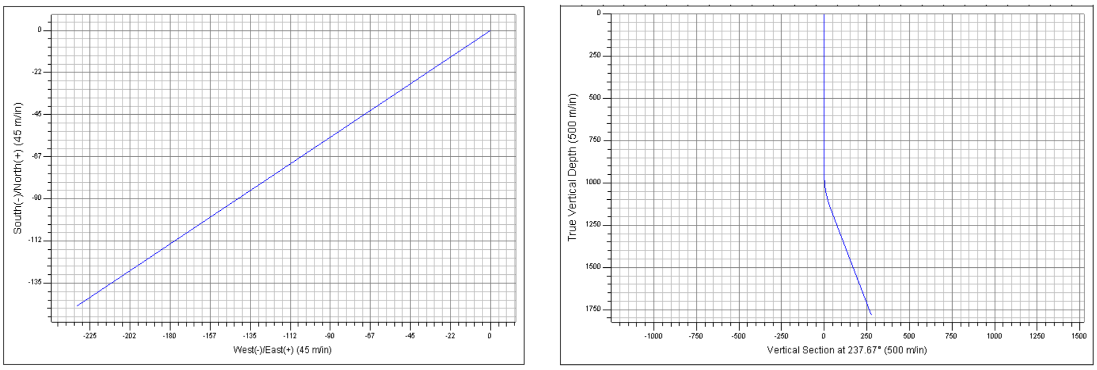
4.1.1 .1 Keyi-14:



Plan View　　　　　　　　Vertical Section View

Figure (4.2): Keyi-14 Surveys

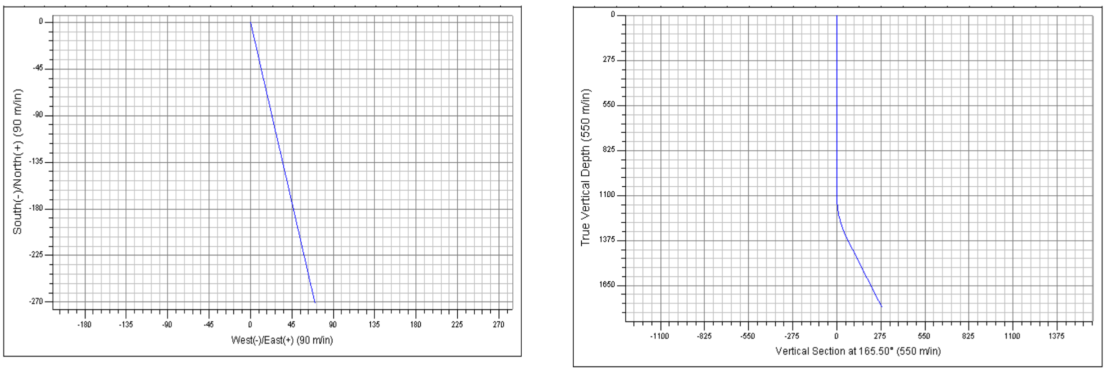
4.1.1 .2 Keyi-10:



Plan View　　　　　　　　Vertical Section View

Figure (4.3): Keyi-10 Surveys

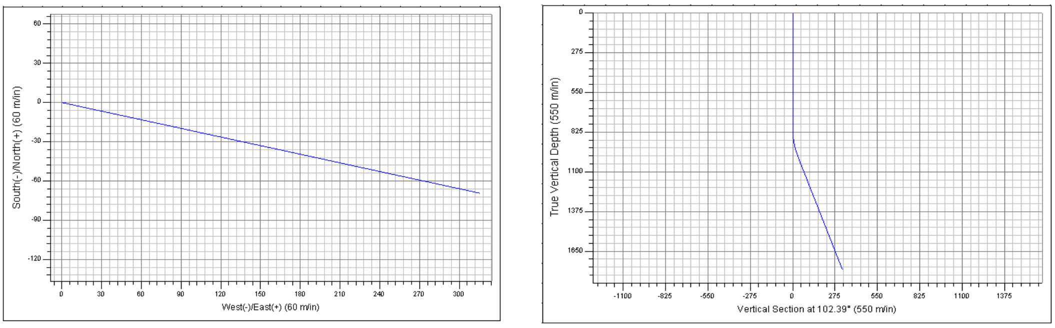
4.1.1 .3 Keyi-11:



Plan View　　　　　　　　Vertical Section View

Figure (4.4): Keyi-11 Surveys

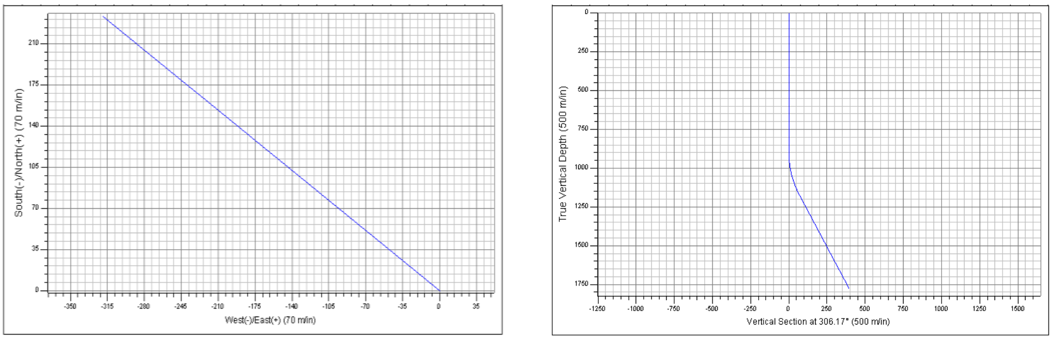
4.1.1 .4 Keyi-13



Plan View　　　　Vertical Section View

Figure (4.5): Keyi-13 Surveys

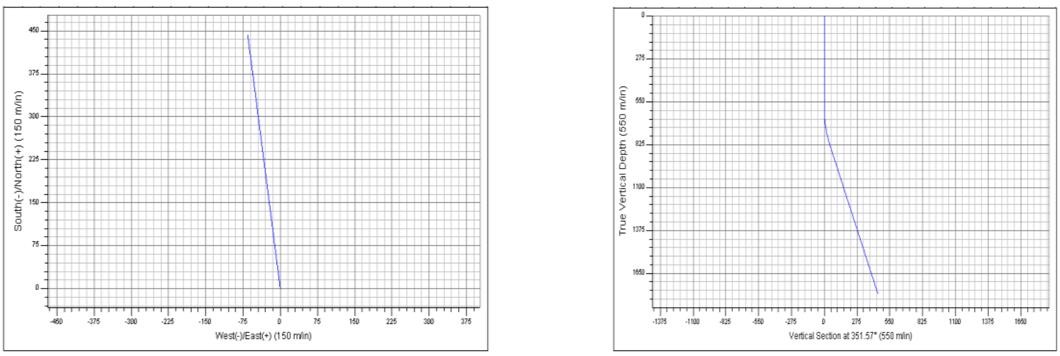
4.1.1 .5 Keyi-15:



Plan View　　　　Vertical Section View

Figure (4.6): Keyi-15 Surveys

4.1.1 .6 Keyi-16:



Plan View　　　　Vertical Section View

Figure (4.7): Keyi-16 Surveys

4.2 Side-Track Design:

Keyi-24 has been selected as case study to design side-track with different scenarios, perform anti-collision risk analysis using different monitoring tools (Travelling Cylinder, Spider Plot, and Ladder Plot), and choose optimum design which meet center to center distance requirement (10 – 15m).

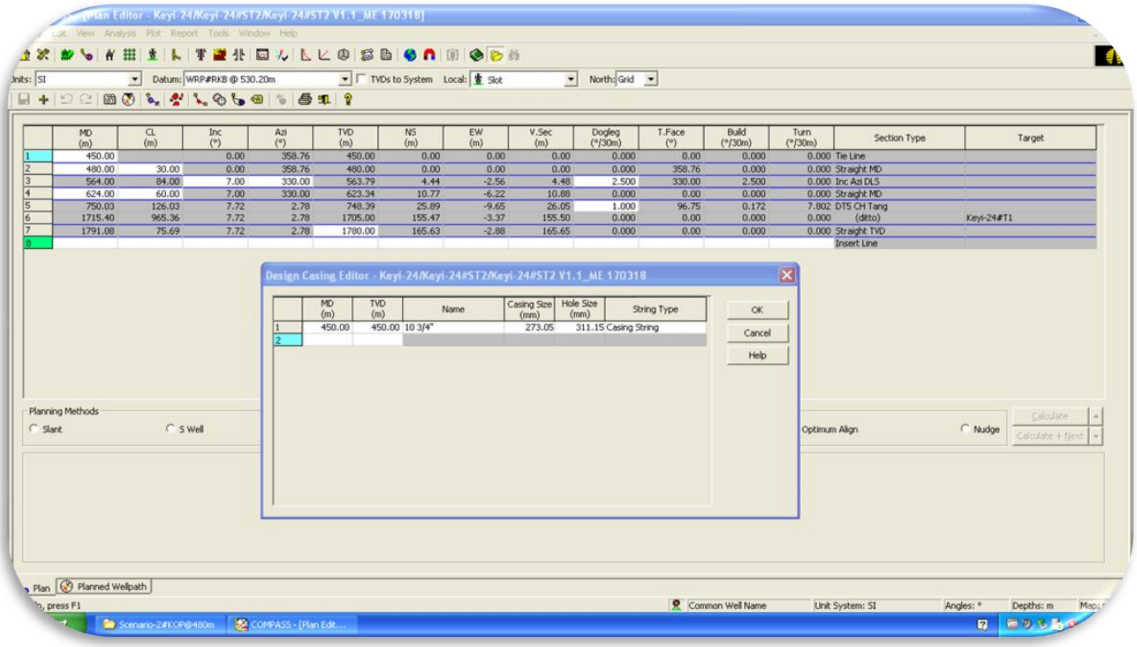
Keyi-24 well data showed in table below:

Table (4.1): keyi-24 data

Well Name	Keyi-24
Well Type	Development
Block	6
Basin	Fula Sub Basin
Latitude	11° 20' 34.091 N
Longitude	28° 15' 46.871 E
Easting (X)	637825.60 m
Northing (Y)	1254182.58 m
Reference Datum	Mean Sea Level
Ground Elevation	521.00 m
Rotary Table Elevation Datum Elevation	9.2 m 530.2 m
Surface Casing	10 ¾’’ @ 450 m.
Geodetic System	Universal Transverse Mercator
Geodetic Datum	WGS 1984 (WGS 1984)
Map Zone	Zone 35N (24 E to 30 E)

4.2.1 Keyi-24 Side track scenarios:

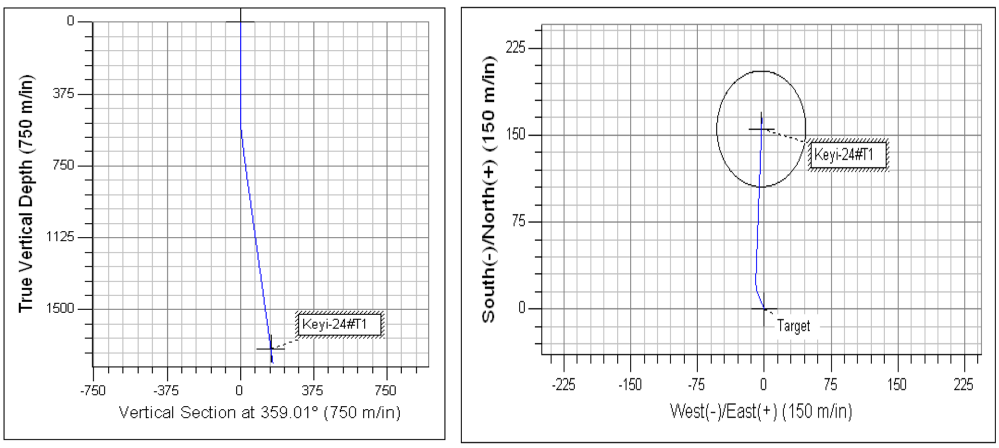
4.2.1.1 Scenario# 1



	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	450.00		0.00	358.76	450.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	480.00	30.00	0.00	358.76	480.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	564.00	84.00	7.00	330.00	563.79	4.44	-2.56	4.48	2.500	330.00	2.500	0.000	Inc Azi DLS	
4	624.00	60.00	7.00	330.00	623.34	10.77	-6.22	10.88	0.000	0.00	0.000	0.000	Straight MD	
5	750.03	126.03	7.72	2.78	748.39	25.89	-9.65	26.05	1.000	96.75	0.172	7.802	DTS CH Tang	
6	1715.40	965.36	7.72	2.78	1705.00	155.47	-3.37	155.50	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1791.08	75.69	7.72	2.78	1780.00	165.63	-2.88	165.65	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

	MD (m)	TVD (m)	Name	Casing Size (mm)	Hole Size (mm)	String Type
1	450.00	450.00	10 3/4"	273.05	311.15	Casing String
2						

Figure (4.8): Scenario#1 Plan



Vertical Section View Plan View

Figure (4.9): Scenario#1 Plot

KOP@ 480m:

In this Scenario well planned to be kicked-off 30m below the 10 ¾'' casing with 2.5 deg/30m towards 330 deg Azimuth (See Figure 4-8), Build to 7 deg inclination before turning to 2.76 deg Azimuth to avoid colliding with offset Wells, From the anti-collision scan it was confirmed that the closest approach was with Keyi-16 as shown by figures below.

The main challenge in this side track plan was mainly the poor survey quality in previous section as it was surveyed with Mechanical single shot (Totco Surveys) so the generated Ellipse Of Uncertainties (EOU's) were very large which increased the collision risk as the accuracy of the bottom hole location were significantly jeopardized. The mitigation measure proposed from our side to reduce the collision risk was to utilize the MWD tool inclinometers to measure the inclination inside the 10 ¾'' casing and to replace the original Totco surveys to improve the survey quality & to reduce the Ellipses Of Uncertainties (EOU's) but unfortunately the center to center was very close so we have decided to re-plan the trajectory to increase the distance & reduce the collision risk.

..mmary

Site Name Offset Well - Wellbore - Design	Reference Measured Depth (m)	Offset Measured Depth (m)	Distance Between Centres (m)	Distance Between Ellipses (m)	Separation Factor	Warning
Keyi-10						
Keyi-10 - Keyi-10 - Keyi-10						Out of range
Keyi-10 - Keyi-10 - Keyi-10						Out of range
Keyi-10 - Keyi-10 - Keyi-10						Out of range
Keyi-11						
Keyi-11 - Keyi-11 - Keyi-11						Out of range
Keyi-13						
Keyi-13 - Keyi-13 - Keyi-13						Out of range
Keyi-13 - Keyi-13 - Keyi-13						Out of range
Keyi-13 - Keyi-13 - Keyi-13						Out of range
Keyi-14						
Keyi-14 - Keyi-14 - Keyi-14	480.00	480.00	15.00	12.96	7.369	CC, ES, SF
Keyi-15						
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	555.78	555.63	42.52	40.29	19.069	CC
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	570.00	569.75	42.55	40.28	18.751	ES
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	660.00	659.08	44.72	42.16	17.498	SF
Keyi-16						
Keyi-16 - Key-16 - Key-16	701.11	700.38	2.58	-0.13	0.952	Level 1 , CC, ES, SF
Keyi-24						
Keyi-24 - Keyi-24 - Keyi-24	480.00	480.00	0.00	-0.63	0.000	Level 1 , CC, SF
Keyi-24 - Keyi-24 - Keyi-24	1,715.25	1,731.72	0.00	-8.27	0.001	Level 1 , ES

Figure (4.10): Anti-collision Summary Report

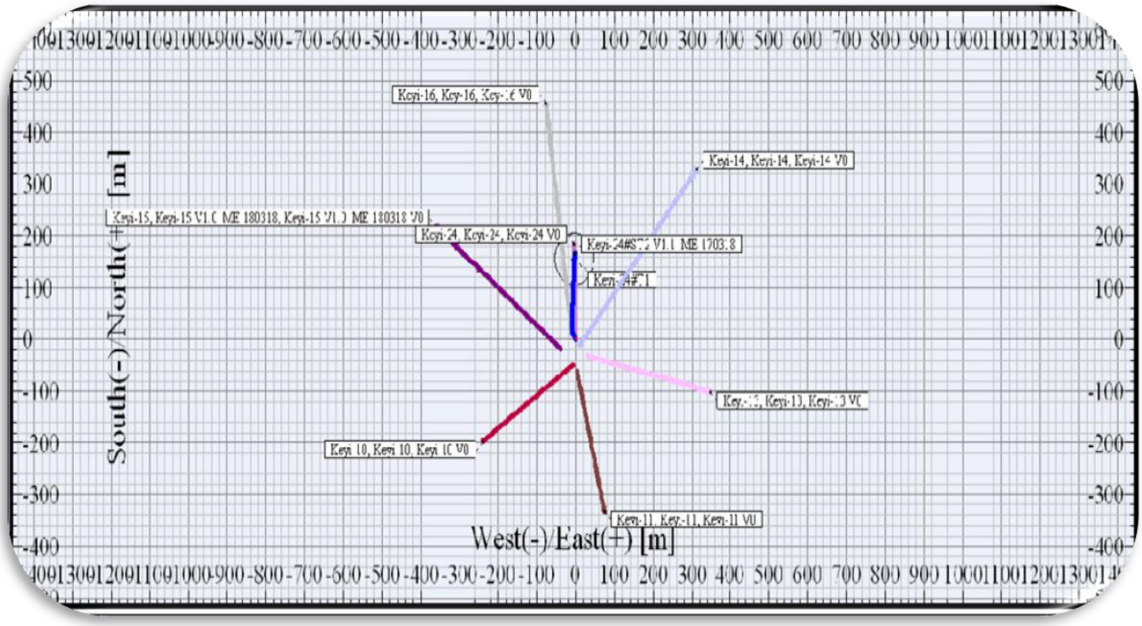


Figure (4.11): Spider Plot

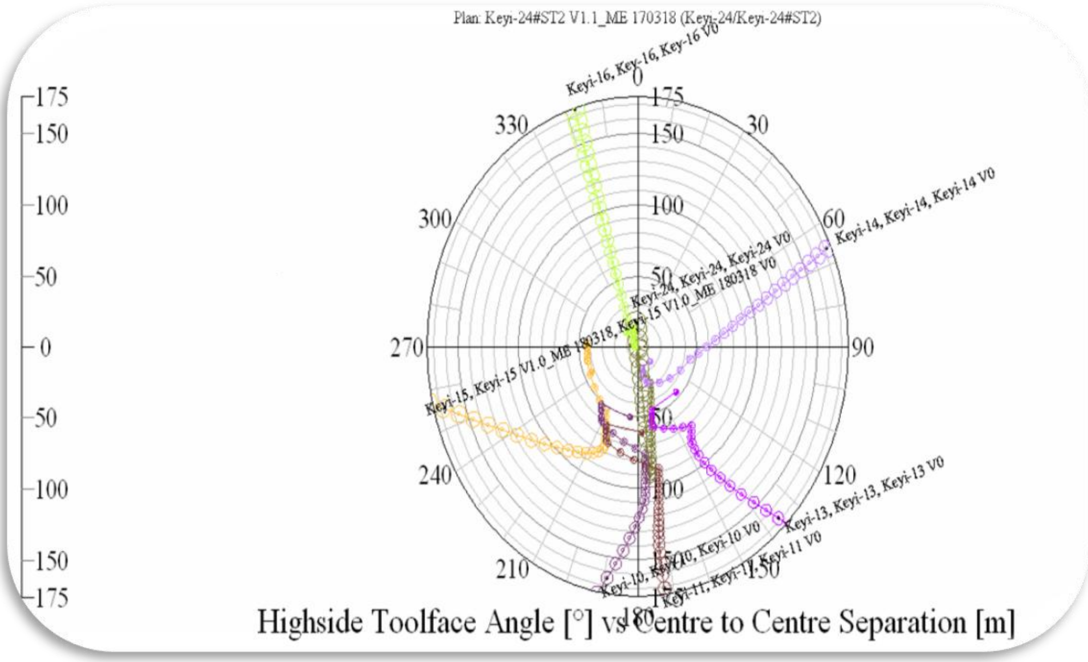


Figure (4.12): Travelling Cylinder (TC) Plot

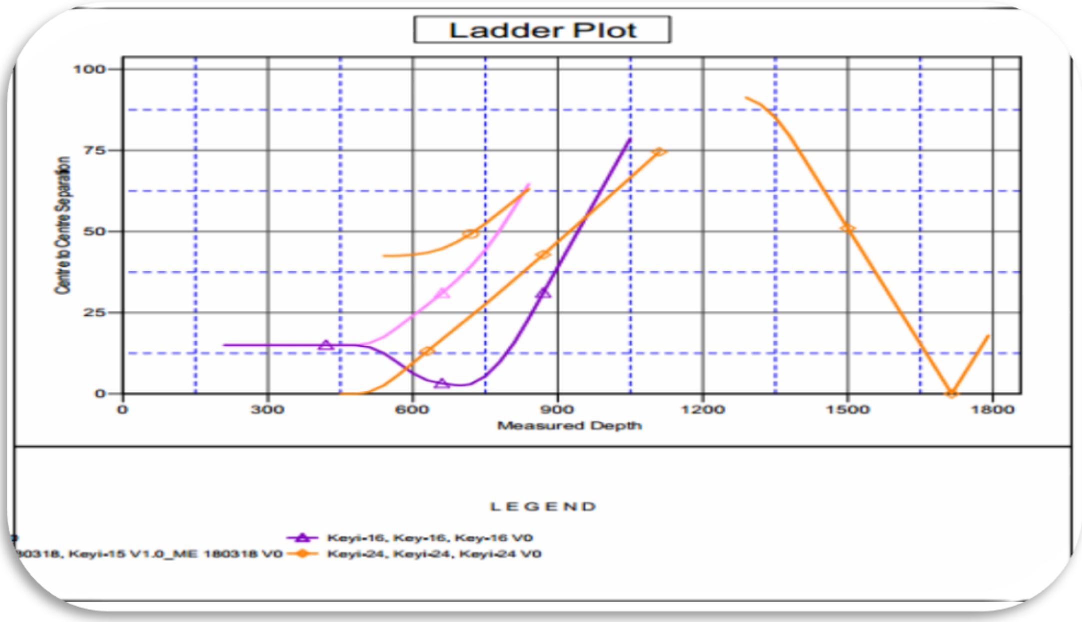
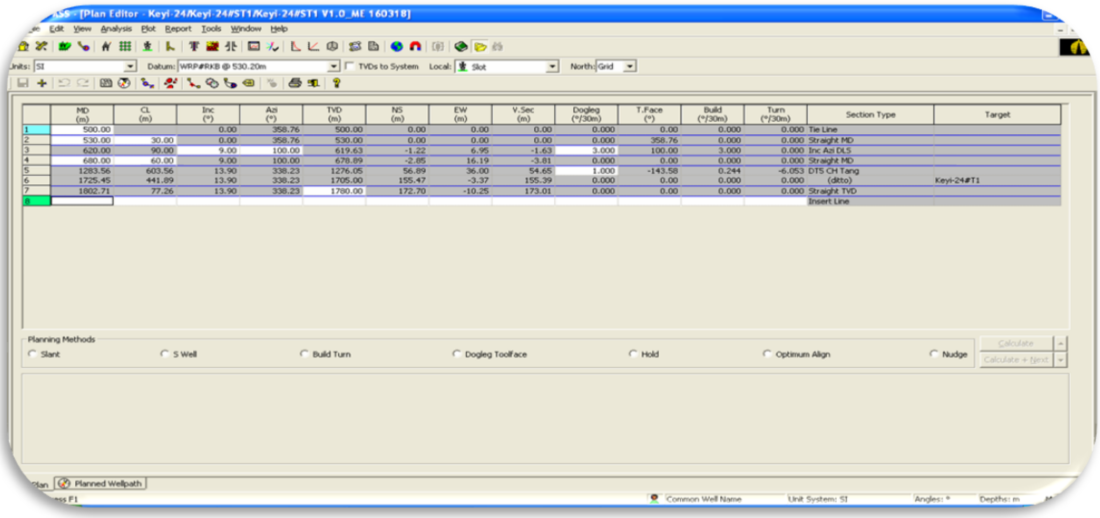


Figure (4.13): Ladder Plot (LP)

The closest center to center distance based on the above Graphs & report was: 2.58m. Based on this analysis this design was rejected due to the high collision risk with **Keyi-16** (existing offset Well).

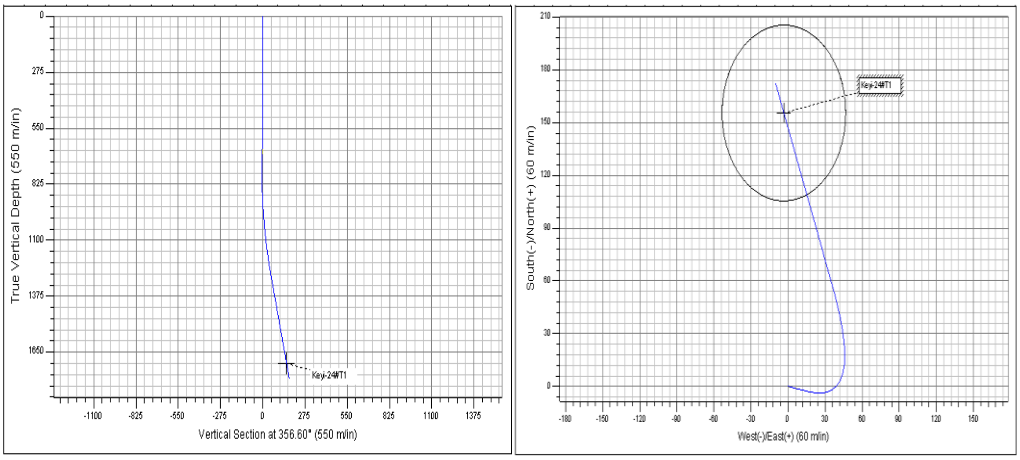
4.2.1.2 Scenario# 2



	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	500.00		0.00	358.76	500.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	530.00	30.00	0.00	358.76	530.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	620.00	90.00	9.00	100.00	619.63	-1.22	6.95	-1.63	3.000	100.00	3.000	0.000	Inc Azi DLS	
4	680.00	60.00	9.00	100.00	678.89	-2.85	16.19	-3.81	0.000	0.00	0.000	0.000	Straight MD	
5	1283.56	603.56	13.90	338.23	1276.05	56.89	36.00	54.65	1.000	-143.58	0.244	-6.053	DTS CH Tang	
6	1725.45	441.89	13.90	338.23	1705.00	155.47	-3.37	155.39	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1802.71	77.26	13.90	338.23	1780.00	172.70	-10.25	173.01	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

#	Measured depth (m)	Incl angle (deg)	Azimuth angle (deg)	Course length (m)	TVD depth (m)	Vertical section (m)	Displ +N/S- (m)	Displ +E/W- (m)	Total displ (m)	At Azim (deg)	DLS (deg/30m)
1	548.64	1.86	100.00	0.00	548.64	-0.07	-0.05	0.30	0.30	100.00	0.00
2	579.12	4.91	100.00	30.48	579.06	-0.49	-0.37	2.07	2.10	100.00	3.00
3	609.60	7.96	100.00	30.48	609.34	-1.28	-0.96	5.44	5.52	100.00	3.00
4	640.08	9.00	100.00	30.48	639.46	-2.36	-1.77	10.04	10.20	100.00	1.02
5	670.56	9.00	100.00	30.48	669.57	-3.47	-2.60	14.74	14.96	100.00	0.00
6	701.04	8.45	97.16	30.48	699.69	-4.47	-3.33	19.34	19.63	99.78	0.69
7	731.52	7.69	92.35	30.48	729.87	-5.09	-3.70	23.60	23.89	98.90	1.00
8	762.00	6.99	86.55	30.48	760.10	-5.29	-3.67	27.49	27.73	97.60	1.00
9	792.48	6.38	79.55	30.48	790.37	-5.08	-3.25	31.01	31.18	95.98	1.00
10	822.96	5.88	71.24	30.48	820.68	-4.46	-2.44	34.15	34.24	94.09	1.00
11	853.44	5.53	61.64	30.48	851.01	-3.43	-1.24	36.92	36.94	91.92	1.00
12	883.92	5.35	51.08	30.48	881.35	-1.98	0.35	39.32	39.32	89.49	1.00
13	914.40	5.36	40.18	30.48	911.70	-0.12	2.33	41.35	41.41	86.77	1.00
14	944.88	5.55	29.68	30.48	942.04	2.14	4.70	42.99	43.25	83.76	1.00
15	975.36	5.92	20.18	30.48	972.37	4.82	7.46	44.27	44.89	80.44	1.00
16	1005.84	6.43	11.98	30.48	1002.67	7.91	10.60	45.16	46.39	76.79	1.00
17	1036.32	7.05	5.10	30.48	1032.94	11.40	14.13	45.68	47.82	72.81	1.00
18	1066.80	7.75	359.38	30.48	1063.17	15.30	18.05	45.83	49.25	68.50	1.00
19	1097.28	8.51	354.64	30.48	1093.34	19.61	22.35	45.59	50.78	63.89	1.00
20	1127.76	9.32	350.71	30.48	1123.45	24.32	27.03	44.98	52.48	59.00	1.00
21	1158.24	10.17	347.41	30.48	1153.49	29.43	32.09	44.00	54.46	53.89	1.00
22	1188.72	11.05	344.62	30.48	1183.45	34.95	37.54	42.64	56.81	48.64	1.00
23	1219.20	11.95	342.24	30.48	1213.32	40.86	43.36	40.90	59.61	43.33	1.00
24	1249.68	12.87	340.19	30.48	1243.09	47.17	49.56	38.79	62.93	38.05	1.00
25	1280.16	13.80	338.41	30.48	1272.75	53.88	56.13	36.30	66.85	32.89	1.00
26	1310.64	13.90	338.23	30.48	1302.34	60.83	62.93	33.59	71.33	28.09	0.11
27	1341.12	13.90	338.23	30.48	1331.92	67.78	69.73	30.87	76.26	23.88	0.00
28	1371.60	13.90	338.23	30.48	1361.51	74.72	76.53	28.16	81.54	20.20	0.00
29	1402.08	13.90	338.23	30.48	1391.10	81.67	83.33	25.44	87.12	16.98	0.00
30	1432.56	13.90	338.23	30.48	1420.69	88.62	90.13	22.73	92.95	14.15	0.00
31	1463.04	13.90	338.23	30.48	1450.27	95.57	96.93	20.01	98.97	11.66	0.00
32	1493.52	13.90	338.23	30.48	1479.86	102.52	103.73	17.29	105.16	9.47	0.00
33	1524.00	13.90	338.23	30.48	1509.45	109.47	110.52	14.58	111.48	7.51	0.00
34	1554.48	13.90	338.23	30.48	1539.04	116.42	117.32	11.86	117.92	5.77	0.00
35	1584.96	13.90	338.23	30.48	1568.62	123.36	124.12	9.15	124.46	4.22	0.00
36	1615.44	13.90	338.23	30.48	1598.21	130.31	130.92	6.43	131.08	2.81	0.00
37	1645.92	13.90	338.23	30.48	1627.80	137.26	137.72	3.72	137.77	1.55	0.00
38	1676.40	13.90	338.23	30.48	1657.39	144.21	144.52	1.00	144.53	0.40	0.00
39	1706.88	13.90	338.23	30.48	1686.97	151.16	151.32	-1.71	151.33	359.35	0.00
[illegible]	1737.36	13.90	338.23	30.48	1716.56	158.11	158.12	-4.43	158.18	358.40	[illegible]

Figure (4.14): Scenario#2 Plan



Vertical Section View Plan View

Figure (4.15): Scenario#2 Plot

KOP@ 530m:

In this Scenario well planned to be kicked-off 80m below the 10 ¾'' casing with 3 deg/30m towards 100 deg Azimuth (figure 4-14), Building to 9deg inclination, 100 deg Azi to 670m MD, Dropping to 5.35 deg inclination (to 883.92m MD), building to 13 deg inclination While turning gradually to 338 deg Azimuth with 1 deg/30m to avoid colliding with offset Wells to 1280m MD, Hold inclination, and Azimuth to TD. (Figure 4-14).

From the anti-collision scan it was confirmed that the closest approach was with Keyi-14 as shown by figures below.

Similar to the previous scenario The main challenge in this side track plan was the poor survey quality in previous section as it was surveyed with Mechanical single shot (Totco Surveys) so the generated Ellipse Of Uncertainties (EOU's) were very large which increased the collision risk as the accuracy of the bottom hole location were significantly jeopardized. The mitigation measure proposed from our side to reduce the collision risk was to utilize the MWD tool inclinometers to measure the inclination inside the 10 ¾" casing & the MWD Standard surveys in the next 80 m below the 10 ¾" casing to improve the survey quality & to reduce the Ellipses Of Uncertainties (EOU's) but unfortunately even the center to center distance had increased comparing to the previous scenario but it was not enough to give us the confident to proceed with this side track.

Summary

Site Name Offset Well - Wellbore - Design	Reference Measured Depth (m)	Offset Measured Depth (m)	Distance Between Centres (m)	Distance Between Ellipses (m)	Separation Factor	Warning
Keyi-10						
Keyi-10 - Keyi-10 - Keyi-10	660.00	659.14	51.32	48.72	19.742	CC, ES
Keyi-10 - Keyi-10 - Keyi-10	720.00	718.45	54.34	51.54	19.406	SF
Keyi-11						
Keyi-11 - Keyi-11 - Keyi-11						Out of range
Keyi-13						
Keyi-13 - Keyi-13 - Keyi-13	773.56	762.37	28.42	25.42	9.484	CC
Keyi-13 - Keyi-13 - Keyi-13	780.00	768.77	28.44	25.42	9.412	ES
Keyi-13 - Keyi-13 - Keyi-13	810.00	798.59	29.01	25.87	9.244	SF
Keyi-14						
Keyi-14 - Keyi-14 - Keyi-14	665.91	665.10	4.32	1.74	1.671	CC, ES, SF
Keyi-15						
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	510.00	510.00	42.72	40.53	19.478	CC, ES
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	570.00	569.97	43.88	41.54	18.796	SF
Keyi-16						
Keyi-16 - Key-16 - Key-16	510.00	510.00	15.00	12.81	6.839	CC, ES
Keyi-16 - Key-16 - Key-16	540.00	540.00	15.07	12.81	6.659	SF

Figure (4.16): Anti-collision Summary Report

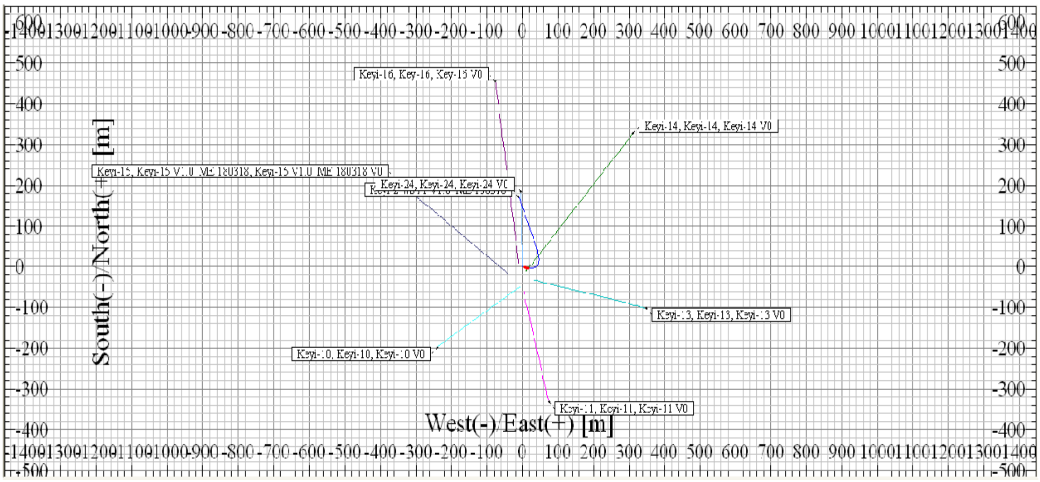


Figure (4.17): Spider Plot

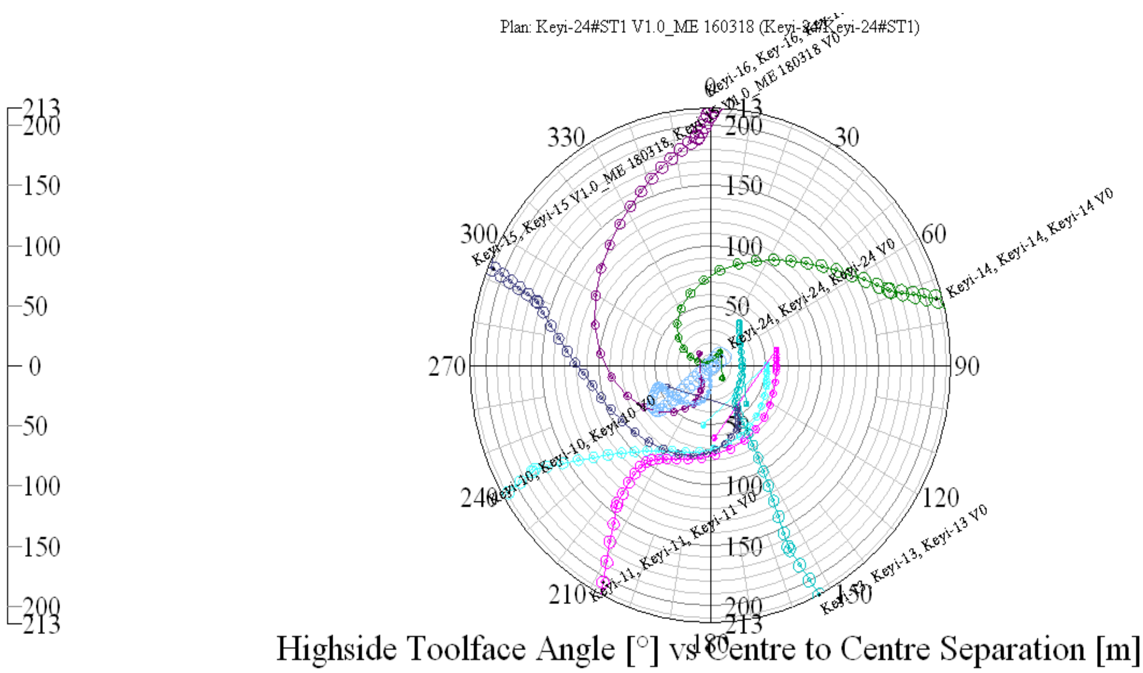


Figure (4.18): Travelling Cylinder (TC) Plot

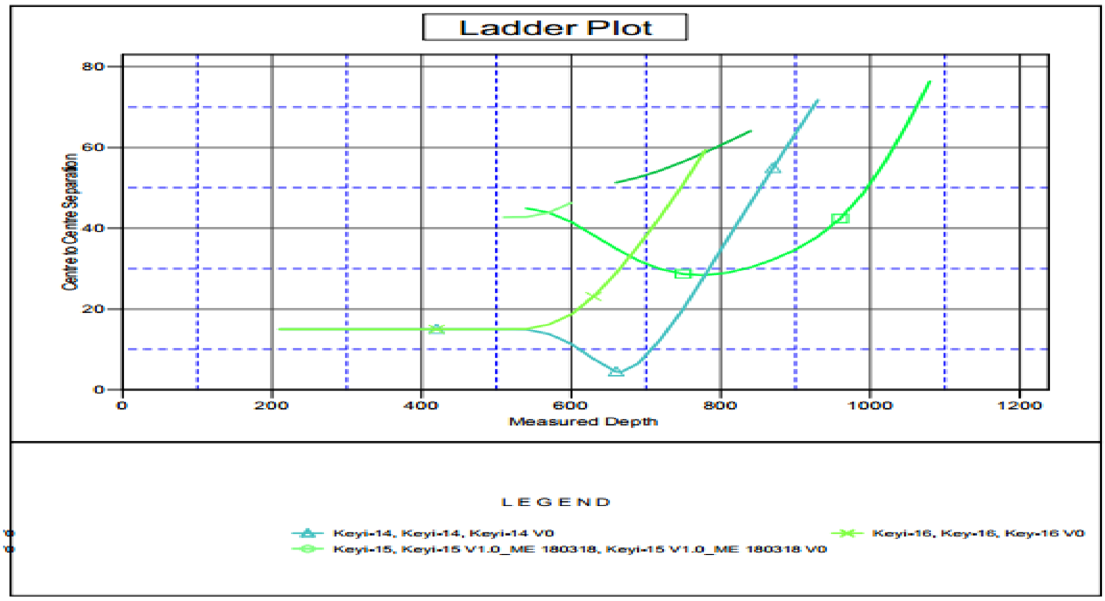
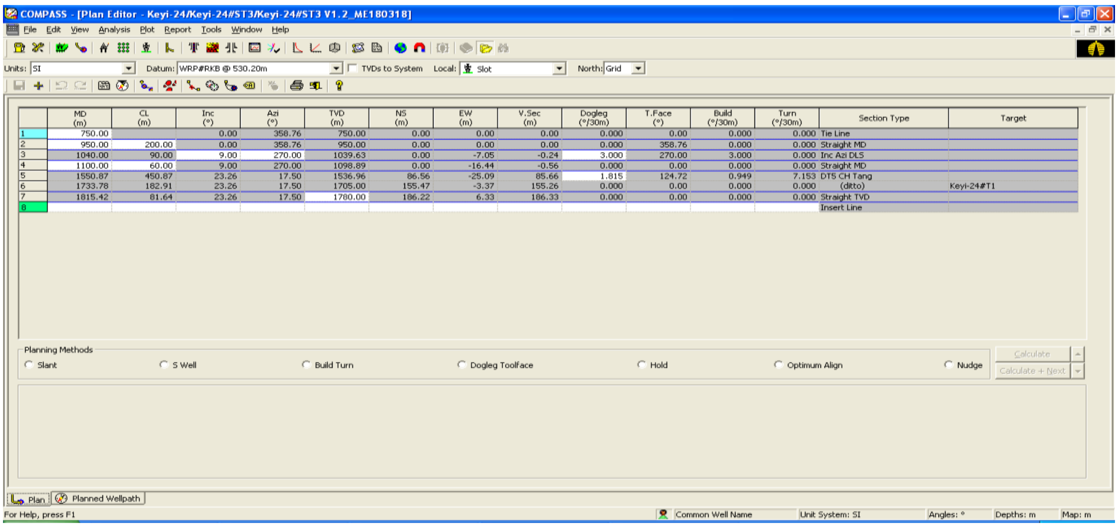


Figure (4.19): Ladder Plot (LP)

The closest center to center distance based on the above Graphs & report was: 4.32m. Based on this analysis this design was rejected due to the high collision risk with **Keyi-14** (existing offset Well) .

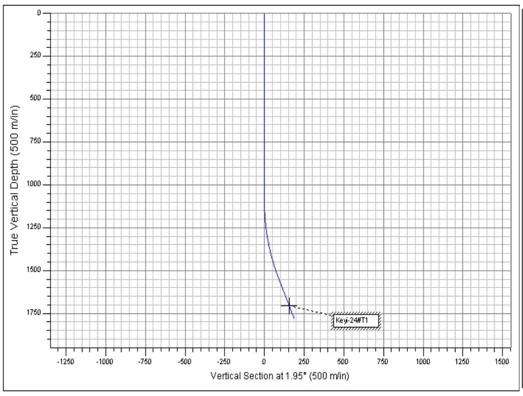
4.2.1.3 Scenario# 3

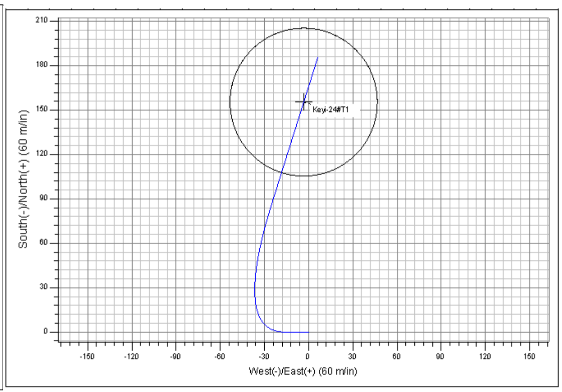


	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	750.00		0.00	358.76	750.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	950.00	200.00	0.00	358.76	950.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	1040.00	90.00	9.00	270.00	1039.63	0.00	-7.05	-0.24	3.000	270.00	3.000	0.000	Inc Azi DLS	
4	1100.00	60.00	9.00	270.00	1098.89	0.00	-16.44	-0.56	0.000	0.00	0.000	0.000	Straight MD	
5	1550.87	450.87	23.26	17.50	1536.96	86.56	-25.09	85.66	1.815	124.72	0.949	7.153	DTS CH Tang	
6	1733.78	182.91	23.26	17.50	1705.00	155.47	-3.37	155.26	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1815.42	81.64	23.26	17.50	1780.00	186.22	6.33	186.33	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

Seq #	Measured depth (m)	Incl angle (deg)	Azimuth angle (deg)	Course length (m)	TVD depth (m)	Vertical section (m)	Displ +N/S- (m)	Displ +E/W- (m)	Total displ (m)	At Azim (deg)	DLS (deg/30m)
1	975.36	2.54	270.00	0.00	975.35	-0.02	0.00	-0.56	0.56	270.00	0.00
2	1005.84	5.58	270.00	30.48	1005.75	-0.09	0.00	-2.72	2.72	270.00	3.00
3	1036.32	8.63	270.00	30.48	1035.99	-0.22	0.00	-6.49	6.49	270.00	3.00
4	1066.80	9.00	270.00	30.48	1066.10	-0.38	0.00	-11.25	11.25	270.00	0.36
5	1097.28	9.00	270.00	30.48	1096.21	-0.54	0.00	-16.01	16.01	270.00	0.00
6	1127.76	8.16	279.77	30.48	1126.34	-0.36	0.33	-20.55	20.56	270.93	1.65
7	1158.24	7.56	292.56	30.48	1156.54	0.64	1.47	-24.54	24.58	273.43	1.82
8	1188.72	7.39	306.71	30.48	1186.76	2.46	3.41	-27.96	28.17	276.96	1.82
9	1219.20	7.67	320.66	30.48	1216.98	5.11	6.16	-30.82	31.43	281.30	1.82
10	1249.68	8.35	332.99	30.48	1247.17	8.57	9.70	-33.12	34.51	286.33	1.82
11	1280.16	9.35	343.09	30.48	1277.28	12.85	14.04	-34.84	37.57	291.95	1.82
12	1310.64	10.58	351.07	30.48	1307.31	17.94	19.18	-36.00	40.79	298.04	1.82
13	1341.12	11.96	357.32	30.48	1337.20	23.84	25.09	-36.58	44.36	304.45	1.82
14	1371.60	13.46	2.24	30.48	1366.93	30.53	31.79	-36.59	48.47	310.99	1.82
15	1402.08	15.03	6.17	30.48	1396.48	38.02	39.27	-36.03	53.29	317.46	1.82
16	1432.56	16.65	9.36	30.48	1425.80	46.29	47.50	-34.89	58.94	323.70	1.82
17	1463.04	18.32	12.00	30.48	1454.87	55.34	56.50	-33.18	65.52	329.57	1.82
18	1493.52	20.01	14.20	30.48	1483.66	65.15	66.24	-30.91	73.10	334.99	1.82
19	1524.00	21.73	16.07	30.48	1512.14	75.72	76.72	-28.07	81.69	339.91	1.82
20	1554.48	23.26	17.50	30.48	1540.28	87.03	87.92	-24.66	91.32	344.33	1.60
21	1584.96	23.26	17.50	30.48	1568.28	98.63	99.40	-21.04	101.61	348.05	0.00
22	1615.44	23.26	17.50	30.48	1596.28	110.23	110.89	-17.42	112.25	351.07	0.00
23	1645.92	23.26	17.50	30.48	1624.28	121.83	122.37	-13.80	123.14	353.56	0.00
24	1676.40	23.26	17.50	30.48	1652.28	133.43	133.85	-10.18	134.24	355.65	0.00
25	1706.88	23.26	17.50	30.48	1680.29	145.03	145.33	-6.56	145.48	357.41	0.00
26	1737.36	23.26	17.50	30.48	1708.29	156.62	156.81	-2.94	156.84	358.92	0.00
27	1767.84	23.26	17.50	30.48	1736.29	168.22	168.30	0.68	168.30	0.23	0.00
28	1798.32	23.26	17.50	30.48	1764.29	179.82	179.78	4.30	179.83	1.37	0.00
29	1815.42	23.26	17.50	17.10	1780.00	186.33	186.22	6.33	186.33	1.95	0.00

Figure (4.20): Scenario#3 Plan





Vertical Section View   Plan View

Figure (4.21): Scenario#3 Plot

KOP@ 950m:

In this Scenario well planned to be kicked-off 400m below the 10 ¾'' casing with 3 deg/30m towards 270 deg Azimuth, Building to 9deg inclination, 270 deg Azi to 1097m MD, Dropping to 7.39 deg inclination (to 1188.72m MD), building to 23 deg inclination While turning gradually to 17 deg Azimuth with 1 deg/30m to avoid colliding with offset Wells to 1554m MD, Hold inclination, and Azimuth to TD (Figure 4-20).

Similar to the above previous two scenarios the main challenge in this side track was mainly due to the poor survey quality in previous section as it was surveyed with Mechanical single shot (Totco Surveys) so the Ellipse Of Uncertainties (EOU's) were very large which increased the collision risk as the accuracy of the bottom hole location were significantly jeopardized. The main value and difference in this scenario comparing to the two other scenarios was the distance below the 10 ¾'' casing up to the Kick Of Point (KOP). This distance has enabled us to significantly improve the survey quality by surveying the entire 400 m up to the KOP by our MWD tool. By replacing the Totco surveys in the previous section by the MWD Inclination surveys & utilized the MWD Standard surveys in the interval below the 10 ¾'' up to the KOP we managed to improve the survey quality and in same time to reduce the produced Ellipses Of Uncertainties (EOU's) so it was the perfect mitigation measure proposed from our side to reduce the collision risk.

From the anti-collision scan it was confirmed that this Scenario is meeting the center to center distances requirements (10-15m) as shown by the graphs below.

Summary						
Site Name Offset Well - Wellbore - Design	Reference Measured Depth (m)	Offset Measured Depth (m)	Distance Between Centres (m)	Distance Between Ellipses (m)	Separation Factor	Warning
Keyi-10						
Keyi-10 - Keyi-10 - Keyi-10	946.52	946.52	49.99	46.18	13.128 CC, ES	
Keyi-10 - Keyi-10 - Keyi-10	990.00	987.84	50.66	46.74	12.911 SF	
Keyi-11						
Keyi-11 - Keyi-11 - Keyi-11	930.00	930.00	60.21	56.45	16.003 CC	
Keyi-11 - Keyi-11 - Keyi-11	960.00	960.00	60.21	56.37	15.660 ES	
Keyi-11 - Keyi-11 - Keyi-11	1,080.00	1,079.14	62.42	58.22	14.857 SF	
Keyi-13						
Keyi-13 - Keyi-13 - Keyi-13	799.73	790.53	45.00	41.58	13.155 CC	
Keyi-13 - Keyi-13 - Keyi-13	810.00	800.75	45.00	41.56	13.065 ES	
Keyi-13 - Keyi-13 - Keyi-13	840.00	828.86	45.66	42.14	12.996 SF	
Keyi-14						
Keyi-14 - Keyi-14 - Keyi-14	581.64	581.65	14.98	12.45	5.927 CC	
Keyi-14 - Keyi-14 - Keyi-14	600.00	599.95	15.03	12.42	5.761 ES	
Keyi-14 - Keyi-14 - Keyi-14	630.00	629.61	15.69	12.95	5.716 SF	
Keyi-15						
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	900.00	900.00	42.72	39.04	11.605 CC, ES	
Keyi-15 - Keyi-15 V1.0_ME 180318 - Keyi-15 V1.0_ME 180318	1,050.00	1,042.90	45.88	41.82	11.309 SF	
Keyi-16						
Keyi-16 - Key-16 - Key-16	600.00	600.00	15.00	12.39	5.749 CC, ES	
Keyi-16 - Key-16 - Key-16	630.00	629.36	15.62	12.88	5.697 SF	
Keyi-24						
Keyi-24 - Keyi-24 - Keyi-24	930.00	930.00	0.00	-1.72	0.000 Level 1 , CC, SF	
Keyi-24 - Keyi-24 - Keyi-24	1,740.00	1,738.03	0.79	-6.83	0.103 Level 1 , ES	

Figure (4.22): Anti-collision Summary Report

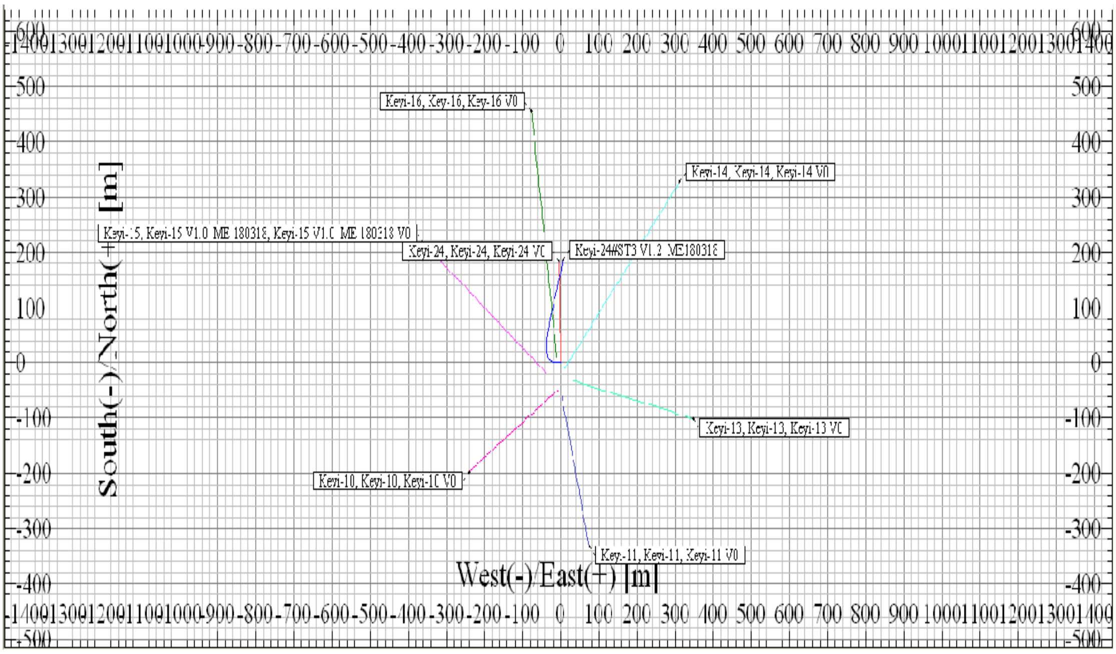


Figure (4.23): Spider Plot

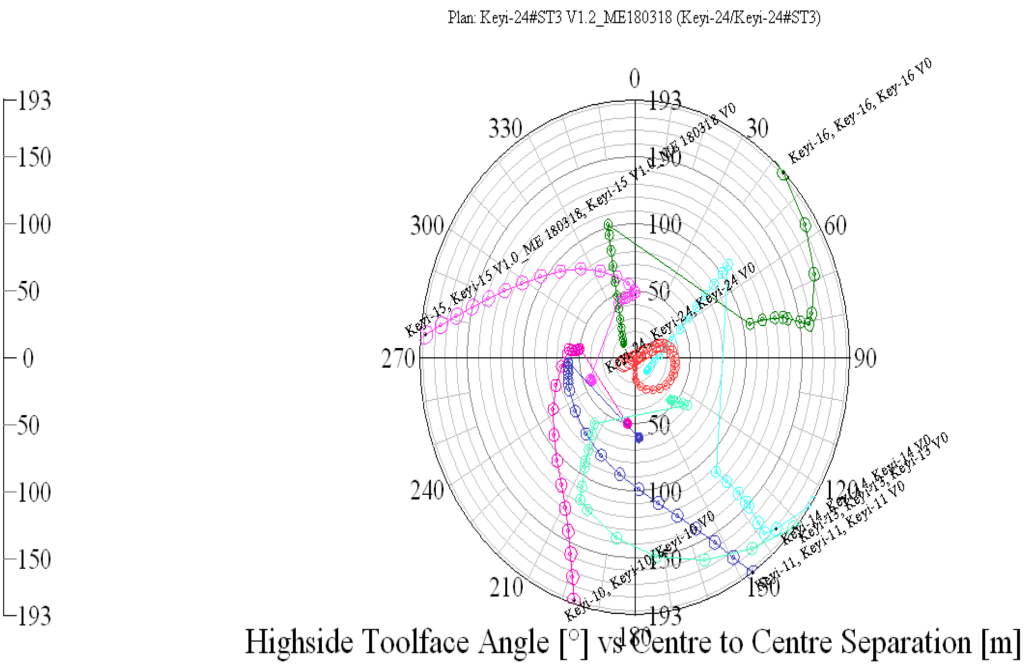


Figure (4.24): Travelling Cylinder (TC) Plot

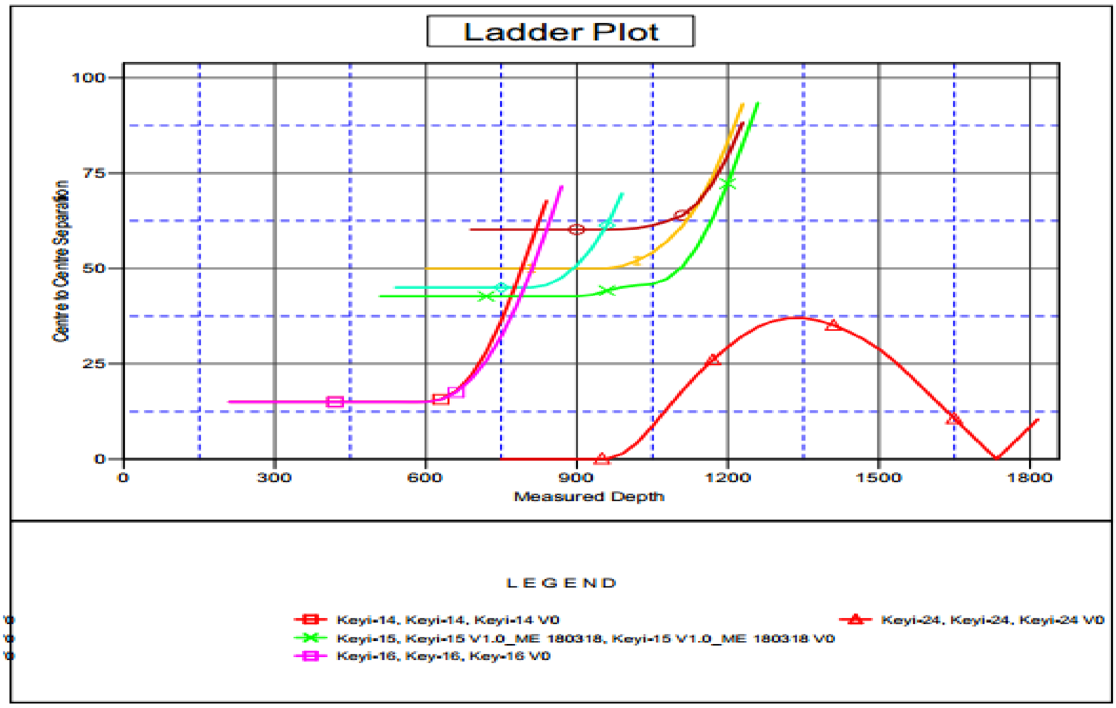
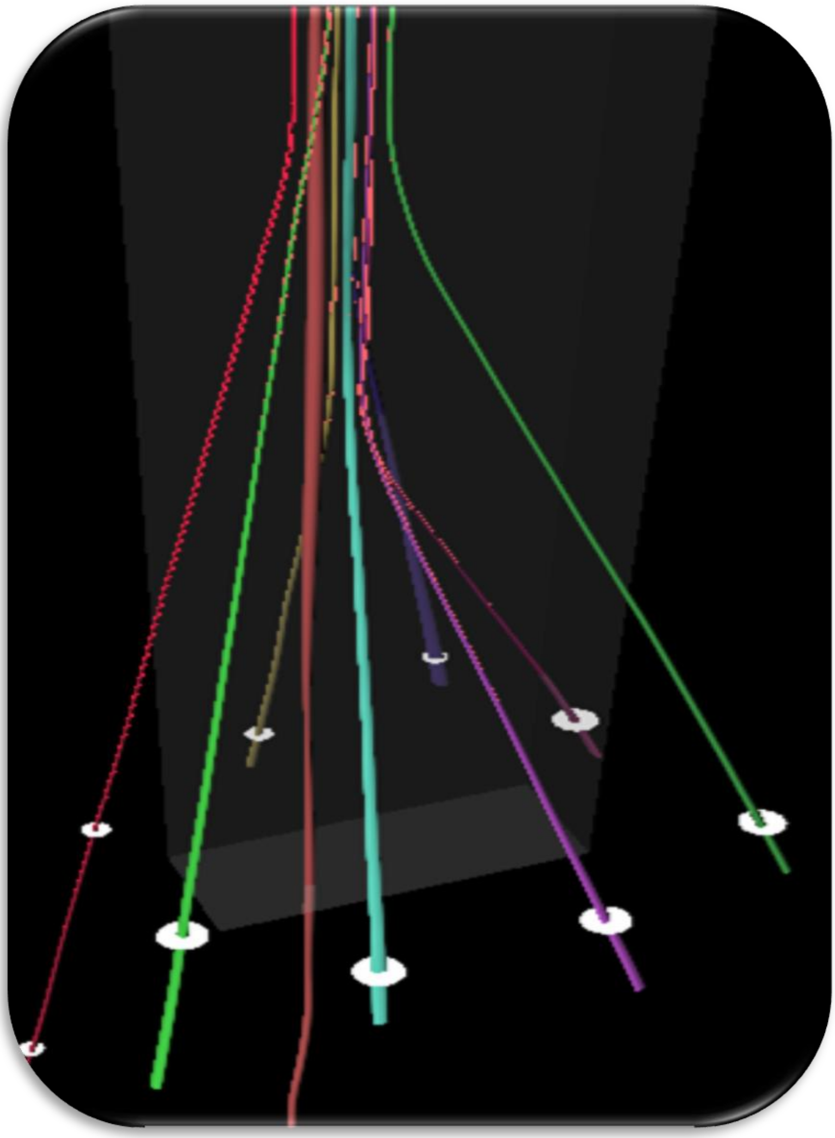


Figure (4.25): Ladder Plot (LP)

Based on the above analysis this design is meeting the design center to center requirements (10-15m), and can be accepted as optimum design.

Chapter Five

Conclusion and Recommendations



Chapter Five

Conclusion and Recommendations

5.1 Conclusion:

Three side track plans with different kick off points (KOP) were prepared in order to optimize the well plan and to reduce the associated side track risks.

Proper risk analysis was done for every proposed side track plan by utilizing the Hazard Analysis and Risk Control Techniques (HARC) to list all expected risks and propose the proper mitigation actions.

- **First ST Plan (KOP#480m)**: KOP 30m below 10 ¾'' casing shoe, Big Ellipses generated due to the very short distance below the casing shoe which led to bad MWD surveys due to the magnetic interference, Center to center distance is 2.58m, SF= 0.957<1 , Plan rejected.
- **Second ST Plan (KOP#530m)**: KOP 80m below 10 ¾'' casing shoe, Reasonable Ellipses generated due the good interval below the casing shoe so better MWD surveys were obtained, Center to center distance is 4.32m, SF= 1.74 >1.5 (Can be drilled with proper risk analysis & mitigation measures), After discussion we decided to go for further optimization.
- **Third ST Plan (KOP#950m)**: KOP 400m below 10 ¾'' casing shoe, Small Ellipses generated due the long interval below the casing shoe which enabled the MWD tool to obtain an excellent surveys , Center to center distance is 15.00m, SF= 5.72 >5.0 (Well can be drilled with no issues), Approved side track plan.

Based on the analysis for the three side track scenarios,

The Third scenario (KOP#950m) was selected as the optimum ST plan

5.2 Recommendations

1- For future design 15m Center to Center distance is the optimum separation between well as it will reduce the risk of collision with adjacent wells.

2- Re-survey the previous drilled section inside the casing utilizing the MWD tool to reduce the well bore Uncertainty.

3- Update the Client survey database with the proper MWD surveys to reduce the collision risk in the upcoming project.

4- Plan to have Gyro surveys in the future side-tack plans to reduce the collision risk even further by having accurate well bore positioning.

5- Design the future side-track plans with deep kick-off point (KOP) for the following two reasons:

- Get clear MWD surveys as no magnetic interference from the Casing shoe.
- Good quality MWD surveys will reduce the Ellipse of Uncertainties (EOU's) and Minimize the collision risks

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Appendix

Keyi-10 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	237.67	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	237.67	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	237.67	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	237.67	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	237.67	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	237.67	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	237.67	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	237.67	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	237.67	250.00	0.00	0.00	0.00	0.000	MWD (2)
11	270.00	0.00	237.67	270.00	0.00	0.00	0.00	0.000	MWD (2)
12	300.00	0.00	237.67	300.00	0.00	0.00	0.00	0.000	MWD (2)
13	330.00	0.00	237.67	330.00	0.00	0.00	0.00	0.000	MWD (2)
14	360.00	0.00	237.67	360.00	0.00	0.00	0.00	0.000	MWD (2)
15	390.00	0.00	237.67	390.00	0.00	0.00	0.00	0.000	MWD (2)
16	420.00	0.00	237.67	420.00	0.00	0.00	0.00	0.000	MWD (2)
17	450.00	0.00	237.67	450.00	0.00	0.00	0.00	0.000	MWD (2)
18	480.00	0.00	237.67	480.00	0.00	0.00	0.00	0.000	MWD (2)
19	510.00	0.00	237.67	510.00	0.00	0.00	0.00	0.000	MWD (2)
20	540.00	0.00	237.67	540.00	0.00	0.00	0.00	0.000	MWD (2)
21	570.00	0.00	237.67	570.00	0.00	0.00	0.00	0.000	MWD (2)
22	600.00	0.00	237.67	600.00	0.00	0.00	0.00	0.000	MWD (2)
23	630.00	0.00	237.67	630.00	0.00	0.00	0.00	0.000	MWD (2)
24	660.00	0.00	237.67	660.00	0.00	0.00	0.00	0.000	MWD (2)
25	690.00	0.00	237.67	690.00	0.00	0.00	0.00	0.000	MWD (2)
26	720.00	0.00	237.67	720.00	0.00	0.00	0.00	0.000	MWD (2)
27	750.00	0.00	237.67	750.00	0.00	0.00	0.00	0.000	MWD (2)
28	780.00	0.00	237.67	780.00	0.00	0.00	0.00	0.000	MWD (2)
29	810.00	0.00	237.67	810.00	0.00	0.00	0.00	0.000	MWD (2)
30	840.00	0.00	237.67	840.00	0.00	0.00	0.00	0.000	MWD (2)
31	870.00	0.00	237.67	870.00	0.00	0.00	0.00	0.000	MWD (2)
32	900.00	0.00	237.67	900.00	0.00	0.00	0.00	0.000	MWD (2)
33	930.00	0.00	237.67	930.00	0.00	0.00	0.00	0.000	MWD (2)
34	950.00	0.00	237.67	950.00	0.00	0.00	0.00	0.000	MWD (2)
35	960.00	1.00	237.67	960.00	-0.05	-0.07	0.09	3.000	MWD (2)
36	990.00	4.00	237.67	989.97	-0.75	-1.18	1.40	3.000	MWD (2)
37	1020.00	7.00	237.67	1019.83	-2.28	-3.61	4.27	3.000	MWD (2)
38	1050.00	10.00	237.67	1049.49	-4.66	-7.36	8.70	3.000	MWD (2)
39	1080.00	13.00	237.67	1078.89	-7.85	-12.41	14.68	3.000	MWD (2)
40	1110.00	16.00	237.67	1107.93	-11.87	-18.75	22.20	3.000	MWD (2)
41	1140.00	19.00	237.67	1136.54	-16.69	-26.38	31.22	3.000	MWD (2)
42	1158.09	20.81	237.67	1153.55	-19.99	-31.58	37.37	3.002	MWD (2)
43	1170.00	20.81	237.67	1164.68	-22.25	-35.16	41.61	0.000	MWD (2)
44	1200.00	20.81	237.67	1192.72	-27.95	-44.16	52.26	0.000	MWD (2)
45	1230.00	20.81	237.67	1220.76	-33.65	-53.17	62.92	0.000	MWD (2)
46	1260.00	20.81	237.67	1248.81	-39.35	-62.17	73.58	0.000	MWD (2)
47	1290.00	20.81	237.67	1276.85	-45.05	-71.18	84.24	0.000	MWD (2)
48	1320.00	20.81	237.67	1304.89	-50.75	-80.19	94.90	0.000	MWD (2)
49	1350.00	20.81	237.67	1332.94	-56.45	-89.19	105.55	0.000	MWD (2)
50	1380.00	20.81	237.67	1360.98	-62.15	-98.20	116.21	0.000	MWD (2)
51	1410.00	20.81	237.67	1389.02	-67.85	-107.20	126.87	0.000	MWD (2)
52	1440.00	20.81	237.67	1417.06	-73.55	-116.21	137.53	0.000	MWD (2)
53	1470.00	20.81	237.67	1445.11	-79.25	-125.21	148.19	0.000	MWD (2)
54	1500.00	20.81	237.67	1473.15	-84.95	-134.22	158.84	0.000	MWD (2)
55	1530.00	20.81	237.67	1501.19	-90.65	-143.23	169.50	0.000	MWD (2)
56	1560.00	20.81	237.67	1529.24	-96.35	-152.23	180.16	0.000	MWD (2)
57	1590.00	20.81	237.67	1557.28	-102.05	-161.24	190.82	0.000	MWD (2)
58	1620.00	20.81	237.67	1585.32	-107.75	-170.24	201.48	0.000	MWD (2)
59	1650.00	20.81	237.67	1613.36	-113.45	-179.25	212.14	0.000	MWD (2)
60	1680.00	20.81	237.67	1641.41	-119.15	-188.26	222.79	0.000	MWD (2)
61	1710.00	20.81	237.67	1669.45	-124.85	-197.26	233.45	0.000	MWD (2)
62	1731.98	20.81	237.67	1690.00	-129.02	-203.86	241.26	0.000	MWD (2)
63	1740.00	20.81	237.67	1697.49	-130.55	-206.27	244.11	0.000	MWD (2)
64	1770.00	20.81	237.67	1725.54	-136.25	-215.27	254.77	0.000	MWD (2)
65	1800.00	20.81	237.67	1753.58	-141.95	-224.28	265.43	0.000	MWD (2)
66	1828.26	20.81	237.67	1780.00	-147.32	-232.76	275.47	0.000	MWD (2)

Keyi-11 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	165.50	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	165.50	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	165.50	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	165.50	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	165.50	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	165.50	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	165.50	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	165.50	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	165.50	250.00	0.00	0.00	0.00	0.000	MWD (2)
11	270.00	0.00	165.50	270.00	0.00	0.00	0.00	0.000	MWD (2)
12	300.00	0.00	165.50	300.00	0.00	0.00	0.00	0.000	MWD (2)
13	330.00	0.00	165.50	330.00	0.00	0.00	0.00	0.000	MWD (2)
14	360.00	0.00	165.50	360.00	0.00	0.00	0.00	0.000	MWD (2)
15	390.00	0.00	165.50	390.00	0.00	0.00	0.00	0.000	MWD (2)
16	420.00	0.00	165.50	420.00	0.00	0.00	0.00	0.000	MWD (2)
17	450.00	0.00	165.50	450.00	0.00	0.00	0.00	0.000	MWD (2)
18	480.00	0.00	165.50	480.00	0.00	0.00	0.00	0.000	MWD (2)
19	510.00	0.00	165.50	510.00	0.00	0.00	0.00	0.000	MWD (2)
20	540.00	0.00	165.50	540.00	0.00	0.00	0.00	0.000	MWD (2)
21	570.00	0.00	165.50	570.00	0.00	0.00	0.00	0.000	MWD (2)
22	600.00	0.00	165.50	600.00	0.00	0.00	0.00	0.000	MWD (2)
23	630.00	0.00	165.50	630.00	0.00	0.00	0.00	0.000	MWD (2)
24	660.00	0.00	165.50	660.00	0.00	0.00	0.00	0.000	MWD (2)
25	690.00	0.00	165.50	690.00	0.00	0.00	0.00	0.000	MWD (2)
26	720.00	0.00	165.50	720.00	0.00	0.00	0.00	0.000	MWD (2)
27	750.00	0.00	165.50	750.00	0.00	0.00	0.00	0.000	MWD (2)
28	780.00	0.00	165.50	780.00	0.00	0.00	0.00	0.000	MWD (2)
29	810.00	0.00	165.50	810.00	0.00	0.00	0.00	0.000	MWD (2)
30	840.00	0.00	165.50	840.00	0.00	0.00	0.00	0.000	MWD (2)
31	870.00	0.00	165.50	870.00	0.00	0.00	0.00	0.000	MWD (2)
32	900.00	0.00	165.50	900.00	0.00	0.00	0.00	0.000	MWD (2)
33	930.00	0.00	165.50	930.00	0.00	0.00	0.00	0.000	MWD (2)
34	960.00	0.00	165.50	960.00	0.00	0.00	0.00	0.000	MWD (2)
35	990.00	0.00	165.50	990.00	0.00	0.00	0.00	0.000	MWD (2)
36	1020.00	0.00	165.50	1020.00	0.00	0.00	0.00	0.000	MWD (2)
37	1050.00	0.00	165.50	1050.00	0.00	0.00	0.00	0.000	MWD (2)
38	1080.00	0.00	165.50	1080.00	0.00	0.00	0.00	0.000	MWD (2)
39	1100.00	0.00	165.50	1100.00	0.00	0.00	0.00	0.000	MWD (2)
40	1110.00	1.00	165.50	1110.00	-0.08	0.02	0.09	3.000	MWD (2)
41	1140.00	4.00	165.50	1139.97	-1.35	0.35	1.40	3.000	MWD (2)
42	1170.00	7.00	165.50	1169.83	-4.13	1.07	4.27	3.000	MWD (2)
43	1200.00	10.00	165.50	1199.49	-8.43	2.18	8.70	3.000	MWD (2)
44	1230.00	13.00	165.50	1228.89	-14.22	3.68	14.68	3.000	MWD (2)
45	1260.00	16.00	165.50	1257.93	-21.49	5.56	22.20	3.000	MWD (2)
46	1290.00	19.00	165.50	1286.54	-30.22	7.82	31.22	3.000	MWD (2)
47	1320.00	22.00	165.50	1314.63	-40.39	10.45	41.72	3.000	MWD (2)
48	1350.00	25.00	165.50	1342.14	-51.97	13.44	53.68	3.000	MWD (2)
49	1373.61	27.36	165.50	1363.33	-62.06	16.05	64.10	2.999	MWD (2)
50	1380.00	27.36	165.50	1369.00	-64.90	16.78	67.03	0.000	MWD (2)
51	1410.00	27.36	165.50	1395.65	-78.25	20.24	80.82	0.000	MWD (2)
52	1440.00	27.36	165.50	1422.29	-91.60	23.69	94.61	0.000	MWD (2)
53	1470.00	27.36	165.50	1448.94	-104.94	27.14	108.40	0.000	MWD (2)
54	1500.00	27.36	165.50	1475.58	-118.29	30.59	122.18	0.000	MWD (2)
55	1530.00	27.36	165.50	1502.22	-131.64	34.04	135.97	0.000	MWD (2)
56	1560.00	27.36	165.50	1528.87	-144.99	37.50	149.76	0.000	MWD (2)
57	1590.00	27.36	165.50	1555.51	-158.34	40.95	163.55	0.000	MWD (2)
58	1620.00	27.36	165.50	1582.16	-171.68	44.40	177.33	0.000	MWD (2)
59	1650.00	27.36	165.50	1608.80	-185.03	47.85	191.12	0.000	MWD (2)
60	1680.00	27.36	165.50	1635.44	-198.38	51.30	204.91	0.000	MWD (2)
61	1710.00	27.36	165.50	1662.09	-211.73	54.76	218.70	0.000	MWD (2)
62	1740.00	27.36	165.50	1688.73	-225.08	58.21	232.48	0.000	MWD (2)
63	1741.43	27.36	165.50	1690.00	-225.71	58.37	233.14	0.000	MWD (2)
64	1770.00	27.36	165.50	1715.38	-238.43	61.66	246.27	0.000	MWD (2)
65	1800.00	27.36	165.50	1742.02	-251.77	65.11	260.06	0.000	MWD (2)
66	1830.00	27.36	165.50	1768.67	-265.12	68.57	273.85	0.000	MWD (2)

Keyi-13 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	102.39	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	102.39	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	102.39	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	102.39	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	102.39	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	102.39	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	102.39	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	102.39	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	102.39	250.00	0.00	0.00	0.00	0.000	MWD (2)
11	270.00	0.00	102.39	270.00	0.00	0.00	0.00	0.000	MWD (2)
12	300.00	0.00	102.39	300.00	0.00	0.00	0.00	0.000	MWD (2)
13	330.00	0.00	102.39	330.00	0.00	0.00	0.00	0.000	MWD (2)
14	360.00	0.00	102.39	360.00	0.00	0.00	0.00	0.000	MWD (2)
15	390.00	0.00	102.39	390.00	0.00	0.00	0.00	0.000	MWD (2)
16	420.00	0.00	102.39	420.00	0.00	0.00	0.00	0.000	MWD (2)
17	450.00	0.00	102.39	450.00	0.00	0.00	0.00	0.000	MWD (2)
18	480.00	0.00	102.39	480.00	0.00	0.00	0.00	0.000	MWD (2)
19	510.00	0.00	102.39	510.00	0.00	0.00	0.00	0.000	MWD (2)
20	540.00	0.00	102.39	540.00	0.00	0.00	0.00	0.000	MWD (2)
21	570.00	0.00	102.39	570.00	0.00	0.00	0.00	0.000	MWD (2)
22	600.00	0.00	102.39	600.00	0.00	0.00	0.00	0.000	MWD (2)
23	630.00	0.00	102.39	630.00	0.00	0.00	0.00	0.000	MWD (2)
24	660.00	0.00	102.39	660.00	0.00	0.00	0.00	0.000	MWD (2)
25	690.00	0.00	102.39	690.00	0.00	0.00	0.00	0.000	MWD (2)
26	720.00	0.00	102.39	720.00	0.00	0.00	0.00	0.000	MWD (2)
27	750.00	0.00	102.39	750.00	0.00	0.00	0.00	0.000	MWD (2)
28	780.00	0.00	102.39	780.00	0.00	0.00	0.00	0.000	MWD (2)
29	800.00	0.00	102.39	800.00	0.00	0.00	0.00	0.000	MWD (2)
30	810.00	1.00	102.39	810.00	-0.02	0.09	0.09	3.000	MWD (2)
31	840.00	4.00	102.39	839.97	-0.30	1.36	1.40	3.000	MWD (2)
32	870.00	7.00	102.39	869.83	-0.92	4.17	4.27	3.000	MWD (2)
33	900.00	10.00	102.39	899.49	-1.87	8.50	8.70	3.000	MWD (2)
34	930.00	13.00	102.39	928.89	-3.15	14.34	14.68	3.000	MWD (2)
35	960.00	16.00	102.39	957.93	-4.76	21.68	22.20	3.000	MWD (2)
36	990.00	19.00	102.39	986.54	-6.70	30.49	31.22	3.000	MWD (2)
37	1002.28	20.23	102.39	998.10	-7.58	34.51	35.34	3.005	MWD (2)
38	1020.00	20.23	102.39	1014.73	-8.90	40.50	41.47	0.000	MWD (2)
39	1050.00	20.23	102.39	1042.88	-11.12	50.63	51.84	0.000	MWD (2)
40	1080.00	20.23	102.39	1071.03	-13.35	60.76	62.21	0.000	MWD (2)
41	1110.00	20.23	102.39	1099.18	-15.57	70.90	72.59	0.000	MWD (2)
42	1140.00	20.23	102.39	1127.33	-17.80	81.03	82.96	0.000	MWD (2)
43	1170.00	20.23	102.39	1155.48	-20.03	91.16	93.33	0.000	MWD (2)
44	1200.00	20.23	102.39	1183.63	-22.25	101.29	103.71	0.000	MWD (2)
45	1230.00	20.23	102.39	1211.78	-24.48	111.42	114.08	0.000	MWD (2)
46	1260.00	20.23	102.39	1239.93	-26.70	121.56	124.45	0.000	MWD (2)
47	1290.00	20.23	102.39	1268.08	-28.93	131.69	134.83	0.000	MWD (2)
48	1320.00	20.23	102.39	1296.22	-31.16	141.82	145.20	0.000	MWD (2)
49	1350.00	20.23	102.39	1324.37	-33.38	151.95	155.58	0.000	MWD (2)
50	1380.00	20.23	102.39	1352.52	-35.61	162.08	165.95	0.000	MWD (2)
51	1410.00	20.23	102.39	1380.67	-37.83	172.22	176.32	0.000	MWD (2)
52	1440.00	20.23	102.39	1408.82	-40.06	182.35	186.70	0.000	MWD (2)
53	1470.00	20.23	102.39	1436.97	-42.28	192.48	197.07	0.000	MWD (2)
54	1500.00	20.23	102.39	1465.12	-44.51	202.61	207.44	0.000	MWD (2)
55	1530.00	20.23	102.39	1493.27	-46.74	212.74	217.82	0.000	MWD (2)
56	1560.00	20.23	102.39	1521.42	-48.96	222.88	228.19	0.000	MWD (2)
57	1590.00	20.23	102.39	1549.57	-51.19	233.01	238.57	0.000	MWD (2)
58	1620.00	20.23	102.39	1577.72	-53.41	243.14	248.94	0.000	MWD (2)
59	1650.00	20.23	102.39	1605.87	-55.64	253.27	259.31	0.000	MWD (2)
60	1680.00	20.23	102.39	1634.02	-57.87	263.41	269.69	0.000	MWD (2)
61	1710.00	20.23	102.39	1662.17	-60.09	273.54	280.06	0.000	MWD (2)
62	1740.00	20.23	102.39	1690.32	-62.32	283.67	290.43	0.000	MWD (2)
63	1760.97	20.23	102.39	1709.99	-63.87	290.75	297.68	0.000	MWD (2)
64	1770.00	20.23	102.39	1718.46	-64.54	293.80	300.81	0.000	MWD (2)
65	1800.00	20.23	102.39	1746.61	-66.77	303.93	311.18	0.000	MWD (2)
66	1830.00	20.23	102.39	1774.76	-68.99	314.07	321.55	0.000	MWD (2)

Keyi-14 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	41.66	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	41.66	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	41.66	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	41.66	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	41.66	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	41.66	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	41.66	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	41.66	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	41.66	250.00	0.00	0.00	0.00	0.000	MWD (2)
11	270.00	0.00	41.66	270.00	0.00	0.00	0.00	0.000	MWD (2)
12	300.00	0.00	41.66	300.00	0.00	0.00	0.00	0.000	MWD (2)
13	330.00	0.00	41.66	330.00	0.00	0.00	0.00	0.000	MWD (2)
14	360.00	0.00	41.66	360.00	0.00	0.00	0.00	0.000	MWD (2)
15	390.00	0.00	41.66	390.00	0.00	0.00	0.00	0.000	MWD (2)
16	420.00	0.00	41.66	420.00	0.00	0.00	0.00	0.000	MWD (2)
17	450.00	0.00	41.66	450.00	0.00	0.00	0.00	0.000	MWD (2)
18	480.00	0.00	41.66	480.00	0.00	0.00	0.00	0.000	MWD (2)
19	510.00	0.00	41.66	510.00	0.00	0.00	0.00	0.000	MWD (2)
20	540.00	0.00	41.66	540.00	0.00	0.00	0.00	0.000	MWD (2)
21	550.00	0.00	41.66	550.00	0.00	0.00	0.00	0.000	MWD (2)
22	570.00	2.00	41.66	570.00	0.26	0.23	0.35	3.000	MWD (2)
23	600.00	5.00	41.66	599.94	1.63	1.45	2.18	3.000	MWD (2)
24	630.00	8.00	41.66	629.74	4.17	3.71	5.58	3.000	MWD (2)
25	660.00	11.00	41.66	659.33	7.86	7.00	10.53	3.000	MWD (2)
26	690.00	14.00	41.66	688.61	12.72	11.31	17.02	3.000	MWD (2)
27	720.00	17.00	41.66	717.52	18.70	16.64	25.04	3.000	MWD (2)
28	750.00	20.00	41.66	745.96	25.82	22.97	34.55	3.000	MWD (2)
29	770.02	22.00	41.66	764.65	31.17	27.74	41.73	2.997	MWD (2)
30	780.00	22.00	41.66	773.91	33.97	30.22	45.47	0.000	MWD (2)
31	810.00	22.00	41.66	801.72	42.36	37.69	56.70	0.000	MWD (2)
32	840.00	22.00	41.66	829.54	50.76	45.16	67.94	0.000	MWD (2)
33	870.00	22.00	41.66	857.35	59.16	52.63	79.18	0.000	MWD (2)
34	900.00	22.00	41.66	885.17	67.55	60.10	90.42	0.000	MWD (2)
35	930.00	22.00	41.66	912.98	75.95	67.57	101.66	0.000	MWD (2)
36	960.00	22.00	41.66	940.80	84.34	75.04	112.90	0.000	MWD (2)
37	990.00	22.00	41.66	968.61	92.74	82.51	124.13	0.000	MWD (2)
38	1020.00	22.00	41.66	996.43	101.14	89.98	135.37	0.000	MWD (2)
39	1050.00	22.00	41.66	1024.25	109.53	97.45	146.61	0.000	MWD (2)
40	1080.00	22.00	41.66	1052.06	117.93	104.92	157.85	0.000	MWD (2)
41	1110.00	22.00	41.66	1079.88	126.32	112.39	169.09	0.000	MWD (2)
42	1140.00	22.00	41.66	1107.69	134.72	119.86	180.32	0.000	MWD (2)
43	1170.00	22.00	41.66	1135.51	143.12	127.33	191.56	0.000	MWD (2)
44	1200.00	22.00	41.66	1163.32	151.51	134.80	202.80	0.000	MWD (2)
45	1230.00	22.00	41.66	1191.14	159.91	142.27	214.04	0.000	MWD (2)
46	1260.00	22.00	41.66	1218.95	168.31	149.74	225.28	0.000	MWD (2)
47	1290.00	22.00	41.66	1246.77	176.70	157.21	236.52	0.000	MWD (2)
48	1320.00	22.00	41.66	1274.59	185.10	164.68	247.75	0.000	MWD (2)
49	1350.00	22.00	41.66	1302.40	193.49	172.15	258.99	0.000	MWD (2)
50	1380.00	22.00	41.66	1330.22	201.89	179.62	270.23	0.000	MWD (2)
51	1410.00	22.00	41.66	1358.03	210.29	187.09	281.47	0.000	MWD (2)
52	1440.00	22.00	41.66	1385.85	218.68	194.56	292.71	0.000	MWD (2)
53	1470.00	22.00	41.66	1413.66	227.08	202.03	303.94	0.000	MWD (2)
54	1500.00	22.00	41.66	1441.48	235.47	209.51	315.18	0.000	MWD (2)
55	1530.00	22.00	41.66	1469.29	243.87	216.98	326.42	0.000	MWD (2)
56	1560.00	22.00	41.66	1497.11	252.27	224.45	337.66	0.000	MWD (2)
57	1590.00	22.00	41.66	1524.92	260.66	231.92	348.90	0.000	MWD (2)
58	1620.00	22.00	41.66	1552.74	269.06	239.39	360.14	0.000	MWD (2)
59	1650.00	22.00	41.66	1580.56	277.45	246.86	371.37	0.000	MWD (2)
60	1680.00	22.00	41.66	1608.37	285.85	254.33	382.61	0.000	MWD (2)
61	1710.00	22.00	41.66	1636.19	294.25	261.80	393.85	0.000	MWD (2)
62	1740.00	22.00	41.66	1664.00	302.64	269.27	405.09	0.000	MWD (2)
63	1770.00	22.00	41.66	1691.82	311.04	276.74	416.33	0.000	MWD (2)
64	1800.00	22.00	41.66	1719.63	319.43	284.21	427.57	0.000	MWD (2)
65	1800.41	22.00	41.66	1720.01	319.55	284.31	427.72	0.000	MWD (2)
66	1830.00	22.00	41.66	1747.45	327.83	291.68	438.80	0.000	MWD (2)
67	1860.00	22.00	41.66	1775.26	336.23	299.15	450.04	0.000	MWD (2)
68	1865.13	22.00	41.66	1780.02	337.66	300.42	451.96	0.000	MWD (2)

Keyi-15 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	306.17	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	306.17	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	306.17	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	306.17	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	306.17	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	306.17	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	306.17	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	306.17	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	306.17	250.00	0.00	0.00	0.00	0.000	MWD (1)
11	270.00	0.00	306.17	270.00	0.00	0.00	0.00	0.000	MWD (1)
12	300.00	0.00	306.17	300.00	0.00	0.00	0.00	0.000	MWD (1)
13	330.00	0.00	306.17	330.00	0.00	0.00	0.00	0.000	MWD (1)
14	360.00	0.00	306.17	360.00	0.00	0.00	0.00	0.000	MWD (1)
15	390.00	0.00	306.17	390.00	0.00	0.00	0.00	0.000	MWD (1)
16	420.00	0.00	306.17	420.00	0.00	0.00	0.00	0.000	MWD (1)
17	450.00	0.00	306.17	450.00	0.00	0.00	0.00	0.000	MWD (1)
18	480.00	0.00	306.17	480.00	0.00	0.00	0.00	0.000	MWD (1)
19	510.00	0.00	306.17	510.00	0.00	0.00	0.00	0.000	MWD (1)
20	540.00	0.00	306.17	540.00	0.00	0.00	0.00	0.000	MWD (1)
21	570.00	0.00	306.17	570.00	0.00	0.00	0.00	0.000	MWD (1)
22	600.00	0.00	306.17	600.00	0.00	0.00	0.00	0.000	MWD (1)
23	630.00	0.00	306.17	630.00	0.00	0.00	0.00	0.000	MWD (1)
24	660.00	0.00	306.17	660.00	0.00	0.00	0.00	0.000	MWD (1)
25	690.00	0.00	306.17	690.00	0.00	0.00	0.00	0.000	MWD (1)
26	720.00	0.00	306.17	720.00	0.00	0.00	0.00	0.000	MWD (1)
27	750.00	0.00	306.17	750.00	0.00	0.00	0.00	0.000	MWD (1)
28	780.00	0.00	306.17	780.00	0.00	0.00	0.00	0.000	MWD (1)
29	810.00	0.00	306.17	810.00	0.00	0.00	0.00	0.000	MWD (1)
30	840.00	0.00	306.17	840.00	0.00	0.00	0.00	0.000	MWD (1)
31	870.00	0.00	306.17	870.00	0.00	0.00	0.00	0.000	MWD (1)
32	900.00	0.00	306.17	900.00	0.00	0.00	0.00	0.000	MWD (1)
33	930.00	3.00	306.17	929.99	0.46	-0.63	0.79	3.000	MWD (1)
34	960.00	6.00	306.17	959.89	1.85	-2.53	3.14	3.000	MWD (1)
35	990.00	9.00	306.17	989.63	4.16	-5.69	7.05	3.000	MWD (1)
36	1020.00	12.00	306.17	1019.12	7.39	-10.11	12.52	3.000	MWD (1)
37	1050.00	15.00	306.17	1048.29	11.52	-15.76	19.52	3.000	MWD (1)
38	1080.00	18.00	306.17	1077.05	16.55	-22.64	28.04	3.000	MWD (1)
39	1110.00	21.00	306.17	1105.33	22.46	-30.72	38.06	3.000	MWD (1)
40	1140.00	24.00	306.17	1133.04	29.23	-39.99	49.53	3.000	MWD (1)
41	1170.00	27.00	306.17	1160.12	36.86	-50.41	62.45	3.000	MWD (1)
42	1183.19	28.32	306.17	1171.80	40.47	-55.36	68.57	3.002	MWD (1)
43	1200.00	28.32	306.17	1186.60	45.18	-61.79	76.55	0.000	MWD (1)
44	1230.00	28.32	306.17	1213.01	53.58	-73.28	90.78	0.000	MWD (1)
45	1260.00	28.32	306.17	1239.42	61.98	-84.77	105.01	0.000	MWD (1)
46	1290.00	28.32	306.17	1265.83	70.37	-96.26	119.24	0.000	MWD (1)
47	1320.00	28.32	306.17	1292.24	78.77	-107.75	133.47	0.000	MWD (1)
48	1350.00	28.32	306.17	1318.64	87.17	-119.24	147.71	0.000	MWD (1)
49	1380.00	28.32	306.17	1345.05	95.57	-130.73	161.94	0.000	MWD (1)
50	1410.00	28.32	306.17	1371.46	103.97	-142.22	176.17	0.000	MWD (1)
51	1440.00	28.32	306.17	1397.87	112.37	-153.71	190.40	0.000	MWD (1)
52	1470.00	28.32	306.17	1424.28	120.77	-165.19	204.63	0.000	MWD (1)
53	1500.00	28.32	306.17	1450.69	129.17	-176.68	218.86	0.000	MWD (1)
54	1530.00	28.32	306.17	1477.10	137.57	-188.17	233.10	0.000	MWD (1)
55	1560.00	28.32	306.17	1503.51	145.97	-199.66	247.33	0.000	MWD (1)
56	1590.00	28.32	306.17	1529.92	154.37	-211.15	261.56	0.000	MWD (1)
57	1620.00	28.32	306.17	1556.33	162.77	-222.64	275.79	0.000	MWD (1)
58	1650.00	28.32	306.17	1582.74	171.17	-234.13	290.02	0.000	MWD (1)
59	1680.00	28.32	306.17	1609.15	179.57	-245.62	304.26	0.000	MWD (1)
60	1710.00	28.32	306.17	1635.56	187.97	-257.11	318.49	0.000	MWD (1)
61	1740.00	28.32	306.17	1661.97	196.37	-268.59	332.72	0.000	MWD (1)
62	1770.00	28.32	306.17	1688.38	204.77	-280.08	346.95	0.000	MWD (1)
63	1800.00	28.32	306.17	1714.78	213.16	-291.57	361.18	0.000	MWD (1)
64	1800.24	28.32	306.17	1715.00	213.23	-291.66	361.30	0.000	MWD (1)
65	1830.00	28.32	306.17	1741.19	221.56	-303.06	375.42	0.000	MWD (1)
66	1860.00	28.32	306.17	1767.60	229.96	-314.55	389.65	0.000	MWD (1)

Keyi-16 Surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	351.57	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	351.57	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	351.57	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	351.57	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	351.57	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	351.57	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	351.57	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	351.57	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	351.57	250.00	0.00	0.00	0.00	0.000	MWD (1)
11	270.00	0.00	351.57	270.00	0.00	0.00	0.00	0.000	MWD (1)
12	300.00	0.00	351.57	300.00	0.00	0.00	0.00	0.000	MWD (1)
13	330.00	0.00	351.57	330.00	0.00	0.00	0.00	0.000	MWD (1)
14	360.00	0.00	351.57	360.00	0.00	0.00	0.00	0.000	MWD (1)
15	390.00	0.00	351.57	390.00	0.00	0.00	0.00	0.000	MWD (1)
16	420.00	0.00	351.57	420.00	0.00	0.00	0.00	0.000	MWD (1)
17	450.00	0.00	351.57	450.00	0.00	0.00	0.00	0.000	MWD (1)
18	480.00	0.00	351.57	480.00	0.00	0.00	0.00	0.000	MWD (1)
19	510.00	0.00	351.57	510.00	0.00	0.00	0.00	0.000	MWD (1)
20	540.00	0.00	351.57	540.00	0.00	0.00	0.00	0.000	MWD (1)
21	570.00	0.00	351.57	570.00	0.00	0.00	0.00	0.000	MWD (1)
22	600.00	0.00	351.57	600.00	0.00	0.00	0.00	0.000	MWD (1)
23	630.00	3.00	351.57	629.99	0.78	-0.12	0.79	3.000	MWD (1)
24	660.00	6.00	351.57	659.89	3.10	-0.46	3.14	3.000	MWD (1)
25	690.00	9.00	351.57	689.63	6.98	-1.03	7.05	3.000	MWD (1)
26	720.00	12.00	351.57	719.12	12.39	-1.84	12.52	3.000	MWD (1)
27	750.00	15.00	351.57	748.29	19.31	-2.86	19.52	3.000	MWD (1)
28	780.00	18.00	351.57	777.05	27.74	-4.11	28.04	3.000	MWD (1)
29	810.00	21.00	351.57	805.33	37.64	-5.58	38.06	3.000	MWD (1)
30	828.72	22.87	351.57	822.69	44.56	-6.60	45.05	2.997	MWD (1)
31	840.00	22.87	351.57	833.09	48.90	-7.25	49.43	0.000	MWD (1)
32	870.00	22.87	351.57	860.73	60.43	-8.96	61.09	0.000	MWD (1)
33	900.00	22.87	351.57	888.37	71.96	-10.67	72.75	0.000	MWD (1)
34	930.00	22.87	351.57	916.01	83.50	-12.37	84.41	0.000	MWD (1)
35	960.00	22.87	351.57	943.65	95.03	-14.08	96.07	0.000	MWD (1)
36	990.00	22.87	351.57	971.30	106.56	-15.79	107.73	0.000	MWD (1)
37	1020.00	22.87	351.57	998.94	118.10	-17.50	119.39	0.000	MWD (1)
38	1050.00	22.87	351.57	1026.58	129.63	-19.21	131.05	0.000	MWD (1)
39	1080.00	22.87	351.57	1054.22	141.16	-20.92	142.71	0.000	MWD (1)
40	1110.00	22.87	351.57	1081.86	152.70	-22.63	154.37	0.000	MWD (1)
41	1140.00	22.87	351.57	1109.50	164.23	-24.34	166.02	0.000	MWD (1)
42	1170.00	22.87	351.57	1137.15	175.76	-26.05	177.68	0.000	MWD (1)
43	1200.00	22.87	351.57	1164.79	187.30	-27.76	189.34	0.000	MWD (1)
44	1230.00	22.87	351.57	1192.43	198.83	-29.47	201.00	0.000	MWD (1)
45	1290.00	22.87	351.57	1247.71	221.90	-32.89	224.32	0.000	MWD (1)
46	1320.00	22.87	351.57	1275.35	233.43	-34.59	235.98	0.000	MWD (1)
47	1350.00	22.87	351.57	1303.00	244.96	-36.30	247.64	0.000	MWD (1)
48	1380.00	22.87	351.57	1330.64	256.50	-38.01	259.30	0.000	MWD (1)
49	1410.00	22.87	351.57	1358.28	268.03	-39.72	270.96	0.000	MWD (1)
50	1440.00	22.87	351.57	1385.92	279.56	-41.43	282.62	0.000	MWD (1)
51	1470.00	22.87	351.57	1413.56	291.10	-43.14	294.28	0.000	MWD (1)
52	1500.00	22.87	351.57	1441.20	302.63	-44.85	305.94	0.000	MWD (1)
53	1530.00	22.87	351.57	1468.85	314.16	-46.56	317.59	0.000	MWD (1)
54	1560.00	22.87	351.57	1496.49	325.70	-48.27	329.25	0.000	MWD (1)
55	1590.00	22.87	351.57	1524.13	337.23	-49.98	340.91	0.000	MWD (1)
56	1620.00	22.87	351.57	1551.77	348.76	-51.69	352.57	0.000	MWD (1)
57	1650.00	22.87	351.57	1579.41	360.30	-53.40	364.23	0.000	MWD (1)
58	1680.00	22.87	351.57	1607.05	371.83	-55.11	375.89	0.000	MWD (1)
59	1710.00	22.87	351.57	1634.70	383.36	-56.82	387.55	0.000	MWD (1)
60	1740.00	22.87	351.57	1662.34	394.90	-58.52	399.21	0.000	MWD (1)
61	1770.00	22.87	351.57	1689.98	406.43	-60.23	410.87	0.000	MWD (1)
62	1800.00	22.87	351.57	1717.62	417.96	-61.94	422.53	0.000	MWD (1)
63	1808.02	22.87	351.57	1725.01	421.05	-62.40	425.64	0.000	MWD (1)
64	1830.00	22.87	351.57	1745.26	429.50	-63.65	434.19	0.000	MWD (1)
65	1860.00	22.87	351.57	1772.90	441.03	-65.36	445.85	0.000	MWD (1)
66	1867.72	22.87	351.57	1780.02	444.00	-65.80	448.85	0.000	MWD (1)

Keyi-24 Primary bore hole surveys

	MD (m)	Inc (°)	Azi (°)	TVD (m)	N/S (m)	E/W (m)	V.Sec. (m)	DLeg (°/30m)	Tool
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000	UNDEFINED
2	30.00	0.00	358.76	30.00	0.00	0.00	0.00	0.000	MWD (1)
3	60.00	0.00	358.76	60.00	0.00	0.00	0.00	0.000	MWD (1)
4	90.00	0.00	358.76	90.00	0.00	0.00	0.00	0.000	MWD (1)
5	120.00	0.00	358.76	120.00	0.00	0.00	0.00	0.000	MWD (1)
6	150.00	0.00	358.76	150.00	0.00	0.00	0.00	0.000	MWD (1)
7	180.00	0.00	358.76	180.00	0.00	0.00	0.00	0.000	MWD (1)
8	210.00	0.00	358.76	210.00	0.00	0.00	0.00	0.000	MWD (1)
9	240.00	0.00	358.76	240.00	0.00	0.00	0.00	0.000	MWD (1)
10	250.00	0.00	358.76	250.00	0.00	0.00	0.00	0.000	MWD (1)
11	270.00	0.00	358.76	270.00	0.00	0.00	0.00	0.000	MWD (1)
12	300.00	0.00	358.76	300.00	0.00	0.00	0.00	0.000	MWD (1)
13	330.00	0.00	358.76	330.00	0.00	0.00	0.00	0.000	MWD (1)
14	360.00	0.00	358.76	360.00	0.00	0.00	0.00	0.000	MWD (1)
15	390.00	0.00	358.76	390.00	0.00	0.00	0.00	0.000	MWD (1)
16	420.00	0.00	358.76	420.00	0.00	0.00	0.00	0.000	MWD (1)
17	450.00	0.00	358.76	450.00	0.00	0.00	0.00	0.000	MWD (1)
18	480.00	0.00	358.76	480.00	0.00	0.00	0.00	0.000	MWD (1)
19	510.00	0.00	358.76	510.00	0.00	0.00	0.00	0.000	MWD (1)
20	540.00	0.00	358.76	540.00	0.00	0.00	0.00	0.000	MWD (1)
21	570.00	0.00	358.76	570.00	0.00	0.00	0.00	0.000	MWD (1)
22	600.00	0.00	358.76	600.00	0.00	0.00	0.00	0.000	MWD (1)
23	630.00	0.00	358.76	630.00	0.00	0.00	0.00	0.000	MWD (1)
24	660.00	0.00	358.76	660.00	0.00	0.00	0.00	0.000	MWD (1)
25	690.00	0.00	358.76	690.00	0.00	0.00	0.00	0.000	MWD (1)
26	720.00	0.00	358.76	720.00	0.00	0.00	0.00	0.000	MWD (1)
27	750.00	0.00	358.76	750.00	0.00	0.00	0.00	0.000	MWD (1)
28	780.00	0.00	358.76	780.00	0.00	0.00	0.00	0.000	MWD (1)
29	810.00	0.00	358.76	810.00	0.00	0.00	0.00	0.000	MWD (1)
30	840.00	0.00	358.76	840.00	0.00	0.00	0.00	0.000	MWD (1)
31	870.00	0.00	358.76	870.00	0.00	0.00	0.00	0.000	MWD (1)
32	900.00	0.00	358.76	900.00	0.00	0.00	0.00	0.000	MWD (1)
33	930.00	0.00	358.76	930.00	0.00	0.00	0.00	0.000	MWD (1)
34	960.00	0.00	358.76	960.00	0.00	0.00	0.00	0.000	MWD (1)
35	990.00	0.00	358.76	990.00	0.00	0.00	0.00	0.000	MWD (1)
36	1020.00	0.00	358.76	1020.00	0.00	0.00	0.00	0.000	MWD (1)
37	1050.00	0.00	358.76	1050.00	0.00	0.00	0.00	0.000	MWD (1)
38	1080.00	0.00	358.76	1080.00	0.00	0.00	0.00	0.000	MWD (1)
39	1110.00	0.00	358.76	1110.00	0.00	0.00	0.00	0.000	MWD (1)
40	1140.00	0.00	358.76	1140.00	0.00	0.00	0.00	0.000	MWD (1)
41	1170.00	0.00	358.76	1170.00	0.00	0.00	0.00	0.000	MWD (1)
42	1200.00	0.00	358.76	1200.00	0.00	0.00	0.00	0.000	MWD (1)
43	1230.00	3.00	358.76	1229.99	0.79	-0.02	0.79	3.000	MWD (1)
44	1260.00	6.00	358.76	1259.89	3.14	-0.07	3.14	3.000	MWD (1)
45	1290.00	9.00	358.76	1289.63	7.05	-0.15	7.05	3.000	MWD (1)
46	1320.00	12.00	358.76	1319.12	12.52	-0.27	12.52	3.000	MWD (1)
47	1350.00	15.00	358.76	1348.29	19.52	-0.42	19.52	3.000	MWD (1)
48	1380.00	18.00	358.76	1377.05	28.04	-0.61	28.04	3.000	MWD (1)
49	1410.00	21.00	358.76	1405.33	38.05	-0.82	38.06	3.000	MWD (1)
50	1414.08	21.41	358.76	1409.13	39.52	-0.86	39.53	3.015	MWD (1)
51	1440.00	21.41	358.76	1433.26	48.98	-1.06	48.99	0.000	MWD (1)
52	1470.00	21.41	358.76	1461.19	59.93	-1.30	59.94	0.000	MWD (1)
53	1500.00	21.41	358.76	1489.12	70.88	-1.53	70.90	0.000	MWD (1)
54	1530.00	21.41	358.76	1517.05	81.83	-1.77	81.85	0.000	MWD (1)
55	1560.00	21.41	358.76	1544.98	92.78	-2.01	92.80	0.000	MWD (1)
56	1590.00	21.41	358.76	1572.91	103.72	-2.25	103.75	0.000	MWD (1)
57	1620.00	21.41	358.76	1600.84	114.67	-2.48	114.70	0.000	MWD (1)
58	1650.00	21.41	358.76	1628.77	125.62	-2.72	125.65	0.000	MWD (1)
59	1680.00	21.41	358.76	1656.70	136.57	-2.96	136.60	0.000	MWD (1)
60	1710.00	21.41	358.76	1684.63	147.52	-3.19	147.55	0.000	MWD (1)
61	1731.87	21.41	358.76	1704.99	155.50	-3.37	155.54	0.000	MWD (1)
62	1740.00	21.41	358.76	1712.56	158.47	-3.43	158.50	0.000	MWD (1)
63	1770.00	21.41	358.76	1740.49	169.42	-3.67	169.46	0.000	MWD (1)
64	1800.00	21.41	358.76	1768.42	180.37	-3.90	180.41	0.000	MWD (1)
65	1812.43	21.41	358.76	1779.99	184.90	-4.00	184.94	0.000	MWD (1)

Plan Editor - Keyi-24/Keyi-24#ST1/Keyi-24#ST1 V1.0_ME 160318

	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	500.00		0.00	358.76	500.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	530.00	30.00	0.00	358.76	530.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	620.00	90.00	9.00	100.00	619.63	-1.22	6.95	-1.63	3.000	100.00	3.000	0.000	Inc Azi DLS	
4	680.00	60.00	9.00	100.00	678.89	-2.85	16.19	-3.81	0.000	0.00	0.000	0.000	Straight MD	
5	1283.56	603.56	13.90	338.23	1276.05	56.89	36.00	54.65	1.000	-143.58	0.244	-6.053	DT5 CH Tang	
6	1725.45	441.89	13.90	338.23	1705.00	155.47	-3.37	155.39	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1802.71	77.26	13.90	338.23	1780.00	172.70	-10.25	173.01	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

Keyi-24 ST#1 Plan

Plan Editor - Keyi-24/Keyi-24#ST2/Keyi-24#ST2 V1.1_ME 170318

	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	450.00		0.00	358.76	450.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	480.00	30.00	0.00	358.76	480.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	564.00	84.00	7.00	330.00	563.79	4.44	-2.56	4.48	2.500	330.00	2.500	0.000	Inc Azi DLS	
4	624.00	60.00	7.00	330.00	623.34	10.77	-6.22	10.88	0.000	0.00	0.000	0.000	Straight MD	
5	750.03	126.03	7.72	2.78	748.39	25.89	-9.65	26.05	1.000	96.75	0.172	7.802	DT5 CH Tang	
6	1715.40	965.36	7.72	2.78	1705.00	155.47	-3.37	155.50	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1791.08	75.69	7.72	2.78	1780.00	165.63	-2.88	165.65	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

Keyi-24 ST#2 Plan

Plan Editor - Keyi-24/Keyi-24#ST3/Keyi-24#ST3 V1.2_ME180318

	MD (m)	CL (m)	Inc (°)	Azi (°)	TVD (m)	NS (m)	EW (m)	V.Sec (m)	Dogleg (°/30m)	T.Face (°)	Build (°/30m)	Turn (°/30m)	Section Type	Target
1	750.00		0.00	358.76	750.00	0.00	0.00	0.00	0.000	0.00	0.000	0.000	Tie Line	
2	950.00	200.00	0.00	358.76	950.00	0.00	0.00	0.00	0.000	358.76	0.000	0.000	Straight MD	
3	1040.00	90.00	9.00	270.00	1039.63	0.00	-7.05	-0.24	3.000	270.00	3.000	0.000	Inc Azi DLS	
4	1100.00	60.00	9.00	270.00	1098.89	0.00	-16.44	-0.56	0.000	0.00	0.000	0.000	Straight MD	
5	1550.87	450.87	23.26	17.50	1536.96	86.56	-25.09	85.66	1.815	124.72	0.949	7.153	DT5 CH Tang	
6	1733.78	182.91	23.26	17.50	1705.00	155.47	-3.37	155.26	0.000	0.00	0.000	0.000	(ditto)	Keyi-24#T1
7	1815.42	81.64	23.26	17.50	1780.00	186.22	6.33	186.33	0.000	0.00	0.000	0.000	Straight TVD	
8													Insert Line	

Keyi-24 ST#3 Plan