

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ



Sudan university of science and technology
College of petroleum engineering and technology
Department of petroleum engineering



Project Title:

Slim hole sidetrack from abandon well

(Case Study a well in Hamra oil field, Block 2B)

الأنحراف من بئر مهجورة بتقنية الحفر بقطر صغير

((تطبيق حقلي في مربع (2B) في حقل (Hamra))

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

This Project is a Property of:

- 1- Abdelmonaim Babikir Abdelmonaim Mahmoud.
- 2- Dalia Mohamed Salih Khairy.
- 3- Eman Yagoub Ali Yagoub.
- 4- Faisal Mokhtar Saeed Mokhtar.

Supervisor:

Dr. Yousif Altahir Bagadi.

October-2016



بسم الله الرحمن الرحيم

Slim hole sidetrack from abandon well



(Case Study a well in Hamra oil field, Block 2B)

الأنحراف من بئر مهجورة بتقنية الحفر بقطر صغير

((تطبيق حقلي في مربع (2B) في حقل (Hamra))

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

This Project is a Property of:

- 1- Abdelmonaim Babikir Abdelmonaim Mahmoud.
- 2- Dalia Mohamed Salih Khairy.
- 3- Eman Yagoub Ali Yagoub.
- 4- Faisal Mokhtar Saeed Mokhtar.

**This project is accepted by college petroleum engineering and
technology department of petroleum engineering**

Project Supervisor: **Dr. Yousif Altahir Bagadi.**

Signature:.....

Head of Department: **Eng. Fatima Ahmed Eltigani.**

Signature:.....

Dean of College: **Dr. Tagwa Ahmed Musa.**

Signature:.....

Date: / / 2016

Opening

بِسْمِ اللّٰهِ الرَّحْمٰنِ الرَّحِیْمِ

قال تعالی:

(نرفع درجات من نشاء وفوق كل ذي علم عليم)

سوره یوسفه الآیة (76)

قال تعالی:

(وقل ربی زدنی علما)

سوره طه الآیة (114)

Dedication

Dedicated to our father, brother, teacher, and academic supervisor Dr. Yousif Altahir Bagadi.

To our fathers and mothers who taught us great lessons about life, guiding, motivation,

innovation and support us along life's level.

Without them we would not become the people who we are today.

To our brothers and sisters who stand with us, encourage us and taught us the real meaning

of helping other people with all we have.

For future generations that hold future of the oil industry in Sudan.

We are honor to offer you this modest work.

Thanks all for giving us a chance to prove and improve our self through all

levels of university life.

Acknowledgment

We would like to express our sincere gratitude and appreciation to my academic supervisor, *Dr. Yousif Altahir Bagadi* for giving us the opportunity and suggestion to write this project. A lot of credit goes to him for the consistent advice, excellent guidance, unflinching support and feedback we got from him in the course of doing this work.

Many thanks also to *Eng. Hamza Ahmad, Eng. Ashraf Eldigair, Eng. Omer Alfarug* and *Eng. Mohanad Mubarak Yosuf* to given us invaluable advice on our project.

Very special thanks to *Greater Nile Petroleum Operating Company (GNPOC)* to given us data and cooperate.

Last but not the least important, we owe more than thanks to our family members, for their financial support and encouragement throughout our life. Without their support, it is impossible for us to finish our college and graduate education seamlessly.

Abstract

Recently, the most important challenge for Sudan oil industry, especially with the drop in oil prices, is how to reduce the drilling and completing costs. This project presents a solution to this problem by introducing the slim hole drilling technology through sidetracking from abandoned well to reach a new promising target in hamra oil field.

This study investigated all the design problems encounter slim hole drilling (such as Torque and drag, wellbore stability, ... etc.). The design and analysis of slim hole sidetrack was conducted by using landmark software for slim hole well profile, bottom hole assembly (BHA), surge & swab, hole cleaning and torque & drag (T&D). Our developed wellbore stability program (using matlab software (GUI)) was utilized to ensure stabilization of borehole (no collapse or fracturing formation problems). Abaqus Finite Element software was used to simulate casing milling process (backer milling bit) and open casing window that necessary for sidetracking operation.

A good result was obtained for slim hole profile with maximum inclination angle 44° and dogleg severity $3\text{deg}/30\text{m}$ this allow drilling operation without key seat problem. Also, a suitable design of BHA to open a window in production casing and a proper BHA to provide enough WOB for sidetracking. From the analysis of surge and swab, we found that no disturbance in bottom hole pressure was observed during RIH and ROH (only 10 -200 sec. stabilized system) and appropriated design of pump rate (ensure a good clean up hole). Torque and drag problem was analyzed and the resultant sinusoidal buckling located below KOP. Wellbore stability software program provides wellbore stability curve region.

Finally, this project explains how to get benefits from abandon wells and reduce the cost of drilling and completion by using slim hole and sidetrack technology.

Key words: slim hole, sidetrack simulator, BHA T&D, hole cleaning, wellbore stability program, landmark.

التجريد

مؤخراً ، أهم تحدي يواجه الصناعة النفطية في السودان خاصة مع انخفاض أسعار النفط في العالم هو كيفية تقليل تكاليف حفر وإكمال آبار جديدة. هذا المشروع يعرض الحل للتغلب علي هذا التحدي عن طريق الانحراف من بئر مهجورة باستخدام تقنية الحفر بقطر صغير للوصول لهدف جديد بالقرب من البئر المهجورة في حقل Hamra.

هذه الدراسة تتحقق من كل المشاكل والتحديات التي تواجه الحفر بقطر صغير مثل (Torque & Drage ، إستقرارية جدار البئر...الخ). في هذا المشروع تم إنشاء مسار الانحراف من البئر المهجورة الي الهدف الجديد القريب باستخدام برنامج Landmark . وأيضاً تم عمل محاكاة لعملية فتح نافذة في أنبوب تغليف البئر المهجورة عن طريق برنامج Abaqus FE . وتم تصميم وإختيار وتحليل BHA المناسبة لعمل الانحراف وتصميم وتحليل لكلاً من (Hole cleaning Torque&drage and Surg&swab ,) باستخدام برنامج Landmark . وأخيراً تم تصميم برنامج عن طريق Matlab (GUI) لتحليل إستقرارية جدار البئر من خلال إنشاء منحنى إستقرارية جدار البئر.

من خلال هذا المشروع تم التوصل الي مسار منحرف من البئر المهجور الي الهدف بزواوية مقدارها 44 درجة ، وتم تحديد BHA المناسبة لعملية فتح نافذة في أنبوب تغليف البئر المهجورة وكذلك تحديد BHA المناسبة التي توفر الوزن المطلوب علي سكين الحفر لعمل الانحراف والوصول للهدف. ومن ثم تم تحديد الزمن المطلوب لعمليات pulling&Running من والي البئر لكل Stand وهو من 10 الي 200 ثانية ، وكذلك تم تحديد معدل ضخ مناسب للمحافظة علي نظافة البئر ونقل الفتات الصخري خارج البئر. وأيضاً تم عمل تحليل Torque&drage ووجد أن هنالك فقط Sinusoidal buckling أسفل KOP ناتج من الميلان والانحراف وهذا لا يسبب مشكلة. وتم الحصول علي منحنى إستقرارية البئر ومنه تم تحديد مدي لكثافة سائل الحفر التي تحافظ علي إستقرارية جدار البئر والحفر دون مشاكل.

أخيراً ، هذا المشروع وضح كيفية الاستفادة من الآبار المهجورة و تقليل تكاليف الحفر والأكمال. حيث أنه تم تقليل تكلفة الحفر والأكمال عن طريق عمل انحراف من بئر مهجورة للوصول للهدف الجديد باستخدام تقنية الحفر بقطر صغير.

كلمات مفتاحية : بئر مهجورة ، تقنية الحفر بقطر صغير ، محاكاة الانحراف، برنامج استقراريه البئر،

. Abaqus ، landmark

List of Contents

Opening.....	ii
Dedication.....	iv
Acknowledgment.....	v
Abstract (English).....	vi
Abstract (Arabic).....	vii
List of Contents.....	viii
List of Figures.....	xiii
List of Tables.....	xvi
Nomenclature.....	xvii

Chapter 1: Introduction

1.1 Introduction:.....	1
1.1.1 Sidetracking:.....	1
1.1.2 Definition of Slim Hole:.....	2
1.2 Statement of the Problem:.....	3
1.3 Objectives of the Project:.....	3
1.4 Methodology:.....	3
1.5 Project Lay Out:.....	4

Chapter 2: Literature Review and Theoretical Background

2.1 Literature Review:.....	5
2.1.1 Introduction:.....	5
2.1.2 Cost Analysis:.....	5
2.1.3 Hydraulic:.....	7
2.1.4 Well Control:.....	8
2.1.5 Buckling Analysis:.....	9
2.1.6 Torque and Drag:.....	9
2.1.7 Surge and Swab Pressure:.....	9
2.2 Theoretical Background:.....	10
2.2.1 Well Planning:.....	10
2.2.1.1 Bottom Hole Targets:.....	10

2.2.1.2 Well Coordinates:.....	11
2.2.1.3 Well Profile: Definitions.....	11
2.2.1.3.1 Inclination Angle:.....	11
2.2.1.3.2 Measured Depth:.....	11
2.2.1.3.3 True Vertical Depth:.....	12
2.2.1.4 Determining the Kick-off Point:.....	12
2.2.1.5 Build-Up/Drop off Rates:.....	12
2.2.2 Planning the Well Profile:.....	12
2.2.2.1 Types of Well Profiles:.....	12
2.2.2.2 Build-Up & Hold Design:.....	13
2.2.3 Deflection Tools:.....	17
2.2.3.1 Whipstocks:.....	17
2.2.3.2 Jetting:.....	18
2.2.3.3 Downhole Motors with Bent Subs:.....	18
2.2.3.4 Steerable Positive Displacement Motors:.....	19
2.2.4 Bottom Hole Assemblies (BHA):.....	19
2.2.4.1 Heavy Weight Drill Pipe (HWDP):.....	19
2.2.4.2 Drilling Jars:.....	20
2.2.4.3 Drill Collar (DC):.....	20
2.2.4.4 Non-Magnetic Drill Collar (NMDC):.....	21
2.2.4.5 Float Sub:.....	21
2.2.4.6 Section Mill:.....	21
2.2.4.7 Diamond Bits:.....	22
2.2.5 Cuttings Transport:.....	22
2.2.6 Surge and Swab:.....	24
2.2.7 Wellbore Stability:.....	24
2.2.8 Torque:.....	26
2.2.9 Friction Factor:.....	27

Chapter 3: Methodology

3.1 Landmark Software:	29
3.1.1 Compass:	29
3.1.2 WellPlan:	29
3.2 Abaqus FE Software:	30
3.3 Matlab Program (GUI):	30
3.4 Slim Hole Sidetrack Design and Analysis:	31
3.4.1 Well Trajectory:	32
3.4.1.1 Data Required:	32
3.4.1.2 Azimuth Calculation:	32
3.4.1.3 Trajectory Calculation:	32
3.4.1.4 Input Data in Compass:	33
3.4.2 Window Milling:	33
3.4.2.1 Input Data:	34
3.4.2.2 Model Parts Construction:	34
3.4.2.3 Assignment of Model's Mechanical Properties:	34
3.4.2.4 Sidetrack Assembly:	35
3.4.2.5 Model Contact Interaction:	35
3.4.2.6 Model Boundary Condition:	35
3.4.2.7 Model Parts Mesh:	35
3.4.2.8 Running Abaqus FE:	35
3.4.2.9 Result Output and Visualization:	35
3.4.3 Bottom Hole Assembly (BHA):	35
3.4.3.1 Selection BHA:	36
3.4.3.2 Drill Collar and HWDP Calculation:	39
3.4.3.3 Input Data in Landmark:	39
3.4.4 Hydraulic:	40
3.4.4.1 Surge and Swab:	40
3.4.4.2 Hole Cleaning Analysis:	42
3.4.5 Wellbore Stability:	43

3.4.5.1 Fracturing Gradient Model:	43
3.4.5.2 Mohr-Coulomb Collapse Gradient Model:	45
3.4.5.3 Minimum Data Required:	46
3.4.6 Torque and Drag Analysis:.....	47
3.5 Slim Hole Sidetrack Design and Analysis Flow Chart:	47

Chapter 4: Results and Discussion

4.1 Well Trajectory:.....	51
4.1.1 Azimuth Calculation:	51
4.1.2 Trajectory Calculation:	51
4.1.3 Input Data in Compass and Landmark:	53
4.1.4 Compass and Landmark Result:	54
4.1.4.1 Well Profile:	54
4.1.4.2 Dogleg Severity:	55
4.1.4.3 Well Path Inclination:	55
4.1.4.4 Well Path Azimuth:	56
4.2 Casing Milling Window (using abaqus (FE) software):.....	56
4.2.1 Construction Slim Hole Sidetrack Model:	56
4.2.2 Model Result and Analysis:	57
4.3 Bottom Hole Assemble:	58
4.3.1 Selection BHA:	58
4.3.2 Drill Collar and HWDP Calculation:	58
4.3.3 Input BHA Data in landmark:.....	60
4.3.3.1 Wellbore Editor:.....	60
4.3.3.2 String Editor:	60
4.3.3.3 BHA Analysis Data:.....	62
4.3.4 BHA Result and Analysis in Landmark Software:	63
4.3.4.1 Displacement Analysis:.....	63
4.3.4.2 Side Force Analysis:	63
4.4 Hydraulic:	64

4.4.1 Surge and Swab Calculation:	65
4.4.2 Input Hydraulic Data in landmark:	66
4.4.2.1 Surge and Swab Input Data:	67
4.4.2.2 Surge & Swab Result and Analysis:.....	68
4.4.2.3 Input hole cleaning data in landmark:	69
4.5 Wellbore Stability:.....	73
4.5.1 Data Required:	73
4.5.2 Input Data in Program:	73
4.5.3 Program Results:	74
4.5.4 Wellbore Stability Curve:	77
4.6 Torque and Drag:	78
4.6.1 Input Torque and Drag Data in Normal Analysis Model in Landmark Software: 78	
4.6.2 Torque & Drag Result and Analysis in Landmark Software:	79
4.6.2.1 Effective Tension Plot:	79
4.6.2.2 Torque Graph:.....	80
 Chapter 5: Conclusions and Recommendations 	
5.1 Conclusion:.....	81
5.2 Recommendation:.....	82
References:.....	83
Appendix A: Report.	85
Appendix B: Code of Wellbore Stability Program	97