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Casing deformation assessment and management in Abu Ghirab oilfield

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Abstract— Risk assessment and management objective is to maximize the probability of a project's success by identifying, analysing, mitigating and controlling the risks.The goals of the drilling management engineers team is to work with drilling clients to significantly reduce cost, time and non productive time through integration of planning and real time drilling solutions. During drilling, deformation occurred to 9⅝" casing in Well AG-1, Well AG-2 and Well AG-3 in Abu Ghirab oilfield. Casing deformation was discovered while running Bottom Hole Assembly (BHA) and tools in the hole as they got an obstruction and stuck due to 9⅝ inch casing deformation in Lower Fars formation This study includes an investigation, analysis and designing new specifications of 9⅝ inch casing using Landmark software. Results of investigations showed poor in cement evaluation practices. Formation integrity tests (FIT) and Casing Integrity Tests (CIT) has not been implemented and Cement Bond Log (CBL) or Segmented Bond Tool (SBT) log has not been running in the hole. The proposed new casing design; increase casing weight, change casing grade, change casing thread type and increase casing design safety factor of collapse and burst load, can avoid the impact of salt creeping on 9⅝" casing. Applying best available technology and drilling risk management to reduce drilling cost and minimize time by mitigating or preventing drilling problems.

Keywords—Risk assessment and management, Casing deformation, Abu Ghirab oilfield, Landmark software.

1. Introduction

Good drilling planning and cementing design are essential to reduce the occurrence of non-uniform loading case. In most sedimentary formations, it is unusual for the formation pressure to equal the overburden pressure due to the element of support provided by the grain to grain contact within the rock matrix. However, in salt formation, because of its homogenous crystalline nature and plastic properties, the material directly transmits lateral loads equivalent to the overburden pressure. Therefore, when designing casing through a plastic salt formation, the external pressure load should be equal to the formation overburden pressure (or use 1 psi/ft external load pressure gradient if local pressures are uncertain)[1] .

Due to the nature of the salt formation, casing is exposed to a higher collapse load than most other sedimentary formations. It is recognized that the external pressure load in the salt formation takes the form of either uniformly or non-uniformly distributed loads. The effects of these are very different and tend to result from different rates of salt movement, and features of the wellbore. Non-uniform loading is amplified by other factors, such as; changes in hole curvature, rate of salt creep, presence of hard rock's embedded in the salt, pipe geometry, pipe stiffness and pipe tension[1].

Salt creep effect causes major problems that are typically associated with well construction in salt formations: excessive torque and pack offs, stuck pipe, casing running blockage, and poor cementing job. In addition, the salt exit may have a rubble zone characterized by mud losses and wellbore instability. Both salt creeping and salt exit related challenges are controlled by mud weight and mud properties[2].Conventional technology serves as the main method for preventing and controlling casing damage but is not effective. No integrated system combining the preventing and controlling method has been introduced. Therefore, the strategy of casing damage prevention and control shall be focused on “prevention” rather than “control”[3].

Also, it was found that poor well cementing is the main cause casing deformation. poor cementing can be the main reason to form no uniform loading on the casing. Also, the cement of weak quality can increase the possibility of casing corrosion, as the casing may come in contact with the surrounding corrosive rock layers[5].

MultiFinder Imaging Tool (MIT) is a multi-finger caliper tool which uniformly distribute along the casing inner wall to detect inner casing wall and corrosion. These logs were colored in a 3D image to visualize the situation of inner wall. Log curves twist seriously as shown in Figure 1 which indicates induced deformation [4].

Casing deformation incidents in southern Iraq oilfields have been reported within the rock salt layers that are attributed to creep of rock salt.

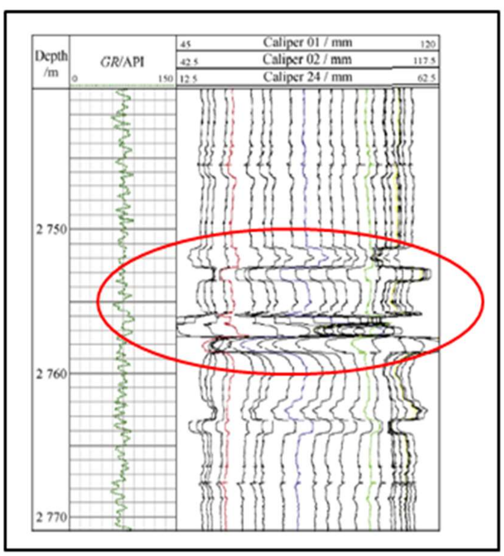

Figure 1 : MIT Caliper Logs.[4]

2. Study Area

Missan oilfields are located in Missan province and close to the Iraq-Iran border. It is about 175km north of Basra city. Missan oilfields which were discovered between 1969 and 1973 comprise three subfields, namely Abu Ghirab, Buzurgan and Fauqi oilfields (Figure 2)[6].

Abu Ghirab structurally, ranges about 30 km times 6 km with north and south domes, which is a NW-SE long axis anticline. Tertiary Asmari is the main reservoir in Abu Ghirab oilfield. Three pay zones are divided in the Asmari reservoir (is divided into north dome and south dome based on structure and OWC) which is A, B and C, the main pay zones are B and A [7].

Three wells were selected in Abu Ghirab oilfield; Well AG-1, Well AG-2 and Well AG-3. Casing deformation was discovered while running Bottom Hole Assembly (BHA) and tools in the hole as they got an obstruction and stuck due to $9\frac{5}{8}$ inch casing deformation in Lower Fars formation.

Lower Fars formation lithology is complex and consists of five members; Mb1, Mb2, Mb3, Mb4 and Mb5. These members consist of thick to thin shale interbedded with thin to thick anhydrite, thin to thick and massive shale interbedded with salt and anhydrite, thin to thick and massive anhydrite interbedded with shale and salt, massive salt with thin beds of anhydrite and thin to thick and massive anhydrite interbedded with shale and dolomite respectively[8].

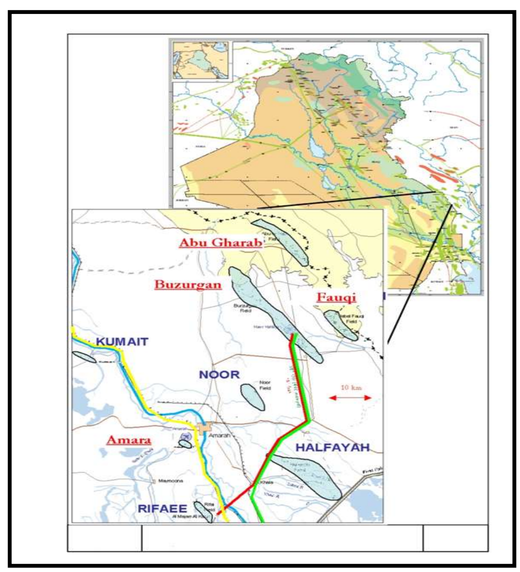

Figure 2: Study Area.[6]

3. Workflow Steps

The workflow to achieve the aims and the objectives of this study is demonstrated as follows:

- Collecting required data for oilfield case studies; casing deformation (collapse) in three wells in Abu Ghirab oilfield.
- Using Landmark software to design new casing specifications for the three selected wells in Abu Ghirab oilfield.
- Analyze and discuss the results.
- Performing drilling risk management and contingency plan to avoid case study problem.

4. Methodology Procedure of 9⅝ inch Casing Deformation

The methodology procedure of 9⅝ inch casing deformation is as follows:

- Select field and well case study.
- Prepare all data requirement; Daily Drilling Reports (DDR), Final Well Reports (FWR), Well Evaluation, Drilling Program (DP), Survey Data, Geological Report, Surface Logging Service (SLS) and Real Time Data.
- Investigate all drilling operations before and after problem occurred.
- Research the problem reasons and record all weak point while operations and mistakes.
- Review problem treatments with analyzing these treatments and report all notes or wrong decision as listing learning in future.
- Check 9⅝" casing design assumptions and design.
- Record the recommendations for new casing design.
- Compare new 9⅝" casing design with old design.
- Perform new 9⅝" casing design for Abu Ghirab wells.
- Analyze the final data and results.

The required data to design a new casing specifications using Landmark software is illustrated in Table 1[9]–[11]

Table 1: Required Data for Abu Ghirab Oilfield Wells Casing Design using Landmark Software.

Data	Purpose of Data
PP & FP Pressure	LM – Casing Seat
FWR	Problem background
FIT or SBT	Check CMT around shoe
DDR	Check Daily operations
Drilling Program	Review well design
Survey Data	LM – COMPASS
9⅝" CBL , MIT	Check Cement bond
BHA	Check BHA Design
Casing Tally	Check Casing and accessories locations
Mud Properties	LM – Stress Check
Rig Specification	LM – Stress Check
SLS	LM – Stress Check
Mud Report	LM – Casing Seat
Geological report	LM – Casing Seat

5. Casing Deformation Investigation

In Abu Ghirab wells, 9⅝ inch casing was deformed. The following information of casing deformation was obtained as a result of research and investigation for these wells:

- Total mud loss occurred during cementing 9⅝ inch casing.
- A DV tool (it is a stage cementing tool which used in selective zone primary cementing) was opened after total mud loss and filling annuals with mud. Opening DV tool is a bad decision in 9⅝ inch casing with total mud loss. Mud loss should be cured and performing 2nd stage cement job and squeezing cement to ensure the existence of cement from casing shoe to DV tool position.
- Bad cement bond.
- Casing pressure test was not performed to 9⅝ inch casing after cement job due to not bumping the cement plugs.
- The pressure in the annulus behind 9⅝ inch casings was 1500 psi.

6. New Casing Design Proposal of Abu Ghirab Oilfield

Due to casing deformation in Abu Ghirab oil field wells and the information that obtained from field observations, a decision was made for a new casing design. In a new casing design, detailed design; the grades of steel, weights, and coupling types were selected (changed) while preliminary design not changed. Casing design process workflow mention in Figure 3.

6.1 *Casing Design using Landmark Software*

Casing design was implemented with Landmark software [12]. In Landmark software, mechanical design, weight and grade selection (Stress Check) was used. Stress Check is a part of Landmark software package which provides designing and analyzing casing strings. Casing design results have been presented in three parts:

- **i.** Casing load cases
- **ii.** Casing and connections specifications design
- **iii.** Actual casing design factor \

6.1.1 Casing Load Cases

Load cases (Burst, Collapse and Tension) from surface to casing shoe are shown in Figure 4 through Figure 6. Load cases profile are demonstrated in two lines; new casing design (blue line) and API pipe rating selection specification**.**

Burst Load Cases

Burst Pressure arises from the fluid column inside the casing. Also, the casing may be exposed to the burst pressure if a kick occurs during drilling operations[13].

Internal pressure*:* The maximum internal pressure at the bottom of the casing is determined from the fracture strength of the formation at the casing shoe. In addition to a safety margin, (usually 1ppg equivalent mud weight)[14] .

External pressure: The external pressure on the surface casing due to the annular drilling fluid helps to resist the burst pressure. The external back up pressure at any surface hole section depth is assumed a normal hydrostatic pressure of a full column of native fluid[14].The burst load, Pb at any point along the casing can be calculated from:

$$Pb = Pi - Pe \quad (1)$$

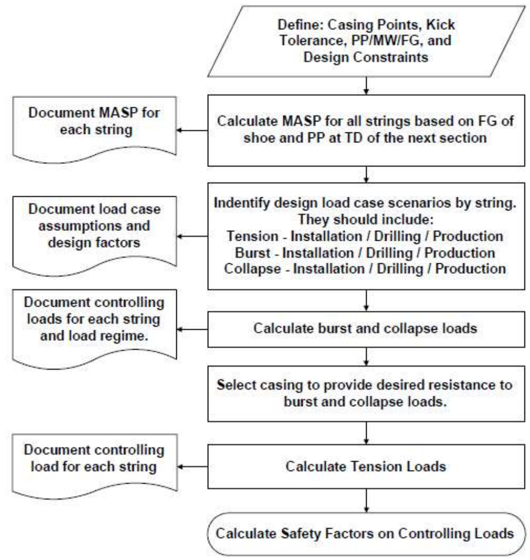

Figure 3: Casing Design process workflow. [12]

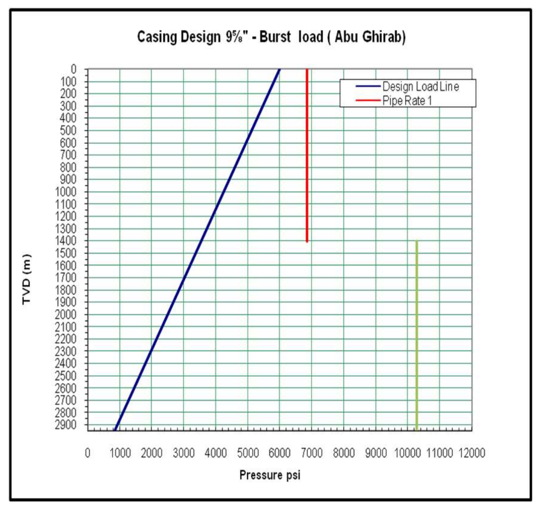

Figure 4: New Casing Burst Load Case ofAbu Ghirab Well.

Collapse Load Cases

Primary collapse loads are generated by the hydrostatic head of the fluid column (usually drilling fluids and sometimes cement slurry) outside the casing string. While drilling through troublesome formations (such as plastic clays and salts), casing subjects to severe collapse pressure [13].

External Pressure*:* The collapse load is the hydrostatic pressure of the heaviest fluid(s) to be left behind the casing. Worst load condition is commonly obtained with cement [14].

The collapse load, Pc at any point along the casing can be calculated from:

$$Pc = Pe - Pi \quad \textbf{(2)}$$

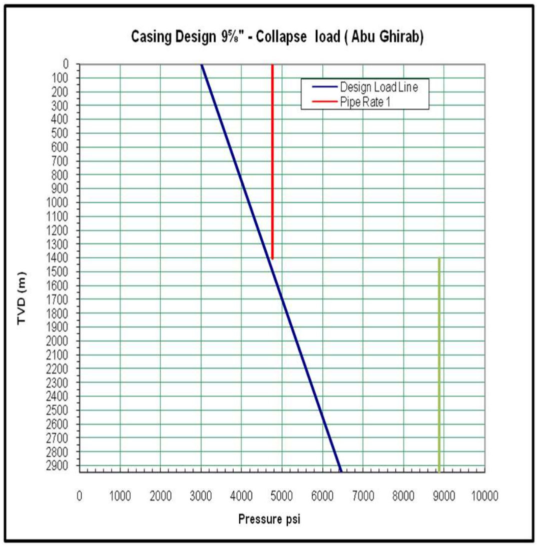

Figure 5: New Casing Collapse Load Case ofAbu Ghrib Well.

Axial Tension LoadCases

Casing may suffer three possible deformations; elastic,elasto-plastic or plastic, under axial tension[13].Collapse and burst on casing are both affected by tensile loading. Tensile loading tends to reduce the collapse resistance and to increase burst resistance of casing [14].

Tension Condition: Once burst and collapse criteria have been chosen, the tensile loadings can be determined from the weight of the casing itself; considering buoyancy. The tensile loading on casing is reduced by buoyancy [14].

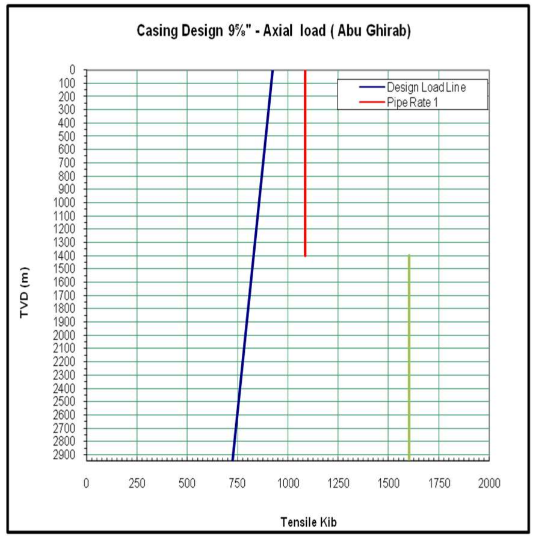

Figure 6: New Casing Axial Tension Load Case ofAbu Ghirab Well.

6.1.2 Casing and Connections Specifications Design

Current casing and connections specifications of Well Abu Ghirab wells are shown in Table 2 and that have been conducted by a new casing design are illustrated in Table 3.

Table 2: Current Casing specification Design ofAbu Ghirab Well.

OD inch	**Grade**	**Weight** lb/ft	**Burst** psi	**Collapse** psi	**Tensile** klb	**Connection**
20	K55	94	2102	522	1482	BTC
13⅜	P110	72	7395	2885	2286	BTC
9⅝	L80	47	6858	4765	1086	VAM TOP
	R95	58.4	10279	8880	1604	VAM TOP

Table 3: New Casing specification Design of Abu Ghirab Well.

OD inch	**Grade**	**Weight** lb/ft	**Burst** psi	**Collapse** psi	**Tensile** klb	**Connection**
20	K55	94	2102	522	1482	BTC
13⅜	P110	72	7395	2885	2286	BTC
9⅝	L80	47	6858	4765	1086	VAM TOP
	T95	58.4	10279	8880	1604	VAM TOP

6.1.3 Actual Casing Design Factor

The new actual casing design factor of Abu Ghirab oilfield wells is shown in Table 4.

Table 4: New Actual Casing Design Factor of Abu Ghirab oilfield.

Load Case	Minimum CSF	20"	13⅜"	9⅝" L80	9⅝" T95
Burst	1.1	4.9	3.37	1.24	1.8
Collapse	1.1	5.4	1.12	1.58	1.47
Tension	1.6	2.96	3.97	1.78	2.8

7. Results Analysis and Discussion of a New Casing Design Proposal and the Problems in Abu Ghirab Wells

After research, investigation and observation of wells drilled in Abu Ghirab oil field; the problems during drilling operation are specific due to the existence of massive, thick sheets of salt-anhydrite formation. In addition to problems occurred and arising due to technical errors.

- The comparison between current and new casing design demonstrated that both of them are the same except 13⅜ inch casing and the grade of 9⅝ inch casing as shown in Table 3. So, current casing specification is accepted with new casing design and API casing design assumptions.
- Due to technical error to detect top of MB1 member in Lower Fars formation, total mud loss (complete mud loss) event occurred. Logging While Drilling LWD for more informed formation evaluation is recommended using.
- Bad cementing job due to total mud loss and unsuccessfully dealt with the problem. But this problem did not affect or causes casing collapse even the annulus pressure build-up was 1500 psi for 13⅜ inch and 9⅝ inch casing.
- According to drilling reports, there is no information of monitoring annulus pressure build up after cementing job and drilling new formation.
- The effect of salt creep during drilling salt formations causes major problems. Casing deformation, stuck pipe, poor cementing job and excessive torque and drag. Problems related drilling salt formation and salt creeping can be controlled by mud weight and mud properties. In addition. It is recommended to conduct geomechanical models analysis of salt creeping to estimate salt creeping rate that lead to estimate damage risks, and to optimize well designs for these challenging conditions.
- The pore pressure profile is an important design parameter for casing design, in terms of both setting depth selection, and required casing capacity for burst as well as collapse loading.The pore pressure is the pressure of the fluid in the pore spaces of the formation. Pore pressures are often expressed as gradients relative to a reference level. In geophysics and rock mechanics, this is the "Free Water Level" FWL, (i.e. seawater level offshore or ground water level on land).

8. Risk Management Guidelines to avoid Casing Deformation in Abu Ghirab Wells

Controlling risk at a “Project Level” means managing risks that relate to support or assist the project operations. These are items such as; the project contract, adherence to the execution plan, managing the staffing plan, ensuring that the proper information is available when needed, and implementing and managing a strong project quality plan. In this study, the problem occurring in the well is managed as follows:

- Select best casing design software and technology.
- Follow API casing design safety factor.
- Select best casing manufacture companies.
- Drift all casing size before run in the hole.
- Consider salt creeping in casing design.
- Salt creeping risk management should be considering in drilling well design.
- Reduction cost and minimise drilling time should be last options in casing design.
- Conduct all cement evaluation practise.
- It is recommended to conduct two stage 9⅝" cement job to avoid complete loss during cement job .Using DV packer technology to reduce hydrustic pressure (external pressure) of annuals (13⅜" and 9⅝").

9. Casing Deformation Contingency Plan during Drilling Operations

Contingency analysis is a process by which contingencies are selected for quantified risks based on an acceptable level of project risk or proposal, and combined to arrive at an overall contingency project valuation. The contingency plan for this case study is demonstrated in Figure 7.

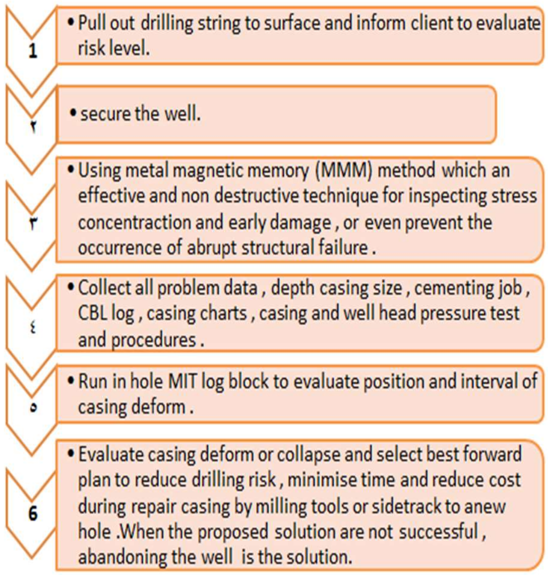

Figure 7: Casing Deformation Contingency Plan during Drilling Operation Guidelines for Abu Ghirab

10. Casing Deformation Risk Assessment and Management Worksheet of Abu Ghirab Oilfield

Risk assessment and management plan to avoid casing deformation in Abu Ghirab oilfield is demonstrated in Table 8.

11. Conclusions

1. According to the new casing design proposal:

- The perfect 9⅝ inch casing specification in Abu Ghirab is Grade T95 and Weight 58.4 lb/ft.
- To avoid the impact of salt creeping on 9⅝ inch casing, change casing grade to T95 and increase casing design safety factor of collapse and burst load case is proposed.
- Thread type VAM TOP (not changed) has an excellent in gastight sealing under combined loads, resistance to bending and resistance to external pressure and compression. It is also easy to use and repair.

2. Before drilling the new hole section, perform Formation Integrity Tests (FIT) and Casing Integrity Tests (CIT) to evaluate the cement bond strength around 9⅝" casing shoe. Also, running in Cement Bond Log (CBL) or Segmented Bond Tool (SBT) log to evaluate the cement effectiveness quality and integrity behind a cemented casing (accurate evaluation of a casing cement job).
3. Applying best available technology and drilling risk management to reduce drilling cost and minimise time by mitigating or preventing drilling problems. That leading the drilling companies to reach their goal; zero Non-Productive Time (NPT) and improve Key Performance Indicators (KPIs).

Acknowledgement

The authors would like to thank the staff of Missan Oil Company (MOC) – Iraq Ministry of Oil for their support, especially the staff in Petrophysic and Drilling sections in Missan Field Operations Division (FOD).

Table A1: Risk Assessment Worksheet of Abu Ghirab Oilfield

Area : Missan	Field : Abu Ghirab	Well : AG1,AG2,AG3

Description of Work Activities: 9⅝ inch casing deformation in Abu Ghirab oilfield

L - LIKELIHOOD		S - SEVERITY				R - Risk Level					RESULT
Category	Definition	Category	Definition			SEVERITY		LIKELIHOOD			
LOW (1)	Remote	LOW (1)	Minor Injury	No Damage	No Pollution		L	1	2	3	Acceptable
MEDIUM (2)	Possible	MEDIUM (2)	Serious Injury	Minor Damage	Minor Pollution		M	2	4	6	Tolerable
HIGH (3)	Probable	HIGH (3)	Major Injury	Major Damage	Major Pollution		H	3	6	9	Unacceptable
								L	M	H	

No.	Hazards Identified	Hazard Effects	Potential Risk level			Mitigation Plan	Control Measurement (Contingency)	Residual Risk level			Results
			L	S	R			L	S	R	
1	9⅝ inch Casing deformation in Abu Ghirab oilfield	9⅝ inch Casing collapse.	3	2	6	Select best casing design software and technology	Immediately pull out drilling string to surface and inform client to evaluate risk level.	2	1	2	Acceptable

Figure 8: Risk Assessment Worksheet of Abu Ghirab Oilfield.

No.	Hazards Identified	Hazard Effects	Potential Risk level			Mitigation Plan	Control Measurement (Contegency)	Residual Risk level			Results
			L	S	R			L	S	R	
1	9⅝ inch Casing deformation in Abu Ghirab oilfield	Temporary Abandon the well	3	2	6	Select standard assumptions of internal and external load cases.	Secure the well.	2	1	2	Acceptable
		89.7 days Non Productive time				Consider salt creeping in casing design.	Check all drilling string, bit, stabilizers if any damage or signal on drilling signal, Check Out side drilling string may be run in the hole wrong size.				
		Stuck pipe and back off drilling string inside 9⅝" casing shoe, Side track the well				Drift all casing size before run in hole.	Collect all problem data, depth casing size, cementing job, CBL log, casing charts, casing and well head pressure test and procedures.				

Figure 8: Risk Assessment Worksheet of Abu Ghirab Oilfield (Continue)

No.	Hazards Identified	Hazard Effects	Potential Risk level			Mitigation Plan	Control Measurement (Contingency)	Residual Risk level			Results
			L	S	R			L	S	R	
1	9⅝ inch Casing deformation in Abu Ghirab oilfield	Schedule delay due to additional remedial casing deformed, added cost	3	2	6	Conduct all cement evaluation practice. Perform casing scraper job before run in hole wire line tools	Run in hole MIT log block to evaluate position and interval of casing deform.	2	1	2	Acceptable
						Select best casing manufacture companies. Select standard assumptions of internal and external load cases.	Evaluate casing deform or collapse and select best forward plan to reduce drilling risk , minimize time and reduce cost : - Repair casing by milling tools - Side track. - Well abandon.				

Figure 8: Risk Assessment Worksheet of Abu Ghirab Oilfield (Continue)

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Nomenclatures

API	American Petroleum Institute
BHA	Bottom Hole Assembly
CBL	Cement Bond Log
COMPASS	Computerized Planning Analysis Survey System
DDR	Daily Drilling Report
DF	Design Factor
DP	Drilling Program
DV	Differential Valve
FIT	Formation Integrity Test
FWR	Final Well Report
KPI	Key Performance Indicator
MD	Measure Depth
MIT	Multifinger Imaging Tool
MMM	Metal Magnetic Memory
NPT	Non Product Time
OWC	Oil Water Contact
PF	Fracture Pressure
PP	Pore Pressure
SBT	Shoe Bond Test
SLB	Schlumberger
SLS	Surface Logging Service
TD	Total Depth
TVD	True Vertical Depth

تقييم وادارة تشوه البطانة في حقل ابو غرب النفطي

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الخلاصة – الهدف من تقييم المخاطر وإدارتها هو زيادة احتمالية نجاح المشروع إلى الحد الأقصى من خلال تحديد المخاطر وتحليلها وتخفيفها والسيطرة عليها. تتمثل أهداف فريق مهندسي إدارة الحفر هو العمل مع عملاء الحفر لتقليل التكلفة والوقت غير المنتج بشكل كبير من خلال التخطيط المتكامل وايجاد حلول مناسبه لمشاكل الحفر في الوقت الحقيقي. خلال عمليات الحفر حدث تشوه في البطانة ذات حجم 9⅝عقدة في الابار AG-1 ، AG-2 و AG-3 في حقل أبو غرب النفطي أثناء انزال مجموعة معدات قاع البئر (BHA) في البئر, حيث حصلت اعاقة و استعصاء لهذه المعدات بسبب تشوه البطانة ذات حجم 9⅝ عقدة في تكوين Lower Fars . تتضمن هذه الدراسة بحث واستقصاء وتحليل مخاطر تشوه وانبعاج البطانة. كذلك تصميم جديد للبطانة ذات حجم 9⅝عقدة باستخدام برنامج لاندمارك.Landmark software أظهرت معلومات تشوه البطانة التي تم الحصول عليها من البحث والاستقصاء، وجود ضعف في ممارسات تقييم السمنت. حيث لم يتم تنفيذ فحوصات التكوين المتكامل (FIT) وفحوصات البطانة (CIT) ولم يتم إنزال معدات تقييم صلابة السمنت (CBL) أو فحوصات صلابة السمنت أسفل البطانة (SBT) في تجويف البئر. يتضمن مقترح تصميم البطانة الجديد؛ زيادة وزن البطانة، تغيير درجة البطانة، تغيير نوع البطانة وزيادة عامل أمان تصميم البطانة للانهيار والانبعاج وذلك لتجنب تأثير زحف التكوينات الملحية على البطانة ذات 9⅝ عقده. ان تحسين تصميم البئر، وممارسات الحفر المثالية، واختيار مصانع بطانة ممتازة، وتحسين دقة تقييمات السمنت من شأنه أن يخفف أو يمنع حدوث هذه المشاكل في حقول النفط.

الكلمات الرئيسية –تقييم وإدارة المخاطر، تشوه البطانة، حقل أبو غرب النفطي، برنامج لاندمارك