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Drilling Cost Optimization by Improvement of Re-entry Well Operational Efficiency in Mahakam Field Offshore Asset Development

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Abstract. The oil price downturn has driven Oil Companies to improve drilling operational efficiency in maintaining low cost for drilling to produce hydrocarbon, moreover in mature field such as the Offshore Asset in Mahakam Field operated by Pertamina Hulu Mahakam (PHM). Re-entry well drilling campaign by sidetracking from existing well has become one of the main strategies initiated by PHM for Offshore Mahakam development to reduce capital cost for a new well. Several optimizations are introduced in order to improve operational efficiency and reduce well cost.

The project is initiated by mapping conventional method of a re-entry well operation, starting from plug & abandoned (P&A), re-entry drilling preparation, milling casing window, drilling sidetrack hole, open-hole logging data acquisition, and well completion. The possibility of improvement on each step are reviewed, covering engineering and operational aspect, including alignment with PHM's company rules, and impact on cost reduction. Special procedures and risk assessments are formulized to ensure all the initiatives can be executed smoothly without issue. Proper selection of parent well candidate is also defined to improve operational efficiency. Field implementation trials are scheduled to allow adequate time to gain operational feedback for next improvement plan.

Many trials have been done in Offshore Mahakam drilling campaign by applying all of improvements. Those are rigless P&A, whipstock setting and milling optimization, and e-line logging through casing window. All of these improvements can be successfully executed without any major issue, particularly on HSEQ. Reduction of well duration is up to 10 days between the conventional method of a re-entry well campaign at the 1st well drilled in June 2019 until the latest well with operational optimization drilled in May 2020. This optimization is equal to around 2 Million USD saving on well cost which is significant in the current environment where most of the wells have marginal reserve. As per today, there are 12 re-entry wells that have been delivered and still counting. Room for improvement is still foreseen to furthermore squeeze the well duration and boost the economics of the wells.

Keyword: Re-Entry Well, Rigless Plug and Abandonment, Sidetrack Drilling, Milling Optimization, E-Line Logging through Casing Window

1 Introduction

Mahakam block is a concession area of oil and gas fields which is operated by Total EP (1966 - 2017) and Pertamina Hulu Mahakam (since 2018). The block includes Mahakam offshore and delta area with multilayer type reservoir which is located in East Kalimantan Province. Mahakam block has been producing oil and gas since more than 50 years ago. Nowadays, this field is categorized as brown field with marginal remaining oil and gas reserve.

The current development of offshore Mahakam Field has reached a mature level, where finding new and economic targets are challenging, especially during the downturn of oil price. Production optimization have been done massively by maximizing remaining reserve from the existing wells through workover or well intervention operation. However, the higher production gain is demanded for Mahakam development continuation.

Drilling a new well can significantly increase oil and gas production. However, it consumes a much higher cost than optimizing the existing wells production. The limited slots on existing platform is also being a constraint for new well drilling due to the expensive cost to build a new platform. Many initiatives have been done to improve the efficiency of drilling operation in Mahakam such as application of batch drilling, well architecture simplification, kick margin optimization, offline activity, and ROP improvement (Maulana et al., 2019).

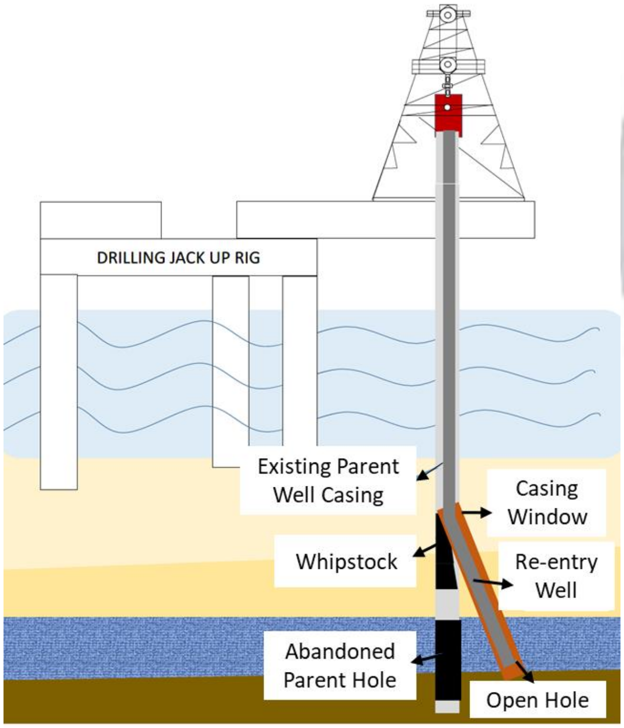

Figure 1. Drilling Re-entry Well Schematic using Jack-Up Rig

The strategy of re-entry well has been massively implemented for offshore Mahakam development since 2019. The main purpose of re-entry well is to drill new reservoir targets from existing well to save the cost of the vertical section including conductor pipe and surface casing of a new well (Jones, 1995).

The wellhead and surface equipment including pipeline and Christmas Tree are also available in place (Sandoval et al, 1994). The selected existing well as parent well is plugged and abandoned to set whipstock at a predetermined depth, then the well is sidetracked and drilled until total depth (**Figure 1**).

By applying a massive new strategy of re-entry well in Offshore Mahakam, the room of improvement is widely opened to optimize drilling cost, especially for activities which is not applied in drilling a new well such as plug and abandonment (P&A) and re-entry drilling preparation (set whipstock, milling casing window, and drill rat hole). This also aligns with the objective to optimize rig and barge utilization due to a limited number of current available rig and barge during oil price downturn. Strategy of rigless P&A is then introduced which can significantly reduce the cost by saving rig operation time. Re-entry drilling preparation is also optimized by applying no multi-cycle bypass valve (MCBPV) test and milling optimization so the preparation only takes single trip from set whipstock until drill rat hole. Proper risk mitigation and prevention is also made for open-hole wireline logging method so drillpipe is no longer needed to convey the wireline down to bottom hole.

2 Methodology

The project is started by mapping conventional method of a re-entry well operation. A list consists of re-entry drilling operation candidate for improvement is generated from this mapping. From the list, a study is conducted which covers engineering and operational aspect and impact on cost reduction. After that, progressive field implementation trials are scheduled for several drilling campaigns. From the trials, evaluation is made so operational feedback can be gathered for next improvement. The cost and duration of optimized re-entry well operation can also be validly compared to the conventional method. The methodology flowchart of this paper is shown in **Figure 2**.

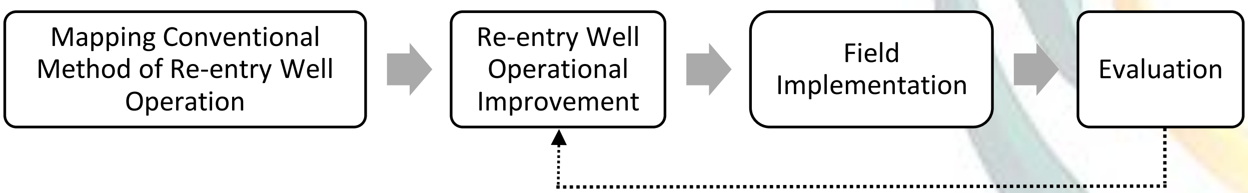

Figure 2. Methodology Flowchart for Drilling Cost Optimization by Improvement of Re-entry Well Operational Efficiency

2.1 Mapping Conventional Method of Re-entry Well Operation

The conventional method of re-entry well operation is usually done in Mahakam by using rig. Before looking after the solution, the conventional re-entry well operation is mapped with objective to generate a list of activities which is possible to be improved. In this section, the operation sequence and drilling technique of conventional re-entry well operation is defined based on first two offshore re-entry wells in the beginning of Mahakam re-entry well campaign. Those are JM-1 and JM-2 which is part of South Mahakam A Campaign. The cost and duration is also calculated as a base case of the conventional method.

2.1.1 Operation Sequence

The re-entry well drilling operation is started with P&A operation in the selected existing wells as parent hole by using Jack-Up Rig. After parent well is set up, the program is continued by re-entry drilling preparation to set hydraulic whipstock at the predetermined sidetrack depth. Then, casing window milling operation is done which is followed by drilling an adequate rat hole to accommodate bottom hole assembly (BHA) prior start drilling. Once drilling to well total depth (TD) completed, direct open-hole logging on wireline conveyed by drillpipe or commonly called pipe conveyed logging (PCL) is performed for data acquisition. Finally, the re-entry well is completed as per completion plan to gain the most optimum production profile. The operation sequence for re-entry drilling can be shown in **Figure 3**.

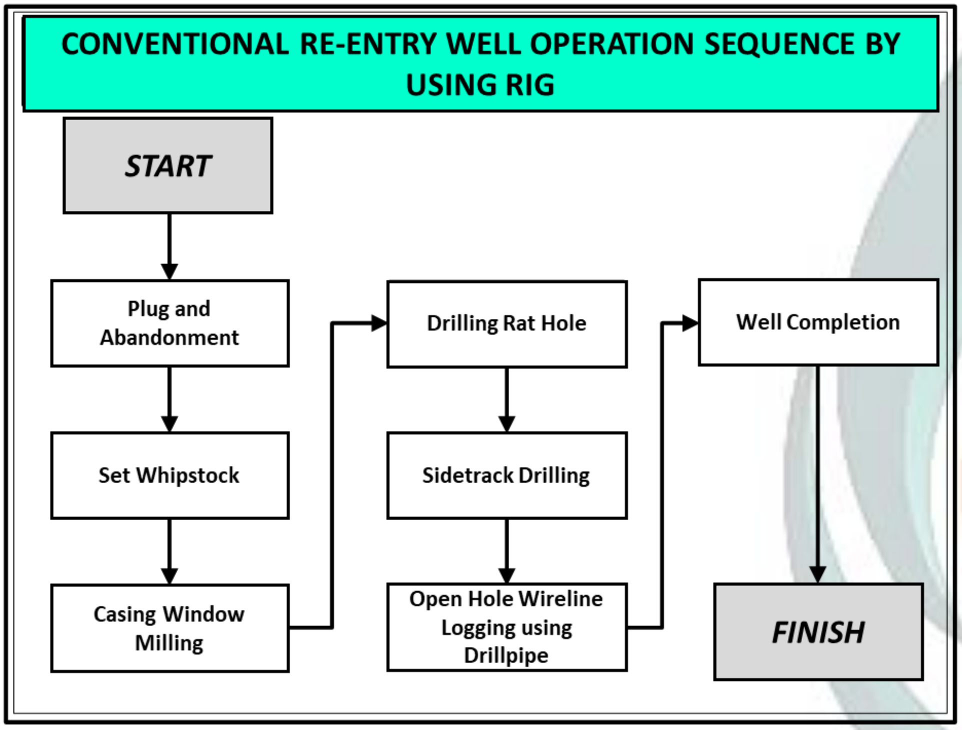

Figure 3. Operation Sequence of Conventional Re-Entry Well Operation

2.1.2 Drilling Technique

The workover program in plug and abandonment for re-entry well consists of two main activities which are cutting and retrieving existing tubing or casing and set cement plug as the permanent barrier to isolate the existing open reservoir zone in parent wells. Then, the parent wells will be considered as a well suspension implies that it will be ready to be re-entered. Sidetracking or milling casing window will be done above the cement plug depth. The schematic of plug and abandonment is shown in **Figure 4**.

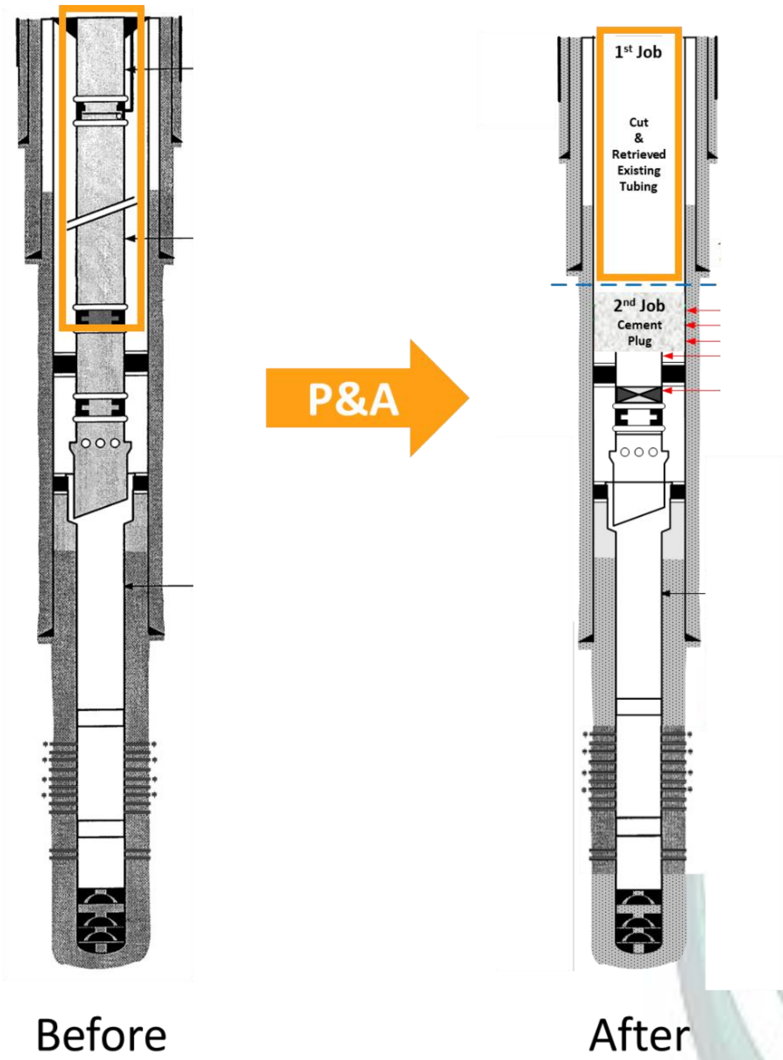

Figure 4. Plug & Abandonment Schematic

MCBPV tool is commonly used for Mahakam re-entry well operation as one part of milling BHA. It is used to set the packer by bypassing the circulation from annulus exit to the packer. The MCBPV will start to bypass the flow after six cycles of circulation. One MCBPV cycle consists of OFF-ON-OFF step which means circulation from zero flowrate to a pre-set flowrate then back to zero flowrate (**Figure 5**). If the cycle has fully used, the tool needs to be reset at surface for next utilization. In conventional method, a dedicated trip is done to test the MCBPV with measurement while drilling (MWD) tool (shallow test) before whipstock installation. This is to ensure that MCBPV can work properly.

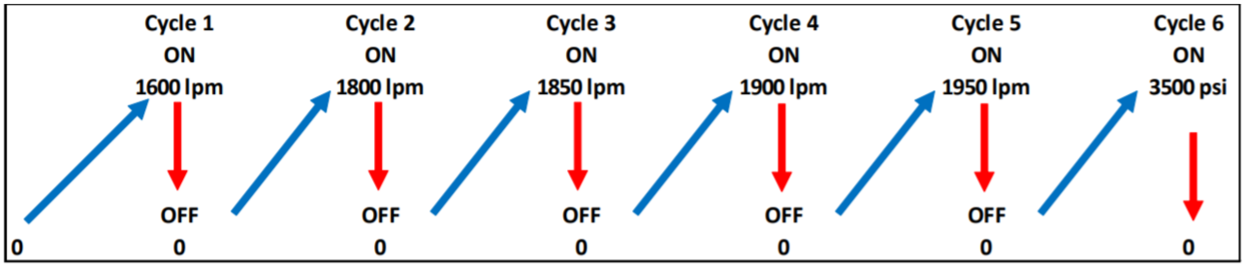

Figure 5. How MCBPV Cycle Works

Milling operation is done after whipstock installation in a single trip with one set of milling BHA. The milling BHA consists of

1. Whipstock & packer,
2. Lead mill (tri-mill),
3. Running tool,
4. MCBPV,
5. MWD,
6. Universal bottom hole orientation (UBHO).

Whipstock is orientated before running into hole, then it will be connected to the lead mill followed by milling BHA as mentioned above. The milling BHA is be delivered by drillstring. After reach at a predetermined depth, whipstock is re-oriented and re-positioned. Then, MCBPV start to bypass the flow after 5 circulation cycles. The packer will be pressurized and set. After that, overpull is done to break the shear bolt that connect whipstock to the tri-mill.

The operation is continued to sidetrack the parent well by milling casing window and drill rat hole. The whipstock will force the milling BHA to deflect from the parent well direction to a sidetrack direction. In conventional casing window milling operation, there are two trips of different set BHA that will be run to mill casing window and drill open-hole formation as the additional distance from the total depth to casing window (rat hole). The rat hole is drilled up to 70-80 m as the space to accommodate drilling BHA so the MWD and logging while drilling (LWD) tool can be secured from damage when rotating through casing window. Drilling rat hole use light motor BHA which consist of

1. Bit as stated in program,
2. Motor for directional purpose,
3. Jar and accelerator.

Sidetrack drilling and well completion is done with no special technique if compared to normal new well drilling operation. After drilling reach TD, open-hole wireline logging is conducted for reservoir data acquisition. The conventional method uses PCL type so the drillpipe conveys the wireline to cover it when pass or reciprocate through casing window. This is to avoid damage that can break the wireline. The schematic of PCL can be seen in **Figure 6**.

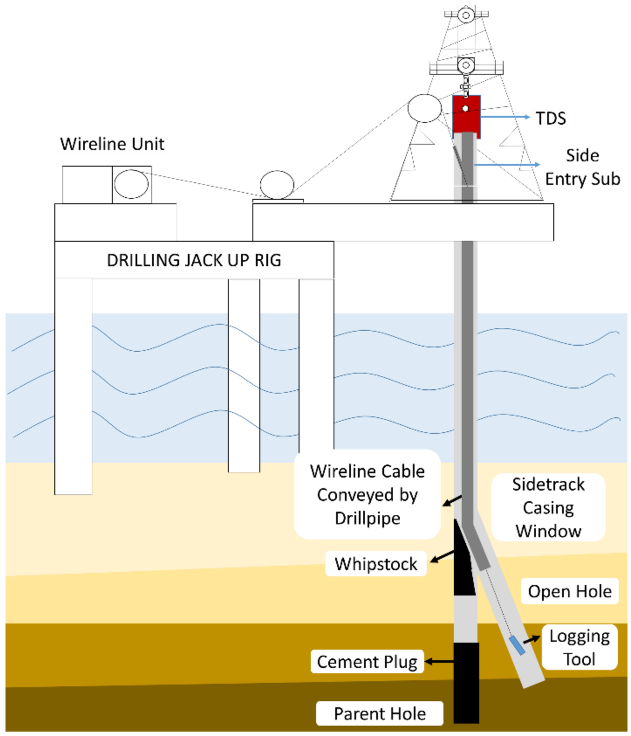

Figure 6. Pipe Logging Conveyed (PCL) by using Drillpipe

2.1.3 Cost and Duration

Each of operation sequence is described in more detail to calculate the duration and cost based on experience of re-entry drilling in Mahakam. The re-entry wells drilling experience in South Mahakam A Campaign will be used for data calculation. The data will be used as a base case to compare with the improved method of re-entry well operation. The duration and cost is shown in **Table 1**.

Table 1. Cost and Duration: Conventional Method of Re-entry Well Operation

Duration of Re-entry Drilling Operation	Well		Average Duration	Cost Estimation
	JM-2	JM-1		
	(days)	(days)	(days)	USD
Plug and Abandonment	7.0	5.4	6.2	1,347,500
Set Whipstock	1.1	1.0	1.1	228,206
Milling Casing Window	1.3	2.6	2.0	425,556
Drilling Rat Hole	2.0	5.0	3.5	763,819
Drilling Open-hole	14.6	7.6	11.1	2,412,463
Open-hole Wireline Logging by using Drillpipe	4.0	3.3	3.7	803,000
Well Completion	3.1	3.4	3.3	706,352
Total Re-entry Drilling Operation	**33.1**	**28.3**	**30.7**	**6,672,307**

2.2 Re-entry Well Operational Improvement

Re-entry well operation consists of special operations which is applied for re-entry well yet it is not applied for a new well drilling. The room for improvement is still widely opened due to the re-entry wells campaign has just massively been initiated as a development strategy for Offshore Mahakam. The improvement candidates are shown in **Figure 7**. Based on mapping of conventional method, these candidates consume significant rig operation time around 16.4 days or equivalent to 3.6 Million USD (27% from total operation). Each activity consumes cost and duration: P&A strategy (6.5 days / $1.42M), re-entry drilling preparation (6.2 days / $1.35M), and open-hole wireline logging (3.7 days / $0.8M).

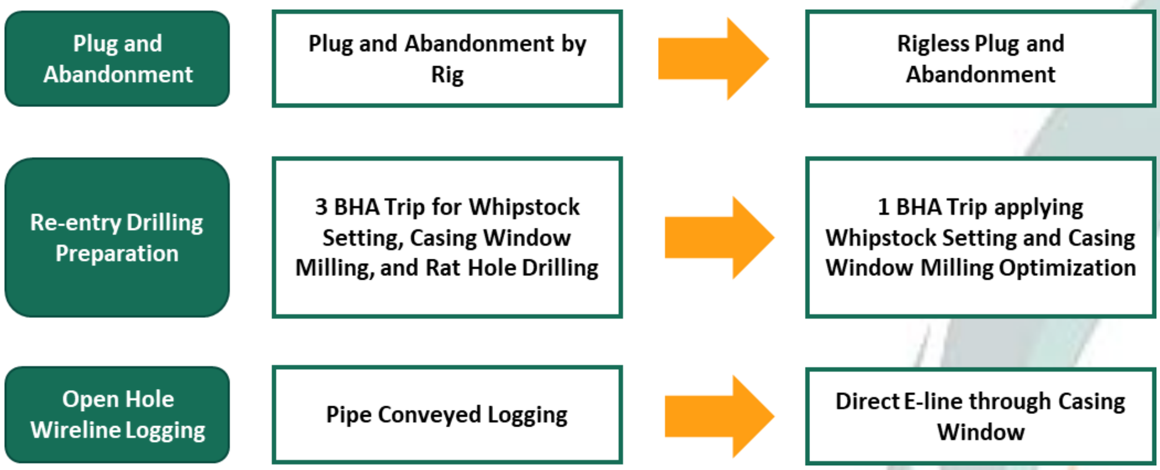

Figure 7. Flowchart of Re-entry Well Operational Improvement

2.2.1 Rigless Plug and Abandonment

Based on mapping of conventional method, the P&A is considered as a quite time-consuming and costly operation in Offshore Mahakam due to the complexity of the program. A rigless strategy is then studied to review engineering and operational aspect, including compliance with PHM's company rules. The strategy of rigless P&A operation can be done by using HWU or well intervention unit.

Hydraulic Workover Unit (HWU) is a snubbing unit with a blow out preventer system thathas the same standard well control procedure with drilling rig operation (**Figure 8**). By having 30 m height with hydraulic system as the main power, HWU 340# has a full capacity of pulling and running tubular pipe (max. tension 122 tons and max. compression tons). The total load of HWU, BOP, and workstring including BHA will be borne by the existing conductor pipe of the well with the stabilizing of 12 guy wires installed on the platform. An additional pumping unit is also required to do a cement plug job. The pumping unit is set up in an offshore barge.

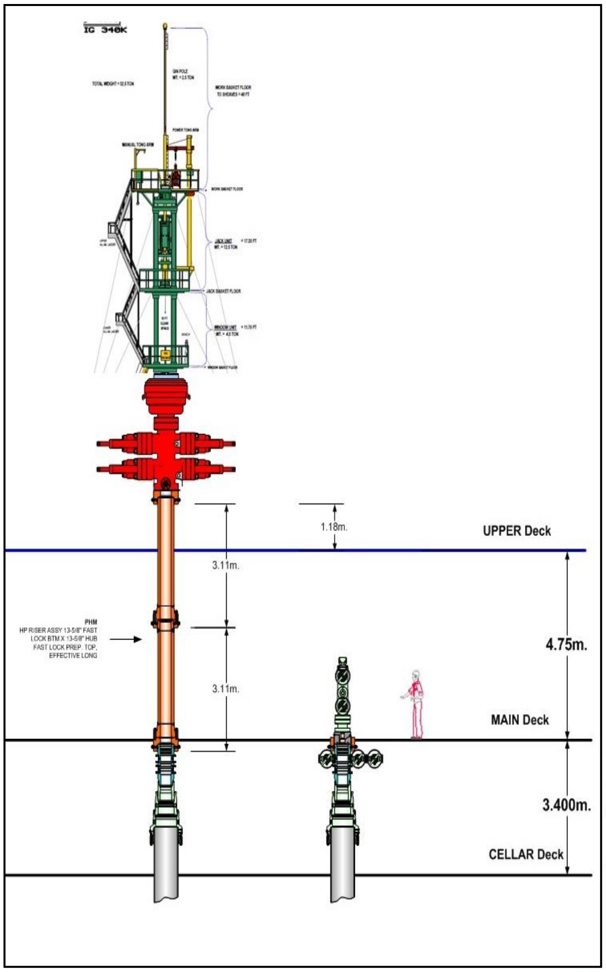

Figure 8. Hydraulic Workover Unit (HWU) Rig Up Schematic

HWU has become the most appropriate unit solution to replace Jack-Up Rig for P&A operation in Offshore Mahakam. It can cover all P&A requirements as a rig can do. The complete capacity of HWU 340# can be considered as the same hoisting system with Jack-Up Rig that can do P&A operation for re-entry well campaign in Offshore Mahakam. If using HWU, planning has to be prepared at least 2 or 3 months before Jack-Up Rig enters the platform. This considers the longer duration if using HWU that has to be matched with rig scheduling, moreover in the environment in which the batch drilling sequence has been a best practice.

Well intervention unit is also considered as an option to do P&A activity. The activity is delivered using slick line and electric line unit of well intervention. The operation sequence is quietly different from the normal P&A. Cement plug activity will be performed after two activities: set tubing plug and punch tubing. Well intervention unit can only perform cement plug and cut tubing. Tubing retrieval will still be delivered by rig before re-entry drilling preparation.

Although, there are other types of P&A job which well intervention can do: under cantilever job and remote operation. Under cantilever job is performed at the same time when Jack-Up Rig operates on the same platform. This job is done through simultaneous operation (SIMOPS) which is stated in PHM's company rule. Proper risk mitigation and prevention are required before conduct the SIMOPS activity. For under cantilever job, the well intervention unit can perform cut tubing, while the cement plug will use the rig pump. Another type of P&A job by well intervention unit is remote operation which the wireline unit is rigged up on top of platform without any barge for pumping unit. For this type of job, the unit can only perform cut tubing, while cement plug will be done by Jack-Up Rig.

2.2.2 Whipstock Setting and Milling Optimization

MCBPV with MWD shallow test requirement is reviewed together with service company that provides the tools. The idea is to eliminate this test which needs a dedicated BHA trip. A risk mitigation strategy is prepared to ensure the MCBPV can work properly with this condition. The strategy can be seen below.

1. MCBPV will be tested at full cycle (six cycles), then reset to zero at company base.
2. Burn one cycle (five cycles remaining) to confirm it is open prior to be sent to rig.
3. Before work the MCBPV cycle at sidetrack depth, circulation test is performed slowly with minimum flowrate as per requirement. Maximum standpipe pressure is also set lower in the beginning. This is to confirm the circulation return to surface and no anomaly occurs.
4. MCBPV will burn one cycle (four cycles remaining) to check MWD signal and detect toolface orientation. If any issue is occurred on MWD signal, land gyro tool onto UBHO using wireline inside drillstring. This will consume another cycle to clean the string from debris prior drop gyro tool (three cycles remaining).

There are still three cycles remaining to fully activate the MCBPV function to bypass the flow. This provides a sufficient gap to avoid the risk of premature whipstock packer set.

The activity of milling casing window and drilling rat hole apply optimum drilling parameter so it will only take single BHA trip using tri-mill BHA. The optimized drilling parameter which is needed to be considered includes rotation per minute (RPM), flowrate (F/R), weight on bit (WOB), and torque. Another factor that has to be taken into account is formation that will be drilled to create rat hole. The most preferable formation to be drilled is shale. The stringent (hard) formation is avoided such as coal and carbonate. The gas bearing sand is also less preferable considering wellbore stability and possibility of well control issue. Proper risk mitigation for operation needs is also prepared as can be shown below.

1. If tri-mill is undergauge more than tolerance, run window mill as contingency plan.
2. When run BHA pass the casing window, run gently until all directional tool pas the casing window or tag bottom.
3. Start drilling with low parameter near casing window.

From Offshore Mahakam experience in South Mahakam A campaign, milling performance (**Table 2**) shows that JM-2 has better depth progress and ROP performance than JM-1. JM-2 takes two BHA trips consist of tri-mill BHA and light motor BHA, while JM-1 takes four BHA trips consist of 2 set of tri-mill BHA, window mill BHA, and light motor BHA. From this experience, the optimized parameter cannot be determined yet due to the data limitation. Feedback from scheduled trials is needed for better milling performance optimization.

Table 2. Parameter of Milling Casing Window and Drilling Rat Hole on South Mahakam A Campaign

Parameter	JM-2	JM-1
Milling and Rat Hole Length (m)	66.3	92.0
Duration (days)	3.3	7.6
Depth Progress (m/day)	20.1	12.1
Instant ROP (m/h)	0.7	0.5

2.2.3 E-line Logging through Casing Window

Direct wireline logging method is introduced as the solution of duration optimization in re-entry well logging operation by reducing the time consumed for running drilpipe to the casing window in re-entry well as the protector and conveyor of e-line. By running e-line directly against the casing window will create an issue of breaking electric wireline due to the roughness of casing window exit. Laboratory experiment through a friction test is done to test wireline integrity when rubbing it to a casing cut end with rough profile. This casing cut end emulates the sidetrack casing window exit. The friction test result shows that the wireline will be broken when it is rubbed by 18 times of reciprocating movement with 13 klbs tension. Based on this experiment, the real logging operation will apply a limitation of reciprocating movement. The limitation of reciprocating movement is 12 times respecting 66% safety factor of wire strength. This is applied as the risk mitigation to avoid breaking the wireline when pass or reciprocate through casing window. By applying this mitigation, the direct e-line logging through casing window can be applicable for re-entry well operation improvement.

2.3 Field Implementation

The re-entry well preparation starts with the selection of existing development well to become the parent well. Proper selection of parent well is required for better optimization results which involve subsurface and drilling aspect. The subsurface aspect includes remaining reserve category and effort requires to access the remaining reserve, while drilling aspect includes surface location selection, sidetrack point optimization, parent well completion, and integrity. The subsurface aspects determine the possibility of well to be put on production in the future through an economical workover or well intervention operation. The surface location and sidetrack point depth selection affect the kick margin and trajectory complexity to hit the reservoir target. Parent well completion and integrity relate to the technical feasibility of re-entry drilling to be done in that parent well.

Scheduled trials are done in several campaigns of re-entry well in Offshore Mahakam applying the re-entry well operation improvements. The improvements are applied step by step i.e. the first campaign only applies rigless P&A, then the next campaign applies rigless P&A with milling optimization, etc. Currently, there are already five more campaigns (10 re-entry wells) that apply the improvement. The milestone of re-entry well operation in Offshore Mahakam can be seen in **Table 3**. Lesson learned or post job analysis is done after each re-entry well operation is completed as to operational feedback for future improvement. The drilling duration and cost are also calculated based on the experience to validly compare with conventional method. Benefits apart from cost optimization is also analyzed as an added value of applying the improved method of re-entry drilling.

Table 3. Milestone of Re-entry Wells in Offshore Mahakam

Campaign	Well	Improvement Application
South Mahakam A	JM-1	-
	JM-2	-
South Mahakam B	SP-1	Rigless P&A by Well Intervention Unit
Peciko	PK-1	Rigless P&A by HWU
	PK-2	
Sisi Nubi 1	SS-1	1. Rigless P&A by HWU 2. Casing Window Milling Optimization
	SS-2	
	SS-3	
Sisi Nubi 2	SS-4	1. Rigless P&A by HWU 2. Casing Window Milling Optimization 3. Direct E-line Logging through Casing Window
Bekapai	BK-1	1. Rigless P&A by HWU 2. Whipstock Setting & Casing Window Milling Optimization 3. Direct E-line Logging through Casing Window

3 Result and Discussion

3.1 South Mahakam B Campaign

The first improvement of re-entry well operation was carried out in SP-1 Well, South Mahakam B campaign. The improvement applies the idea of performing remote well intervention job for rigless P&A. The first sequence of P&A that is cutting the existing tubing was performed by wireline well intervention unit that is installed on the platform without using Jack-Up Rig.

The remote well intervention operation for P&A was safely delivered in SP-1 Well with 2.5 days of P&A duration optimization if compared to P&A by Jack-Up Rig (**Figure 9**). This means it has also saved $ 562,500 from SP-1 Well total cost. However, additional activity of retrieving the existing cut tubing and setting cement plug are still done by Jack-Up Rig which takes 4.5 days. This is then evaluated as the next aspect that can be optimized. The utilization of other rigless unit such as HWU with pumping unit is proposed for next re-entry well campaign in Offshore Mahakam.

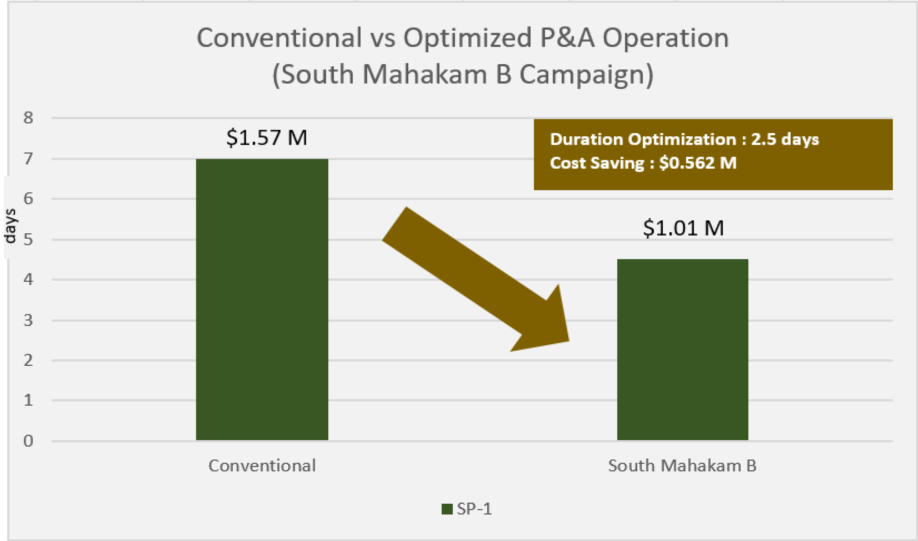

Figure 9. South Mahakam B Campaign Cost Optimization

3.2 Peciko Campaign

The complete rigless P&A activity was done for PK-1 and PK-2 Well in Peciko campaign. The complete P&A by HWU includes tubing cutting, tubing retrieval, and cement plug. The operation uses wireline unit and HWU 340# that is set up on the platform with a pumping unit in an offshore barge. The P&A activity was delivered without any incident in total of 56 days (31 days for PK-1 and 25 days for PK-2). This improvement application contributed to the 7 days of rig duration optimization or equivalent to $1,540,000 cost saving (estimated cost saving: $645,000 for PK-1 & $895,000 for PK-2) in Peciko Campaign (**Figure 10**).

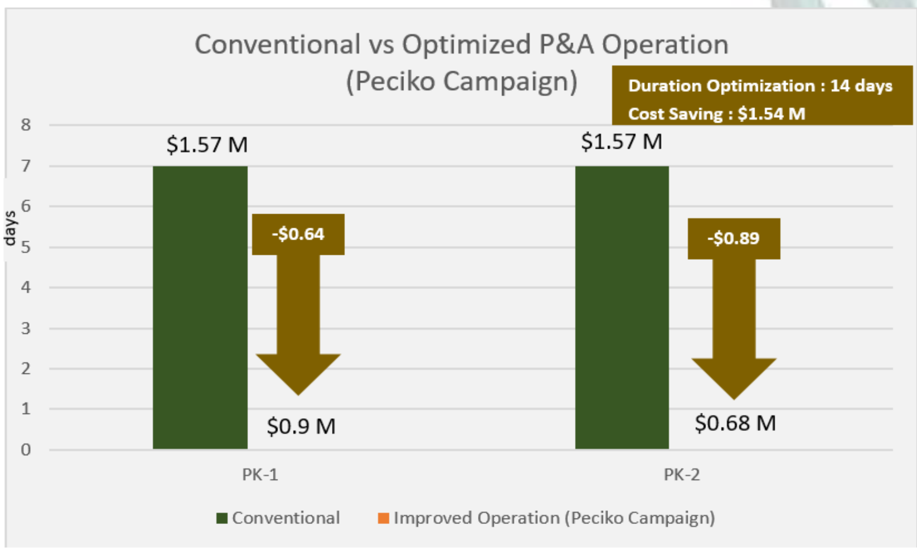

Figure 10. Peciko Campaign Cost Optimization

The great preliminary engineering design lesson learned is also captured from this first rigless P&A activity by HWU in Mahakam Field. There was an issue of un-retrievable cut tubing due to high dragging force while pulling out cut tubing using HWU #340. The cause of this issue is the presence of cement or solid settling behind the cut tubing depth which builds excessive drag force while cut tubing is pulled out of hole. Because of this issue, there is a great additional operation duration for multiple cut tubing operations (finding free tubing depth) and pulling out the cut tubing using maximum HWU#340 power in this Peciko Campaign. By considering that HWU 340# has less capacity than Jack-Up Rig, the evaluation of solid settling and cement contamination behind tubing cut depth should be clearly considered for the next campaign to determine the optimum tubing cut depth. The determination will use the most conservative additional distance from estimated top of cement and solid settling behind tubing estimation depth that was stated on the existing well's cement job report.

3.3 Sisi Nubi A Campaign

Rigless P&A activity in Sisi Nubi Campaign (SS-1, SS-2, and SS-3 Well) showed a well improved deliverability with the focus of optimizing tubing cut depth selection from the last lesson learned in the previous campaign. This rigless P&A activity took 52 days (Previous Peciko Campaign = 56 days for 2 wells) with total Jack-Up Rig duration optimization of 26.5 days and total estimated cost saving of $4,170,000. The highlight of the P&A activity in this campaign is the first trial of rigless tubing and casing removal in SS-3 Well which contributed to the optimization of 12.5 days Jack-Up Rig operation days and $2,010,000 cost saving estimation (**Figure 11**).

Two trip BHA for milling casing window and drilling rat hole was also initiated in this campaign with full of attention to the optimum milling parameter (RPM, flowrate, WOB, and torque). The optimum milling parameter is based on the previous 7 wells operation evaluation. The initiative can be performed without any issue and has contributed to the Jack-Up Rig duration optimization of 7.9 days and estimated cost saving of $ 1,777,500 in Sisi Nubi A Campaign.

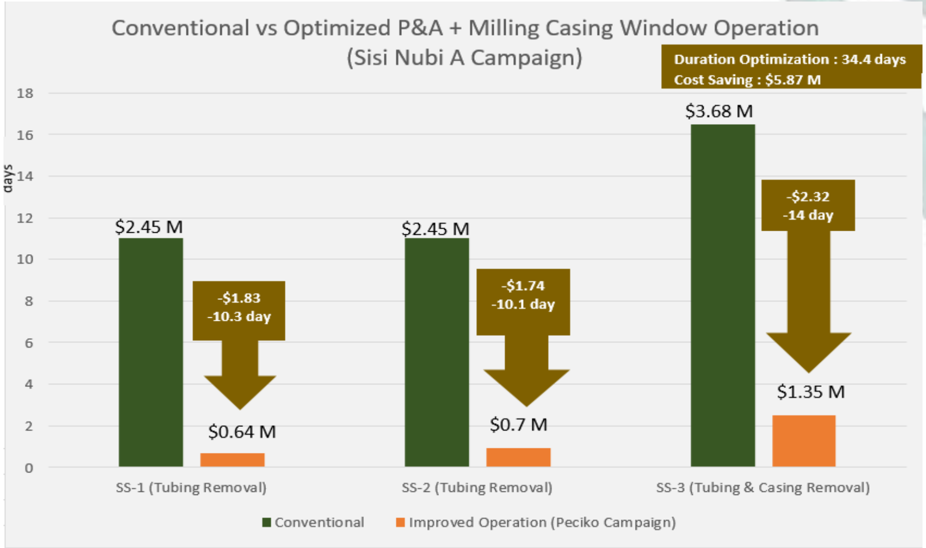

Figure 11. Sisi Nubi A Campaign Cost Optimization

3.4 Sisi Nubi B Campaign

SS-4 well had just been planned when the Sisi Nubi A Campaign operation was ongoing. This plan is an initiative plan for achieving additional potential reserves in Sisi Nubi A Campaign. The P&A activity cannot be done by using HWU 340# as the Jack-Up Rig has been set up on the platform. The remote well intervention operation for cutting tubing was then performed followed by Jack-Up Rig for retrieving cut tubing and setting cement plug. This is the same strategy as the previous South Mahakam Campaign. However, this P&A activity is performed by under cantilever job simultaneously (SIMOPS) with the Jack-Up Rig operating on the platform. This P&A activity by under cantilever job contributed to the Jack-Up Rig duration optimization of 3 days and the total estimated cost saving of $675,000 (**Figure 12**).

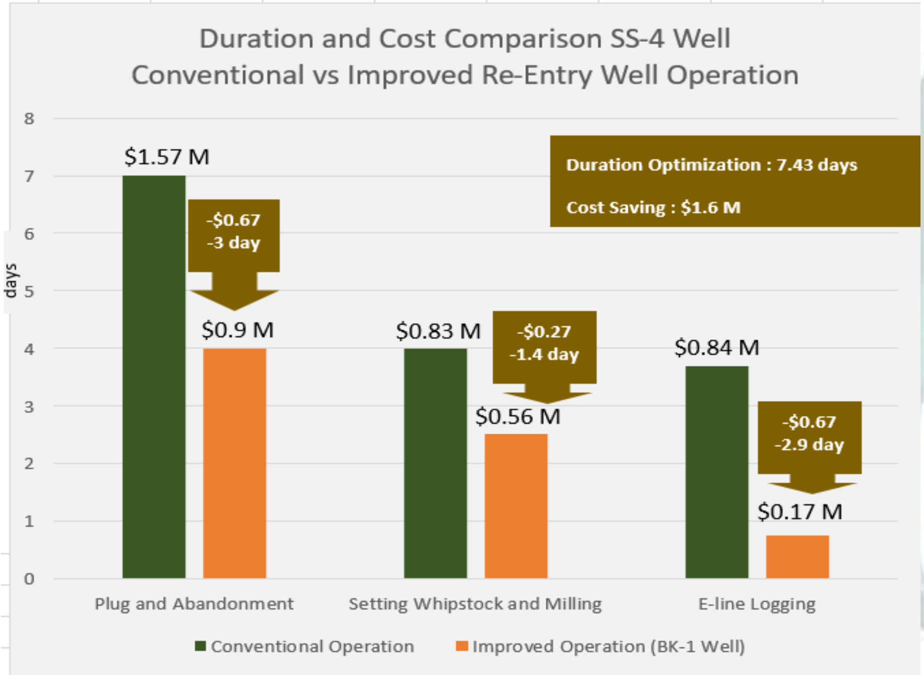

Figure 12. Sisi Nubi B Campaign Cost Optimization

On the other hand, there was an anomaly observed on the broken mill blade condition during the milling casing window operation in SS-4. Additional BHA trip using casing window mill was then performed for milling casing window and drilling rat hole. The lesson learned that can be captured is that the milling parameter should be limited as an evaluation for the next campaign.

Direct e-line logging through casing window was also performed in SS-4 as the first trial in Offshore Mahakam. The post job condition of e-line was in acceptable criteria (no broken part). This activity contributed to the Jack-Up Rig duration optimization of 3 days and estimated cost saving of $671,250 in Sisi Nubi B Campaign.

3.5 Bekapai Campaign

BK-1 is the first well which applies all of proposed improvement and performed without any issue. The improvement includes rigless P&A by HWU, whipstock setting & milling optimization, and direct e-line logging through casing window. No MCBPV shallow test in order to optimize whipstock setting was also performed as the newest applied improvement in the re-entry well campaign. With no MCBPV test, whipstock setting optimization contributed to the Jack-Up Rig duration optimization of 0.4 days and estimated cost saving of $80,250 in Bekapai Campaign.

By applying all of proposed improvement for re-entry well operation, BK-1 is awarded as the fastest well drilled in Offshore Mahakam which can be completed in 13.5 days with cost around $6M. The improved re-entry well operation can optimize Jack-Up Rig duration of 21.43 days and estimated cost saving of $4,821,750. The rigless P&A by HWU can optimize rig duration of 12.5 days and cost of $2M. The re-entry drilling preparation which consists of whipstock setting and milling optimization can optimize rig duration of 6.8 days and cost of $2.6M. The open-hole wireline logging using direct e-line method can optimize rig duration of 2.1 days and cost of $0.5M. **Figure 13** shows the duration and cost comparison between conventional and improved re-entry well operation. Detail duration and cost calculation can be found at **Attachment A**, **Attachment B**, and **Attachment C**.

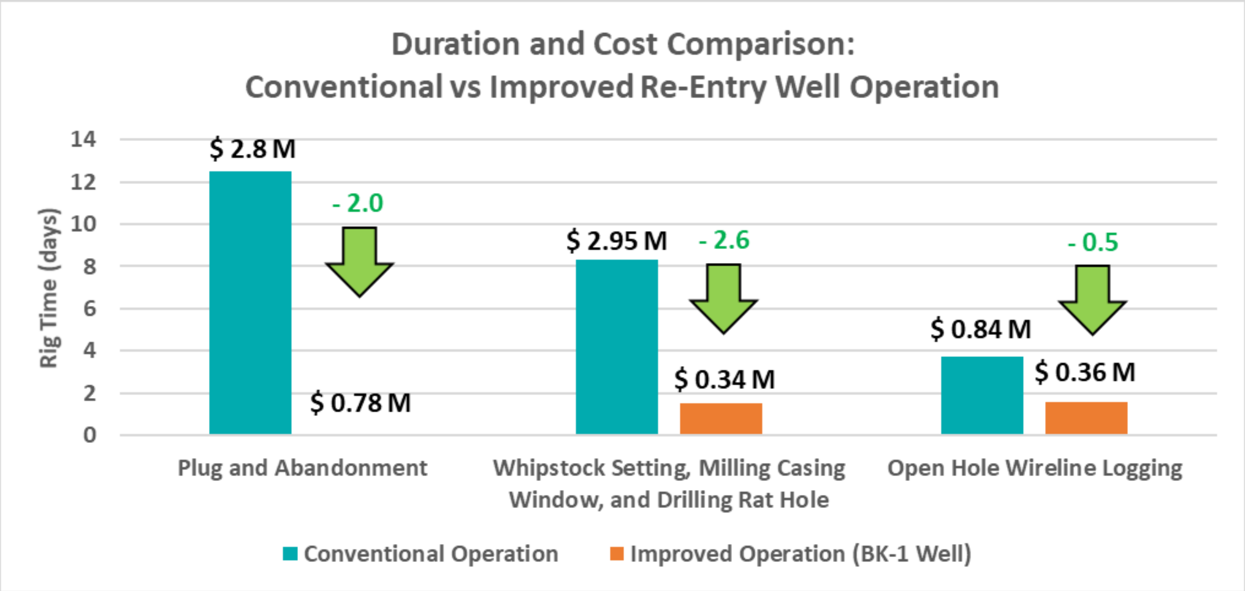

Figure 13. Rig Duration and Cost Comparisons: Conventional vs Improved Re-Entry Well Operation

4 Conclusion

All proposed improvements for re-entry well operation have contributed to the operational efficiency optimization with a total estimated cost saving of $14,600,812 from all of re-entry well campaign performed in Offshore Mahakam. The improved re-entry well operation can optimize Jack-Up Rig duration of 21.43 days and estimated cost saving of $4,821,750. The improvements consist of rigless P&A, whipstock setting & milling optimization, and e-line logging through casing window.

In summary, the deliverability of re-entry well performance has been improved to 2 times faster than the conventional re-entry well operation duration. This means the yearly target of development wells in Offshore Mahakam relatively still can be achieved even if there is a reduction on Jack-Up Rig unit due to the current oil price downturn. Most importantly, the improved re-entry well operation can be a new strategy for the development of the marginal Offshore Mahakam Field with limited platform slot. All of these initiatives have been implemented without compromising safety aspects. Moreover, the e-line logging through casing window can reduce open-hole exposure duration which implies to risk reduction of well control issues in drilling operation.

Window of improvements are still opened for the future re-entry well operation by optimizing the rigless unit utilization for doing the rigless drilling operation in Offshore Mahakam.

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Attachment A. Economical Evaluation of Estimated Total Cost Saving Rigless P&A Using HWU 340# in Offshore Mahakam

P&A Using Jackup Drilling Rig					
Number	Wells	Tubular Retrieved while P&A	Duration (days)	Estimated Cost	Average Estimated Cost
1	MHK-1	tubing and casing	12.5	$ 2,812,500	$ 2,800,000
2	MHK-2	tubing	8	$ 1,800,000	$ 1,575,000
3	JM-1	tubing	6	$ 1,350,000	
4	JM-2	tubing	7	$ 1,575,000	
Rigless P&A using Well Intervention Remote					
Number	Wells	Tubular Retrieved while P&A	Duration (days)	Estimated Cost	Estimated Cost Saving (Avg. Est. Cost Using Rig - Using HWU 340#)
1	SP-1	tubing	4.5	$ 1,012,500	$ 562,500
2	SS-4	tubing	4	$ 900,000	$ 675,000
Rigless P&A using HWU 340#					
Number	Wells	Tubular Retrieved while P&A	Duration (days)	Estimated Cost	Estimated Cost Saving (Avg. Est. Cost Using Rig - Using HWU 340#)
1	SS-3	tubing and casing	23	$ 790,000	$ 2,010,000
2	BK-1	tubing dual string	26	$ 780,000	$ 2,020,000
3	PK-1	tubing	31	$ 930,000	$ 645,000
4	PK-2	tubing	25	$ 680,000	$ 895,000
5	SS-1	tubing	14	$ 490,000	$ 1,085,000
6	SS-2	tubing	15	$ 500,000	$ 1,075,000
Estimated Total Cost Saving Rigless P&A using HWU 340#					**$ 8,967,500**
Estimated Total Cost Saving Rigless P&A using HWU 340# / well (tubing and casing removal)					**$ 2,015,000**
Estimatied Total Cost Saving Rigless P&A using HWU 340# / well (tubing removal)					**$ 925,000**

Attachment B. Economical Evaluation of Estimated Total Cost Saving Setting Whipstock and Milling Optimization in Offshore Mahakam

Two Trip BHA for Milling Casing Window and Drilling Additional Rat Hole					
Number	Wells	Casing Window	Duration (days)	Estimated Cost	Average Estimated Cost
1	JM-1	Double Casing 9-5/8" x 13-3/8"	7.6	$ 1,710,000	$ 2,800,000
2	JM-2	Single Casing 9-5/8"	3.3	$ 742,500	$ 838,125
3	SP-1	Single Casing 9-5/8"	4.4	$ 990,000	
4	PK-1	Single Casing 9-5/8"	4	$ 900,000	
5	PK-2	Single Casing 9-5/8"	3.2	$ 720,000	
One Trip BHA for Milling Casing Window and Drilling Additional Rat Hole					
Number	Wells	Casing Window	Duration (days)	Estimated Cost	Estimated Cost Saving (Avg. Est. Cost before - after improvement)
1	SS-1	Single Casing 9-5/8"	0.7	$ 157,500	$ 680,625
2	SS-2	Single Casing 9-5/8"	0.9	$ 202,500	$ 635,625
3	SS-3	Single Casing 13-3/8"	2.5	$ 562,500	$ 275,625
4	SS-4	Single Casing 9-5/8"	2.52	$ 567,188	$ 270,938
5	BK-1	Double Casing 9-5/8" x 13-3/8"	1.22	$ 274,500	$ 2,525,500
Setting Whipstock with MCBPV Shallow Test					
Number	Wells	-	Duration (days)	Estimated Cost	Average Estimated Cost
1	Sisi Nubi Campaign	-	0.7	$ 157,500	$ 157,500
Setting Whipstock without MCBPV Shallow Test					
Number	Wells	-	Duration (days)	Estimated Cost	Estimated Cost Saving (Avg. Est. Cost before - after improvement)
1	Bekapai Campaign	-	0.3	$ 67,500	$ 90,000
Estimated Total Cost Saving One Trip BHA for Milling Casing Window and Drilling Additional Rat Hole					**$ 4,478,313**
Estimated Total Cost Saving (Single Casing Window) / well					**$ 658,125**
Estimated Total Cost Saving (Double Casing Window) / well					**$ 2,525,500**

Attachment C. Economical Evaluation of Estimated Total Cost Saving E-Line Logging through Casing Window in Offshore Mahakam

Pipe Conveyed Logging Activity					
Number	Wells	-	Duration (days)	Estimated Cost	Average Estimated Cost
1	JM-1	-	3.3	$ 742,500	$ 840,000
2	JM-2	-	4	$ 900,000	
3	SP-1	-	3.9	$ 877,500	
Electric Line Logging through Casing Window					
Number	Wells	Casing Window	Duration (days)	Estimated Cost	Estimated Cost Saving (Avg. Est. Cost before - after improvement)
1	SS-4	Single Casing 9-5/8"	0.75	$ 168,750	$ 671,250
2	BK-1	Double Casing 9-5/8" x 13-3/8"	1.58	$ 356,250	$ 483,750
Estimated Total Cost Saving					**$ 1,155,000**
Estimated Total Cost Saving /well					**$ 577,500**