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Evaluation of Alternative Solutions to Recover Deferred Oil Production due to Facility Constraint: Case Study of Bravo Gathering Station in an Oil Company, PT. XYZ

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Abstract - **Bravo is one of PT. XYZ's biggest oil fields and its fluid production is treated at Bravo Gathering Station. Lately, Bravo GS has been facing a serious production problem. Several oil producers are shut-in as the field production exceeds the processing capacity. This has resulted a significant amount of deferred-oil-production (DOP) and revenue loss.**

This research aims to identify the root cause and figure out the solution to eliminate constraints. Brainstorming and Focus Group Discussions with experts is extensively used in this research during problem analysis and alternative creation using Value Focused Thinking (VFT) approach. Multiple alternative solutions are developed, using safety, economic performance, cost efficiency, and execution cycle time as the decision criteria. Analytical Hierarchy Process is used in this research for decision making process, and Experts are requested to provide rating on pairwise comparisons of each criterion and alternative based on their technical knowledge and experience. The 3rd alternative solution which reduce the incoming water production through the water shut-off (WSO) job appears to be the best alternative solution according to the consolidated AHP result. The result indicates that this alternative has a very strong upside on safety, cost efficiency, and execution cycle-time criteria among other alternatives.

Keywords: **Deferred Oil Production (DOP), Constrained Production, Value-Focused Thinking (VFT), Analytical Hierarchy Process (AHP)**

I. INTRODUCTION

Bravo GS is one of PT. XYZ's largest fluid processing facility, where the majority of fluid processed here is coming from Bravo oilfield. Last year, Bravo GS treated around 667,000 barrels of produced fluid per day, yielded approximately 23,000 barrels of oil per day.

In 2018, PT. XYZ declared 'Zero Water Discharge' (Zewadi) at Bravo GS. Since then, discharging excess water into the environment is no longer allowed. As the result, the entire produced water must be reinjected back to the ground. As Bravo field production increases over time, maintaining zewadi is becoming more and more difficult. At a certain point, the facility is no longer able to accommodate all production and in order to keep operating within facility design limit, some oil producers have to be shut in to reduce the incoming fluid. The unrealized oil production from those shut-in wells is known as 'deferred oil production' or DOP, and the number keeps growing. From 2019 to 2020, the cumulative DOP volume has amounted to 189,500 BOPD which approximately equal to 9.8 Million USD in revenue (2019-2020 average oil price $51.6). Currently, the deferred production has reached 70,000 BWPD which associate with approximately 500 BOPD. The situation could have been getting worse since more wells are expected to be shut-in, considering the additional 45,000 BWPD fluid production from the new wells in 2021. Therefore, the amount of production that has to be sacrificed is potentially rising to 120,000 BWPD.

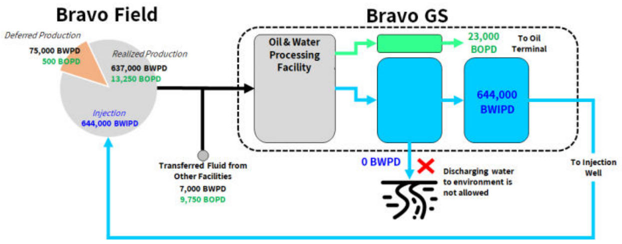

Figure 1. Bravo GS Production System

This research is aiming to identify the root causesof the said issue and also to figure out the best alternative solution to eliminate constraints and recover the deferred oil production to maximize the revenue.

II. METHODOLOGY

The type of business issue raised in this research is a single case study and the methodology used is the generic problem-solving format and decision-making process.Brainstorming and Focus Group Discussion (FGD) with the experts are also used in this research especially during problem analysis and alternative creation phase.

During problem analysis, root cause analysis (RCA) was conducted to figure out the underlying problem. It used the help from multiple subject matter experts (SME) through brainstorming and FGD process. One of the RCA tools used in this step is the Cause-and-Effect Diagram

(CED). The tool is designed to sort potential causes of a problem while organizing the causal relationships (Doggett, 2005). It is chosen for its simplicity, easy-to-use, fit for brainstorming-type discussion, promotes structure while allowing some creativity, and works best when the problem is well-defined and data-driven, Scholtes (1996)

In the alternative creation phase, the value-focused thinking (VFT) approach is used as opposed to alternative focused thinking (AFT). VFT approach articulates value as the most fundamentally important aspect than just creating alternatives for decision making. The best solution must be viewed as best by all parties involved. Therefore, during the alternative creation, the cross-functional involved is made to agreeon a combined aspired values and then the project team derive those values into several decision criteria for further alternative selection.

Furthermore, the Analytical Hierarchy Process (AHP) method is used in this research for the alternative selection.Aside from its popularity as one of the most widely used methods for multi-criteria decision analysis (MCDA), the primary reason why this decision analysis tool is chosen to achieve research objective is because its ability to perform an evaluation for both quantitative and qualitative analysis which fits to the type of decision criteria in this research. The method that Thomas L or developed in the 1980s is defined as a decision-making approach that involves structuring multiple criteria into a hierarchy, evaluating the relative importance of each criterion, comparing alternatives against each criterion, and calculating the overall ranking of the alternatives.

III. RESULTS

Root Cause Analysis (RCA)

The following chart is one of the most important analyses conducted during RCA process. This chart illustrates equipment capacity versus fluid production from the field. In conclusion, water injection pumps (WIP) system is observed as equipment that has the bottlenecksince it has the lowest capacity among other equipment at Bravo GS.Other than the facility capacity issue, other possible root causes such as policy change, fluid production increase, and reservoir dynamics were also identified to contribute the constrained production of Bravo GS.

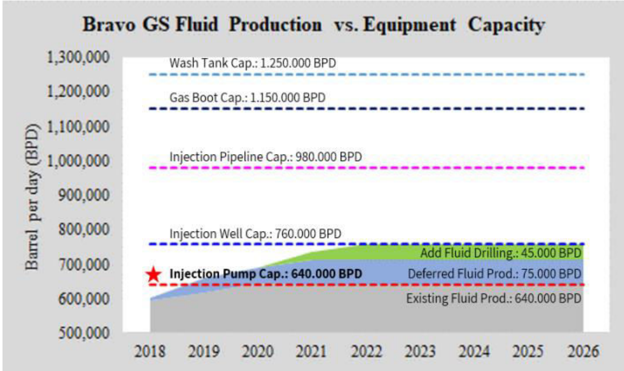

Figure 2. Bravo GS Fluid Production and Equipment Capacity

During the brainstorming and FGD session with the experts, those potential root causes were narrowed down to four root causes of the problem which includes, Zewadi implementation, the insufficient number of water injection pumps, high rate production as the result of waterflood optimization, and the WOR increase. Discussion on the possible root causes can be seen in the following table:

TABLE 1. ROOT CAUSE ANALYSIS OF THE PROBLEM

Possible Root Cause	Discussion	Root Cause?
Zewadi Implementation	Since its implementation in 2018, Bravo GS is no longer able to discharge excess water to the canal/pit.	Y
Insufficient number of water injection pumps	All 17 existing water injection pump has been maximized, yet the output rate still lower than the incoming fluid production from the field.	Y
Underperformed equipment	Most of the pumps are considered aging. However, the current performance is acceptable with regular maintenance	N
Poor equipment reliability	The reliability of the water injection pump is acceptable. The average downtime is less than 2%.	N
WOR Increase	Bravo field had a significant WOR increase in the last 3 years. Meaning to produce the same amount of oil, the amount of water that has to lift is increased significantly, therefore adding the burden to the gathering station.	Y
Water conning issue	Water conning issue is a possible cause of water rate increase, but this has only occurred in the relatively small percentage of producer wells	N
Commingle production	Commingle production has been reviewed during workover completion.	N
New Drilling well	New drilling well is part of field development.	N
High rate production as part of waterflood optimization.	Higher fluid withdrawal meaning adding more volume to be processed, therefore, add a significant burden to Bravo GS	Y

1. *Zewadi Implementation*: The policy certainly affects how Bravo GS operated. Bravo GS is used to discharge excess water to the canal/river. However, since its implementation, no surface discharge is allowed. It contributes to the increase of production deferment since its implementation in 2018.
2. *Insufficient number of water injection pumps*: Bravo GS is currently equipped with 17 Water Injection Pumps (WIP) and is still considered inadequate, thus becoming the bottleneck for the system. Based on the facility assessment, these WIPs system is proven to have the lowest capacity among other equipment in Bravo GS's overall oil production system.
3. *Water oil Ratio (WOR) increase*: The WOR is a ratio of water (in barrels) we have to lift to yield 1 (one) barrel of oil. The higher the WOR, the more water that has to be handle by the facilities. WOR increase is a natural occurrence that must happen eventually when

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producing oil. However, the situation can get worse quickly if an oil well production is combining a high rate and commingle completion, which is applied in Bravo Field.

4. *High rate production*: As part of field development and maturing resources, additional fluid production is kept added to the system. New drilling wells and Waterflood Optimization (WFO) efforts are notable contributors to higher incoming fluid production to Bravo GS.

For the record, the root cause that related to the zewadi policy will be excluded for further analysis due to its inapplicability nature. Zewadi implementation is also believed to align with one of the company values, therefore there will be no further effort to higher-level management to change this policy. Meanwhile, the other three root causes were becoming the main focus and explored further for the basis of alternative creation. The complete CED diagram as the result of FGD is shown in the figure below:

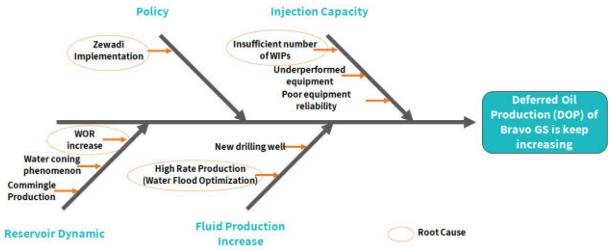

Figure 3. The CED for Bravo GS Production Deferment

Alternative Creation

The fundamental value that aspires to be achieved is implementing the process change to eliminate constraints of Bravo GS effectively and efficiently to maximizing revenue. At the same time, keep maintaining safety as the top priority. Four criteria that reflect this value are derived, including safety, economic performance, cost efficiency, and execution cycle time. These criteria are going to be the center of evaluation for the alternative solutions. Six alternatives solutions, consist of three individual alternatives plus three hybrid alternatives, are created to address the issue as follow:

- *Install Additional Water Injection Pump (WIP):* Adding more WIP to the injection system seems like the most obvious solution to increasing injection capability and addressing the root cause related with limited injection capacity. There are 2 WIPs from other facilities that are identified as underutilized and can be relocated to Bravo GS. A new capacity that can be added is approximately 70,000 BWIPD. However, the installation will require construction work to modify the existing injection pipeline system, therefore it might require capital investment (CAPEX). Due to its complexity, this alternative is expected to have a longer duration to be completed.
- *Send a Portion of Water Production to Other Gathering Station:* This alternative is expected to address one of the root cause that related to fluid production increase due to the waterflood expansion initiative This option is made possible by the existence of an interconnection water line to nearby GS called Tango GS, that can be used up to 50,000 BWPD for Bravo GS. Unlike Bravo GS, Tango GS has an environmental permit that allows discharging water as long as the chemical properties are met. Extensive pipeline repair is also needed, plus the current environmental permit of Tango GS might need to modify to accommodate the changes.
- *Reduce Incoming Water Production by Executing Water Shut-off Campaign*: This alternative aims to attack the root cause related to WOR increase, meaning to fix the problem from subsurface by isolating the water zone. 14 active oil producer wells matched the screening criteria based on a recent subsurface evaluation. From this execution, around 45,000 BWPD of water rate is expected to be reduced. All of the cost components for this option are OPEX therefore the execution will be much quicker.
- *Hybrid Alternative Solution*: Combining alternatives is possible since each alternative is not entirely mutually exclusive. Besides, combining alternatives also enables to capture of the whole potential of deferred production since there is no single alternative that can maximize additional capacity up to 120,000 BWPD as the long-term fluid forecast implies.

Analysis of Alternatives

Before selecting the best alternative solution, some quantitative parameters such as production forecast, project cost, and economic are calculated to compare one alternative to another as shown in the Table 1 below.

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TABLE 2. THE SUMMARY OF ALTERNATIVE SOLUTIONS

Aspect	Alt-1	Alt-2	Alt-3
Description	Install two additional Water Injection Pump (WIP) at Bravo GS	Send a Portion of Water Production to Other GS	Reduce Incoming Water Production by Executing Water Shut-off Campaign
Add. Capacity & Initial Oil Gain	70,000 BWIPD **700 BOPD**	55,000 BWIPD **587 BOPD**	45,000 BWIPD **426 BOPD**
Oil Reserve	605 MBO	517 MBO	378 MBO
Project Cost	**CAPEX $ 541,133**	**CAPEX $ 425,176**	**OPEX $ 359,000**
Safety	Change in WIP number. Run with a higher injection rate may increase risk both in surface and subsurface ops	Reactivating an old water line may increase the risk of operation. Risk and hazard mitigation is necessary.	No significant changes from the current operation of Bravo GS
Project Economic	NPV, $362 M **DPI, 1.70** ROR, 100% Payout time (POT), 12 mo	NPV, $381 M **DPI, 1.94** ROR, 148% Payout time (POT), 10 mo	NPV, $193 M **DPI, 1.56** ROR, >800% Payout time (POT), 2 mo
Cost Efficiency	Make use of 2 idle WIP from other GS. Capital investment is reduced significantly. All project cost is CAPEX	Extensive pipeline repair, including dismantling, patching, sleeving. Reduce significant capital investment to buy and construct a new pipeline All project cost is CAPEX	No CAPEX investment Project cost will absorb annual workover well service OPEX budget.
Exec. Cycle Time	21 weeks	20 weeks	13 weeks

Aspect	Alt-4	Alt-5	Alt-6
Description	Combination of Alt-1 and Alt-2	Combination of Alt-1 and Alt-3	Combination of Alt-2 and Alt-3
Add. Capacity & Initial Oil Gain	125,000 BWIPD **993 BOPD**	115,000 BWIPD **882 BOPD**	100,000 BWIPD **818 BOPD**
Oil Reserve	787 MBO	699 MBO	668 MBO
Project Cost	**CAPEX $ 966,308**	CAPEX $ 541,133 OPEX $ 359,000 **TOTAL $ 900,133**	CAPEX $ 425,176 OPEX $ 359,000 **TOTAL $ 784,176**
Safety	Combination of Alt-1 and Alt-2	Combination of Alt-1 and Alt-3	Combination of Alt-2 and Alt-3
Project Economic	NPV, $209 M **DPI, 1.23** ROR, 30% Payout time (POT), 27 mo	NPV, $38 M **DPI, 1.04** ROR, 19% Payout time (POT), 28 mo	NPV, $89 M **DPI, 1.12** ROR, 44% Payout time (POT), 14 mo
Cost Efficiency	Combination of Alt-1 and Alt-2	Combination of Alt-1 and Alt-3	Combination of Alt-2 and Alt-3
Exec. Cycle Time	21 weeks	21 weeks	20 weeks

Production is forecasted simply by how many shut-in wells can be turned on after the additional capacity is created. Three types of production decline rate called low, base, and high case (15%, 30%, and 45% respectively) are also introduced to capture subsurface risk and uncertainty. Project cost is estimated by referring to a similar project and project duration will be calculated accordingly to the project complexity. Economic analysis is run using Chevron's standard practice of petroleum economic evaluation for a 5-year project window to provide a broader understanding of economic benefit from the asset development perspective. The summary of alternatives, production impact, cost, and the result of economic analysis are presented in Table 2above. The analysis result shows that all alternatives have a positive NPV, ranging from M$ 38 to M$ 381, indicates that the projected earnings generated exceed the anticipated costs. Yet, there are two alternatives (Alt. 5 and Alt. 6) that fall below the company DPI threshold (1.2). Therefore, these two alternatives will be drop for further analysis and selection.

Analytical Hierarchy Process (AHP)

AHP starts with the construction of a hierarchy that describes the problem. As shown in figure 3 below, the overall objective is placed on top of the tree, followed by the main attributes below. The next step is to choose between attributes or alternatives through a series of pairwise comparisons. The pairwise comparisons are made relative to the importance, likelihood, desirability and are based on a numeric scale. Experts are selected to provide their assessment, and information in table 1 will assist them to give a verdict and rating on a pairwise comparison of the criteria and alternatives based on their technical knowledge and experience.

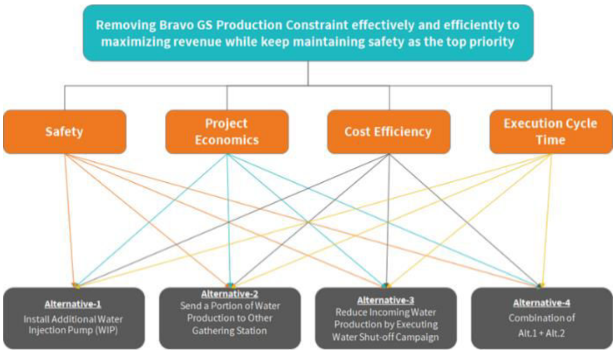

Figure 4. AHP Hierarchy

Recommended Business Solution

This research uses an online web-based tool called AHP-OS to analyze and aggregate the result of the expert assessments (Goepel, 2018). In the AHP-OS tool, CR value is calculated to reflect consistency. The consolidated result for both decision criteria and alternatives met the CR threshold < 10%, which is 0.1% and 2.6%, respectively. This number indicates a consistent verdict from the experts. As shown in figure 4 below, "Safety" is the most important criterion with 42.1% weight then followed by "Economic Performance" with 36.7% weight. Further analysis of the decision alternative using the AHP-OS tool suggests that Alt-3: **Reduce Incoming Water Production by Executing Water Shut-off Campaign** has the highest priority ranking (36.6%) among other alternatives consolidated result.

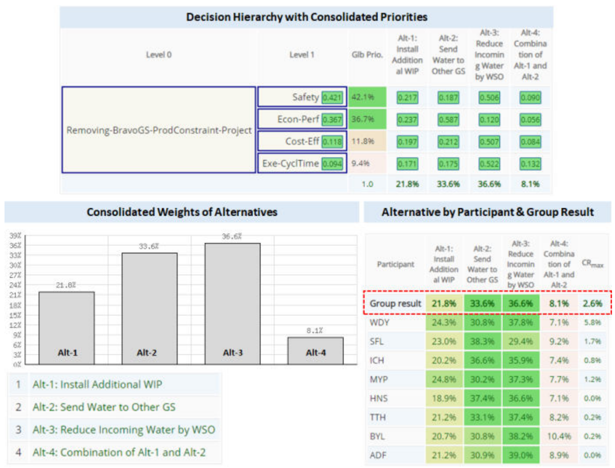

Figure 5. Consolidated Result of AHP Analysis

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IV. DISCUSSION

From a quick quantitative observation, it is slightly unexpected to have the Alt-3 as the best solution considering the number of promised additional capacity, promised oil gain, and economic performance among other alternatives. However, based on the AHP result, it is confirmed that Alt-3 has a very strong upside on safety, cost efficiency, and execution cycle-time criteria. It all links to how the expert's verdict on the decision criteria (Level-1). As shown in figure 5, where "Safety" is the highest-ranking priority (42.1%). The group seems to agree that Alt-3 has the lowest risk on safety since the implemented changes are only focused on the subsurface side. It also has a better score in the cost efficiency aspect since the funding to execute the alternative comes from the OPEX budget, which recovered faster in the current PSC scheme. Even though not superior in terms of NPV and DPI, Alt-3 also has another strength on other economic indices such as Payout time (POT) and ROR. It has the quickest payback period, which is only around two months, and the highest ROR, which is >800%

V. CONCLUSION

Brainstorming and FGD with the experts that are used extensively in this research are proven to be helpful during the problem analysis and alternative creation phase. In the session, four potential root causes and six alternative solutions to eliminate the constraint that leads to production deferment increase in Bravo GS are identified. The fundamental value that aspires to be achieved from this initiative is implementing the process change to eliminate constraints of Bravo GS effectively and efficiently to maximizing revenue. At the same time, keep maintaining safety as the top priority. Four decision criteria that reflect this value are derived, including safety, economic performance, cost-efficiency, and the execution cycle time. This research also reveals that the AHP method is proven to provide a clear advantage in the decision-making process by enabling a combination of qualitative and quantitative analysis and accommodate subject matter expert (SME) verdict into the decision-making process. The AHP result suggests that Alt-3: Reduce Incoming Water Production by Executing Water Shut-off Campaign has the highest priority ranking (36.6%) among other alternatives consolidated result.

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