

Utilization of Small Size Drilling Rig for Workover Operation in Dieng Geothermal Field

Daniel Adityatama², Agung W. Mukti¹, Dorman Purba², Riviani Kusumawardani², Rany Putri², Farhan Muhammad²,
R. Bayu Wibowo¹

¹Geo Dipa Energi, Aldevco Octagon, Jakarta,

²Rigsis Energi Indonesia, Equity Tower 49th Floor, SCBD, Indonesia;

daniel.adityatama@rigsis.com

Keywords: Dieng, geothermal, workover, well, scale, casing remedial, Indonesia

ABSTRACT

Dieng Unit 1 Power Plant is located in Dieng Geothermal Field, Central Java, and has been operating since 2002. Dieng Unit 1 is currently experiencing production decline due to problems in its wells. Apart from scaling problem in the production/injection wells, another most common problem in Dieng Geothermal Field is the casing damage due to casing collapse or corrosion. To address this issue, a workover campaign has been planned to remove the silica scale and remediate the casing damage by squeeze cementing and re-line or casing tie-back.

The existing production facilities in the well pad poses a big challenge in performing workover in Dieng Geothermal Field, as the smaller unit like Hydraulic Workover Unit (HWU) will not be able to perform any casing tie-back. On the contrary, the bigger drilling rig options may not have small enough footprint that can be accommodated by the current well pad layout in Dieng due to existing surface facilities such as master valve, pipeline, separator and brine pond. A proper workover method with the fit-for-purpose rig is significant to ensure a successful workover operation. This paper investigates the challenges in planning workover to remove mineral scale and remediate casing damage in Dieng Geothermal Field. The process of selecting the most suitable drilling rig type is also discussed, including the advantages and disadvantages of the available options. Finally, the lessons learned and room for improvement for the future planning and operation in Dieng is presented.

1. INTRODUCTION

Dieng Geothermal Field is situated in Central Java Province at around 2,000 meter above sea level, and concession work area size around 63 km². Current developed Dieng geothermal field comprises of two systems, Sileri hydrothermal system (20 wells), and Sikidang hydrothermal system (27 wells). The existing power plant configuration in Dieng Geothermal Field is 1 x 55 Mega Watt (MW), but currently generates around 39 MW. At present, there are 5 production wells that are showing production decline which require staged and programmed subsurface treatment.

The treatment for the declining wells is one of the company's efforts to fulfil the production target in 2019 and to support the Small-Scale Power Plant programme. It requires an effective treatment by combining a *fit-for-purpose* rig with a suitable workover jobs for those five wells. A thorough study to assess the technical and financial feasibility of workover activity for those wells is required to successfully increase the production to meet the target.

2. OBJECTIVES

The purposes of this paper are as follow:

- Summarize the process of planning workover for five production wells in Dieng;
- Identify the challenges during workover planning phase;
- Summarize the lessons learned and room for improvement for future workover planning.

3. POSSIBLE WELLBORE PROBLEMS

Scaling and corrosion are known as a common problem in geothermal industry. Specifically, the five wells that will undergo workover in Dieng are having similar problems:

1. Sulfide scale deposition in the wellbore and the reservoir in the vicinity of the wellbore. This mineral scale deposition reduces the diameter of the wellbore, thus reducing geothermal fluid flow and decreasing the production.
2. Metal loss on the 13-3/8" or production casing. Magnetic Thickness Detector (MTD) surveys were carried out and revealed severe metal losses in some areas of the production casing that might indicate leak on the casing. Casing leak in geothermal may cause groundwater intrusion to the wellbore, reducing the temperature, or even cease the production of the well.
3. Casing damage due to fatigue failure or casing implosion due to heated trapped water in the cement.

Figure 1 shows some of the wellhead schematics overlaid with identified problem on top of it.

3.1. Difficulties in Identifying Wellbore Problems

It must be noted that the presence of obstruction in the wellbore prevented further well investigation to be carried out below that depth, making it is impossible to accurately predict what is out there and how long the workover may take. Another important note

is that MTD survey only indicates metal loss, not positively confirms that there is a leak. PTS survey and Down Hole Video (DHV) survey are required to confirm casing leak in the wellbore.

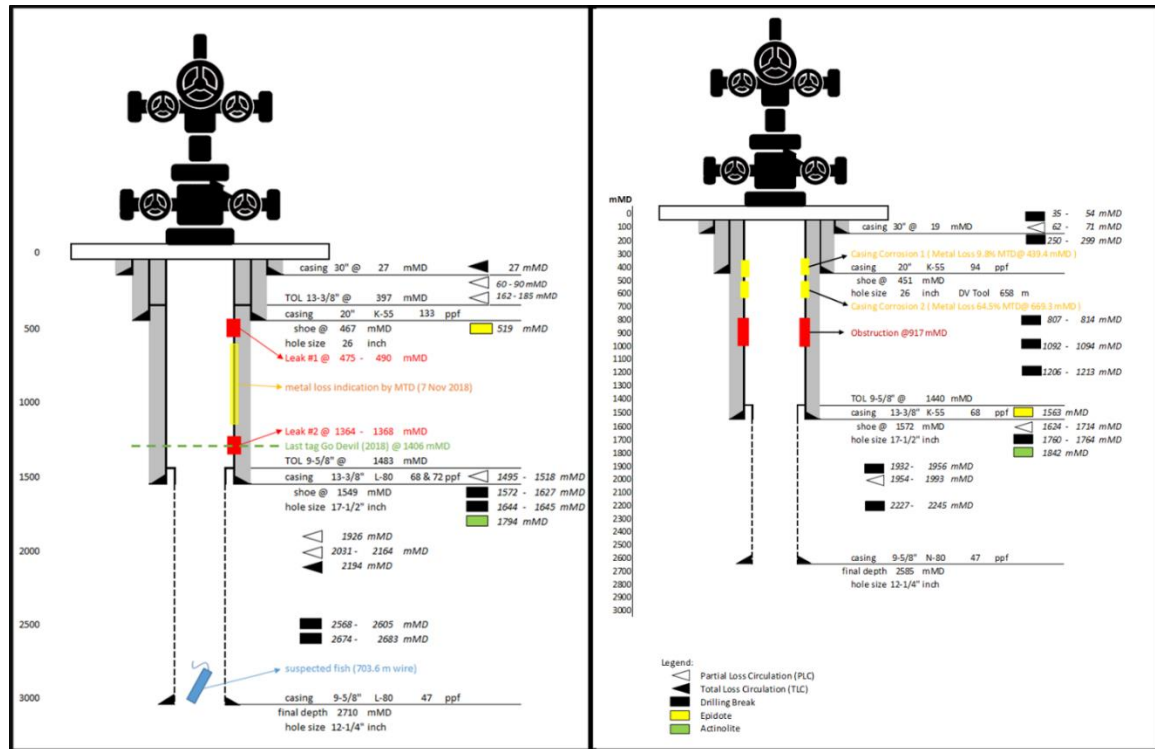


Figure 1. GDE-11 (left) and GDE-13 (right) schematics with identified problems overlaid on it.

4. BASIC WELL DATA

The five production wells showing production decline which require staged and programmed subsurface treatment are described in Table 1.

Table 1. Basic well data for 5 wells to be undergone workover.

Well Name	Casing Design	Total Depth (m-MD)
GDE-11	30" conductor, 20" surf csg, 13-3/8" anchor csg / prod csg, 9-5/8" perf liner	2,717
GDE-12	30" conductor, 20" surf csg, 13-3/8" anchor csg / prod csg, 9-5/8" perf liner	2,566
GDE-13	30" conductor, 20" surf csg, 13-3/8" anchor csg / prod csg, 9-5/8" perf liner	2,641
GDE-14	30" conductor, 20" surf csg, 13-3/8" anchor csg / prod csg, 10-3/4" scab liner, 9-5/8" perf liner	2,522
GDE-15	30" conductor, 20" surf csg, 13-3/8" anchor csg / prod csg, 9-5/8" prod liner, 7" perf liner	2,366

5. WELL REMEDIAL PLANNING

To recover Dieng's productivity, it is important to have a fit for purpose workover planning. Five phase of project management was applied to correctly identify the project objectives and planning (Rose 2013, Dumrongthai and Putra 2015). Figure 2 shows the five phases of designing the workover activity along with deliverables for each phase.

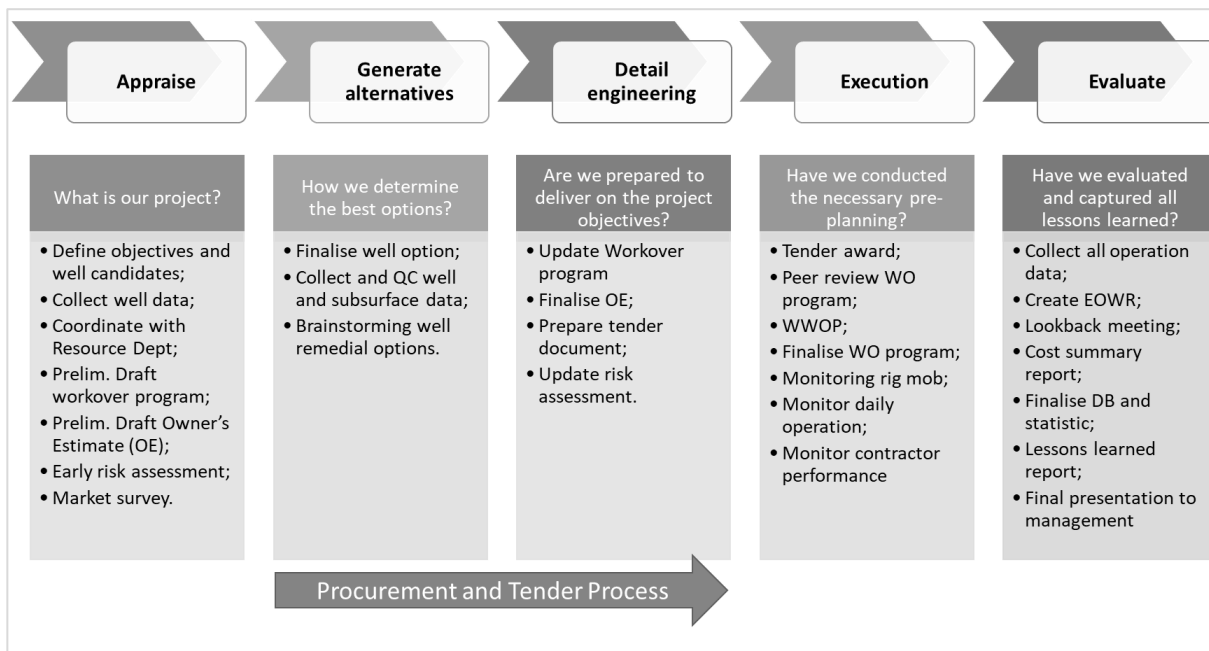


Figure 2. Five phases of project management were applied to design the workover program in Dieng Field.

5.1. Workover Action Assessment

An intensive communication with Company's Resource & Facility Department was conducted to correctly identify what have to be done to recover the productivity of the wells. It was decided that the workover should perform the following well remedial actions:

a. Mechanical Milling / Reaming

Mechanical reaming activity cleans the well from various obstacle such as mineral scale and oxide layer deposited in the wellbore. Cleaning is performed by running drill bit or milling tool (tapered mill and watermelon mill) using drill strings and Bottom Hole Assembly (BHA) in various depth. In geothermal well, the scale deposition commonly occurs in the diameter change spot, such as top of liner of liner hanger. The difference in diameter will cause flashing in geothermal fluid, thus reducing the solubility of the mineral and resulted in scale deposit. The mineral scale deposition can also occur in the feedzone in the vicinity of the perforated or slotted liner, thus hindering the geothermal fluid flow from reservoir to the wellbore. The mineral scale is expected to be crushed by the rotation of the drill bit and the weight of BHA. Mechanical milling is also expected if there are casing damage such as casing collapse or implosion.

b. Plug and Squeeze Cementing

Cement plug and squeeze cementing are the remedial cementing job to plug any leaks on the casing to recover the well integrity. Generally, the cement plug and packer are positioned first in the designated area to isolate the leaking part of the casing, thus the cement then can be pumped and squeezed into the leaking zone only. One of the challenges of performing this job on geothermal well is that it is common to find more than one leaking zone, thus make squeeze cementing become a very time-intensive activity. The presence of scale further complicates the squeeze cementing job, as it will greatly decrease the ability of the packer to isolate the leaking zone of the casing.

c. Casing tie-back and cementing

Casing tie-back or re-liner is an attempt to address the casing leakage due to the corrosion or collapse by inserting smaller diameter casing into the damaged casing. This is performed when the existing casing repair using squeeze cementing method is considered ineffective or will take too long. In the case of GDE-12, the 13-3/8" casing is deemed unworthy for a production casing, so it will be replaced with smaller 9-5/8" casing. This will reduce the maximum production capacity of the well, but it is considered better than risking the well keep declining and might someday not produce at all.

5.2. Rig Type Selection

A proper workover method with the fit-for-purpose rig is significant to ensure a successful workover operation. There are three main requirements for the workover units or rig for conducting workover in Dieng:

- Able to safely withstand the maximum load of drill string + BHA up to the total target depth;
- Able to safely withstand the maximum load during running casing and cementing;
- Able to operate in the existing well pads without requiring adjacent wells' master valves to be dismantled.

Based on workover team's assessment, the first two requirements phased out 550 HP rig and 460K HWU. The third requirement was proven to be the most difficult to satisfy, as larger rig (1000 HP and above) will not be able to participate due to their large footprint. Even not all of 750 HP rig can satisfy that requirement, as some 750 HP rigs have a slingshot construction that require larger footprint.

To assess the first and second requirement, the following calculations are performed (the calculation sheet shown in this paper is only for GDE-13 as an example due to it has the longest production casing section):

5.2.1. Drill String Weight Analysis

The 750 HP rig that will be used in the workover activity must be able to withstand the weight of the drill string with various BHA configuration and the weight of casing during casing tie-back for GDE-13 workover (Table 2).

Table 2. Drill string weight calculation for various BHA configuration.

BHA	Activity Description	Weight on air (lbs)
BHA#1	<i>Reaming obstruction inside 13-3/8" casing to top of 9-5/8" liner (1,440 m-MD) using 11-1/4" mill, stabilizer, 6-1/2" DC, Jar and 5" DP. (Include block, hook, top drive, and drag)</i>	109,320
BHA#2	<i>Cleanout 9-5/8" casing to TD (2,100 m-MD) using 11-1/4" mill, stabilizer, 6-1/2" DC, Jar and 5" DP. (Include block, hook, top drive, and drag)</i>	182,974
Casing	<i>Running 9-5/8" tieback casing up to 1,434.5 m-MD (assuming the wellbore is empty / no water present). (Include block, hook, top drive, and drag)</i>	221,642
Casing	<i>Running 9-5/8" tieback casing up to 1,434.5 m-MD (assuming the wellbore is filled with water). (Include block, hook, top drive, and drag)</i>	193,454

The maximum load that must be borne by 750 HP rig unit is 221,642 lbs during running 9-5/8" tie-back casing. But this is assuming that there is no fluid at all inside the wellbore which is very unlikely due to the well and casing will be pumped with water continuously during running 9-5/8" tie-back casing. The water pumped to the wellbore will not diminish quickly due to the presence of wooden plug and cement plug. The empty wellbore condition may occur if the water escape from the leaking spots in 13-3/8" casing. This can be mitigated by pumping the water with higher rate than the water loss rate; which can be measured by conducting injectivity test prior running the casing.

5.2.2. Casing Strength Analysis

The 9-5/8" casing used for the GDE-13 tie-back is rated at 47 lbs/ft (ppf). The casing strength analysis is performed to ensure that the casing can withstand the cement hydrostatic pressure. The calculation for the worst-case scenario where no water inside casing and cementing using 16.2 lbs/gallon (ppg) cement and the most likely scenario where the inside of the casing is filled with water and using 15.8 ppg cement are summarised in Table 3 and Table 4 below respectively.

Table 3: Scenario 1 - Casing collapse analysis for empty casing condition and using heavier (16.2 ppg) cement (worst case scenario).

9-5/8" tie-back casing (47 ppf)			
Total casing length	1,434.5 m	4,705.16 ft	
Cement weight		16.2 ppg	Assuming using 16.2 ppg cement for tie-back casing cementing job
Total cement hydrostatic pressure (net external pressure)		3,963.63 psi	Assuming no water inside the casing, and outside of the casing is full of 16.2 ppg cement
Casing external collapse pressure rating		4,760 psi	Assuming 9-5/8" casing, 47 ppf, L-80
Safety design factor		1.20	

Table 3 assumes that there is no water inside the casing and the outside of the casing (annulus) is full of 16.2 ppg cement. The casing collapse rating is higher than the cement hydrostatic pressure, and it gives safety factor of 1.20, which satisfy the recommended safety factor design of 1.2 proposed by Hole (2008).

Table 4: Scenario 2 - Casing collapse analysis under most-likely scenario (casing full of water and using 15.8 ppg cement).

9-5/8" tie-back casing (47 ppf)			
Total casing length	1,403 m	4,705.16 ft	
Cement weight		15.8 ppg	Assuming using 15.8 ppg cement for tie-back casing cementing job
Total cement hydrostatic pressure behind casing – water hydrostatic inside casing (net external pressure)		1,827.68 psi	Assuming the inside of the casing is full of water, and outside of the casing is full of 15.8 ppg cement
Casing external collapse pressure rating		4,760 psi	Assuming 9-5/8" casing, 47 ppf, L-80
Safety design factor		2.60	

The scenario in Table 4 assumes that the casing is full of water and in the outside of the casing is full of cement with 15.8 ppg cement. The safety design factor is 2.60, which is above the recommended 1.2 safety design factor proposed by Hole (2008). This scenario is considered the most-likely scenario based on proposed procedure.

5.2.3. 750 HP Rig Capability Analysis

Table 5 below summarizes the 750 HP rig capacity to perform the proposed workover / well remedial operation.

Table 5. 750 HP rig unit capability analysis for GDE-13 workover.

Capability	Rig capability	GDE-13 condition	Remark
Rig clearance height to accommodate the existing stack height of wellhead, master valve and BOPE	4.9 m rotary beam clearance height.	2.5 m wellhead and master valve height and 3.6 m BOPE stack gives total height of ~6.1 m.	Rig clearance is not sufficient, need modification on substructure (add pony sub)
Maximum load capacity	Mast: 360.000 lbs (90%) Substructure: 223.250 lbs (90%)	Maximum drill string load: 221,642 lbs (weight of tie-back casing in the air)	Rig capable to withstand the maximum operating load.
Minimum footprint area due to the existing production facilities in Pad	750 HP rig unit is commonly able to operate within 3,750 m ² minimum area.	Enough for rig to operate but require production facilities dismantle.	

Table 5 shows that the 750 HP rig unit is able to satisfy the minimum criteria of the proposed workover programme in GDE-13. However, there are several aspects that should be carefully monitored such as the substructure dimension, and it is advised that a proper site survey should be conducted to produce a proper rig layout plan.

5.3. Rig Contract Type

To keep up with the very tight schedule, the bundled contract procurement process was used (Figure 3). This was meant to simplify and accelerate the procurement process while at the same time keeping the cost from rising too high as often in the case of Integrated Project Management (IPM) contract type (Muhammad, et al. 2019, Isa, et al. 2017, Purwanto, et al. 2018).

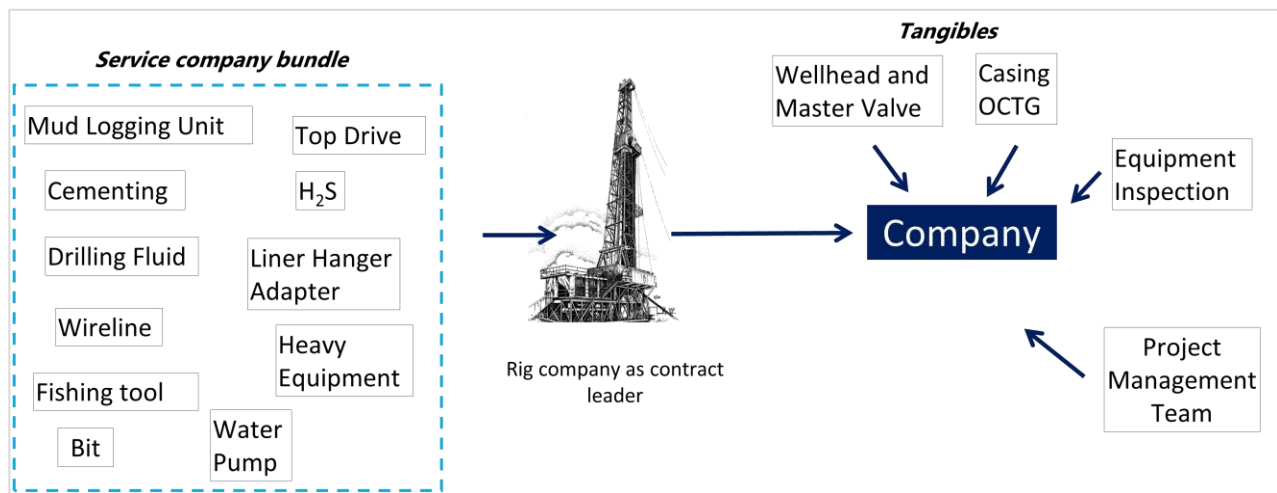


Figure 3. Bundled service illustration.

6. DEVELOPING WORKOVER PROGRAM

As shown in Figure 2, the next step is the detailed engineering for developing workover program. As most of wells in Dieng were drilled in 1998 by other company (ELC 2019) and the legacy data is currently scattered and not organized in a proper database, it is paramount to collect the relevant well data and reconfirm its accuracy to the Resource and Facility Department. Figure 4 shows the work flow of developing workover program in Dieng.

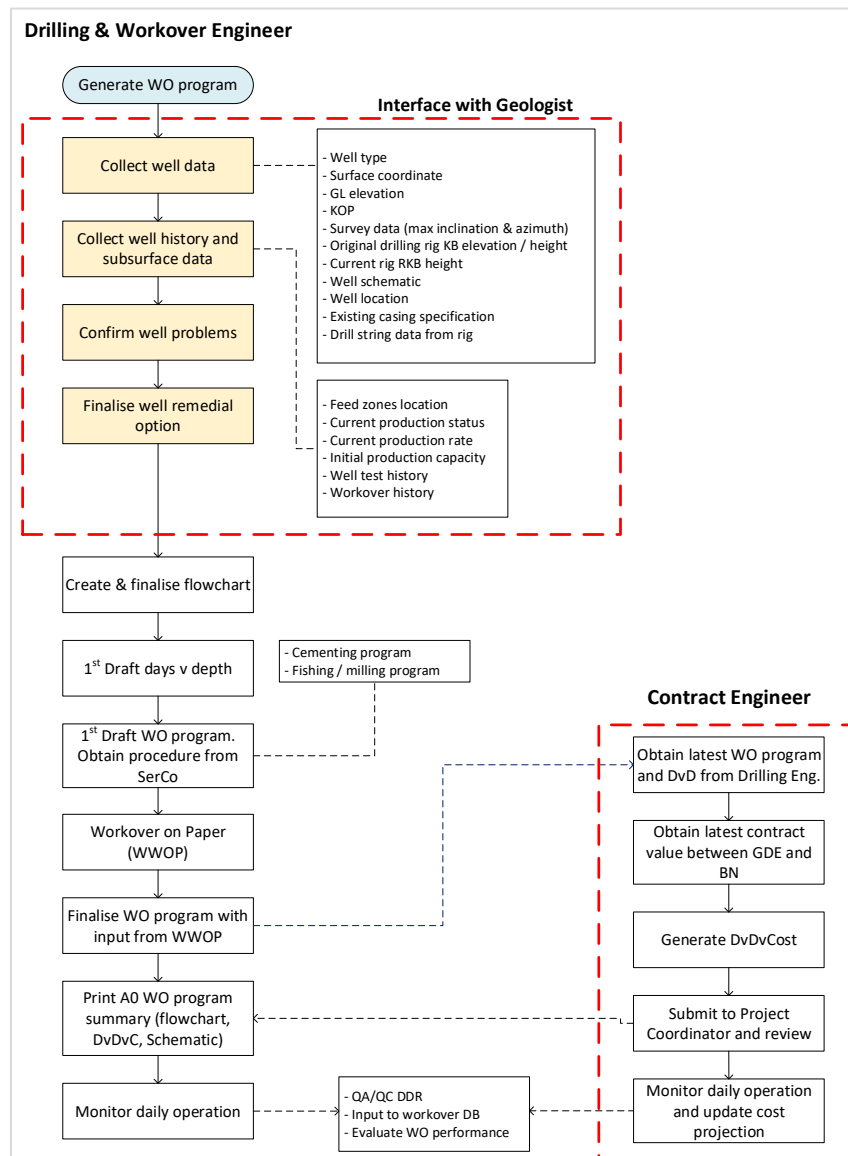


Figure 4. Workover program development flowchart.

In developing the workover programs, it is very important to get involvement from all key personnel involved, especially from cementing engineers and fishermen. This is due to squeeze cementing, milling jobs, and fishing jobs are the most critical jobs that has the highest level of uncertainties are squeeze cementing jobs, milling jobs and fishing jobs. Various possible scenarios must be assessed and expressed in the form of a decision flowchart (if-then rule) to assists the decision-making process during operations. This way, the risk of non-productive-time (NPT) due to wait-on-decision can be minimized.

7. SUMMARY AND CHALLENGES

By employing a systematic project management approach (Figure 2) to develop workover program for 5 wells in Dieng, several results are obtained:

- To remediate identified wellbore problems, the workover activity must include mechanical milling/reaming, remedial cementing, casing re-lining and cementing, and mechanical reaming to clean out the production zone of the well.
- Most of 750 HP rig available in Indonesia should be able to do the proposed workover activity in the most cost-effective manner.

Several challenges were faced during the planning phase:

- Limited well investigation data complicates the planning phase, as there is no data on how thick the mineral scale deposition is.
- Unknown well condition below the last tagged depth.
- Limited information on the presence or the size of the casing leak. This make the remedial cementing calculation and planning difficult and forced the workover team to use a lot of guess / assumptions during planning phase.

8. PATH FORWARD

It should be noted and carefully considered that the workover activity is not a routine job, especially with a lot of downhole condition uncertainty. Thus, it is imperative that the workover team should conduct various risk mitigation actions prior and during the rig procurement in order to ensure the accuracy of the data and information from the rig / equipment provider candidates. The aforementioned risk mitigation actions are as follow:

- a. Performance check of the equipment unit that will be used through interview and background check from the previous user of the unit that passes the technical assessment. This has to be done obtain complete information regarding other risks that have not been identified in the preliminary assessment.
- b. Complete check on the supporting documents of the equipment unit that passes the technical assessment such as latest inspection certificate on main components, latest operational report, maintenance record, and competence certificate of the main personnel.
- c. Inspection by 3rd party inspector on the equipment unit that passes technical assessment.
- d. Peer review on the well investigation results on the four well candidates that are subject to workover. This is crucial to ensure that there will be no additional work that need to be done beyond the original scope. Further well investigation by running PTS tool might be required to obtain more accurate information regarding the casing condition (i.e. exact casing leak positions, exact position of the feed zone, etc.).
- e. Develop a workover program in the form of a decision flowchart (if-then rule) in sufficient level of detail based on input from various parties involved, especially cementing and fishing companies. This is to facilitate the decision maker in making decisions during operations.

It is advised that the workover team organizes Risk Assessment Workshop for all personnel involved in the workover operation, especially from the contractor or service provider side. The aim of the workshop is to socialize and communicate the workover programme and for the final check and chance for the involved personnel and stakeholders to give input or feedback to improve the workover programme, and in turn will increase the safety level and success rate of the workover operation.

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