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PETROLEUM AUTHORITY OF BRUNEI DARUSSALAM

Brunei Darussalam Oil and Gas Exploration and Production Guidelines

Volume 8: Gas Cap Development Guidelines



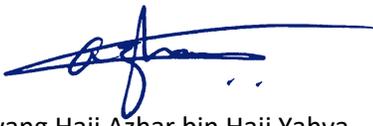
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This guideline sets out the approach the Authority is likely to take, taking into account that each application will be assessed on its facts, case-by-case.

This guideline will be reviewed by the Authority from time to time, and amended as appropriate in light of further development, changes in law or practice.

This guideline is supplemental to and not a substitute for any law or regulation, and does not constitute legal advice.

Table of Contents

Abbreviations6

Definitions7

1. Introduction9

 1.1 Background 9

 1.2 Objectives..... 9

 1.3 Roles and Responsibilities..... 9

 1.4 Scope of Work..... 10

2. Gas Cap Category and Recategorization Workflow.....11

 2.1 Gas Cap Category 11

 2.2 Gas Cap Recategorization Workflow 12

3. GOR Relaxation for Maximising Oil Rim Recovery13

4. Workflow for Approval Process.....14

5. Minimum Requirements for Submission of Gas Cap Development15

6. Documentation and Timeline18

7. General Reporting19

 7.1 Gas Cap Development Database..... 19

 7.2 GOR Relaxation and No GOR Constraint Data 20

References.....21

Appendices21

 Appendix A 22

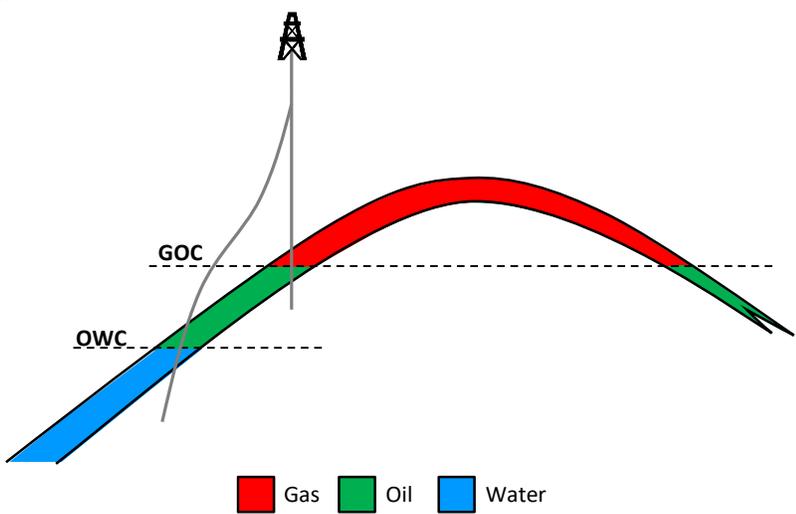
Abbreviations

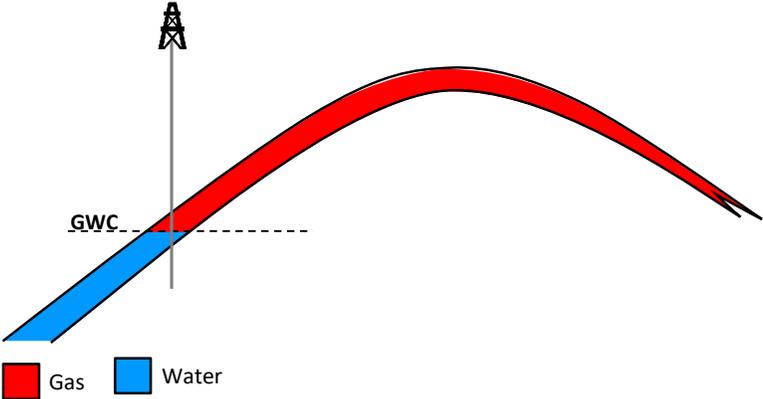
In these guidelines, the following abbreviations are used for the following terms:

BHP	Bottom Hole Pressure
CGR	Condensate-Gas Ratio
EUR	Estimated Ultimate Recovery
FDP	Field Development Plan
GCBD	Gas Cap Blowdown
GOR	Gas Oil Ratio
IRR	Internal Rate of Return
NFF	Note for File
NPV	Net Present Value
OFM	Oil Field Manager
PABD	Authority
PMA	Petroleum Mining Agreement as defined in the Petroleum Mining Act, Cap.44
PVT	Pressure Volume Temperature
VIR	Value to Investment Ratio
WHP	Wellhead Pressure

Definitions

In these guidelines, the following terms are defined as follows:

<p>Associated Gas</p>	<p>Associated gas is natural gas found in contact with or dissolved in crude oil in the reservoir. It can be further categorized as Gas-Cap Gas or Solution Gas.</p>  <p>The diagram illustrates a reservoir cross-section with a well at the top. The reservoir is divided into three layers: Gas (red), Oil (green), and Water (blue). The Gas-Oil Contact (GOC) is indicated by a dashed line, and the Oil-Water Contact (OWC) is indicated by another dashed line. The gas layer is shown as a red cap over the oil layer, which is in turn over the water layer. A well is shown at the top, with a vertical line extending down to the GOC level.</p>
<p>Formation Gas</p>	<p>This is the natural gas produced from any reservoir.</p>
<p>Gas Cap Gas</p>	<p>Gas-Cap Gas is a free natural gas which overlies and is in contact with oil in the reservoir. It is a subset of Associated Gas.</p>
<p>Gas Oil Ratio (GOR)</p>	<p>Gas to oil ratio in an oil field, calculated using measured natural gas and crude oil volumes at stated conditions. The gas oil ratio may be the solution gas oil ratio, symbol R_s, produced gas oil ratio, symbol R_p, or another suitably defined ratio of gas production to oil production.</p>
<p>GOR Constraint</p>	<p>GOR constraint is the limit set to control the decline of the reservoir energy by restricting the relative volumes of the produced free gas from the reservoir.</p>
<p>GOR Relaxation</p>	<p>Lifting the initial GOR Constraint to an agreed revised limit to continue oil production and maximize oil recovery.</p>
<p>Liquid Gas</p>	<p>This is the produced gas liberated from the oil.</p>

<p>Non-associated Gas</p>	<p>Non-associated gas is natural gas accumulation that does not contain quantities of crude oil; usually Gas-Water Contact (GWC) is observed.</p> 
<p>Solution Gas</p>	<p>Solution gas is natural gas which is dissolved in oil in the reservoir at the prevailing reservoir conditions of pressure and temperature. It is a subset of Associated Gas.</p>
<p>Solution GOR (R_s)</p>	<p>The ratio of the volume of gas that is dissolved in the oil in the reservoir at the current reservoir conditions of pressure and temperature.</p>

1. Introduction

1.1 Background

These guidelines relate to gas cap development and constitutes Volume 8 of the Brunei Darussalam Oil and Gas Exploration and Production Guidelines.

These guidelines are introduced by the Petroleum Authority of Brunei Darussalam (the “Authority”) with the intention of ensuring the development of economic oil recovery has been maximised prior to gas cap development. These guidelines are also aligned with the upstream directive issued by the office of the Minister of Energy on 22nd September 2011 (Appendix A) i.e. to maximise economic ultimate recovery of total hydrocarbon fluids.

In general, free gas and Solution Gas represents a significant part of reservoir energy required to produce oil. However, free gas is also the most mobile fluid in the reservoir and there is a tendency of it being produced preferentially, thereby prematurely depleting the reservoir energy which in turn has an impact on oil ultimate recovery.

Every effort must be made by the Operator to produce the oil rim regardless of thickness or geometry of the oil column prior to any application for the Authority’s approval for a gas cap development. Applications must include all relevant technical and economic evaluations to support the release of the gas cap and any gas cap development activities can only be carried out after approval from the Authority is obtained.

1.2 Objectives

These guidelines set out the documents/information required and procedure for an operator to follow in submitting an application for gas cap development.

1.3 Roles and Responsibilities

Oil and gas operators in Brunei are responsible for compliance with all applicable laws and Government / Authority directives, obligations to their respective petroleum mining agreements and industry best practices.

1.4 Scope of Work

This guideline provides guidance for oil and gas Operators in Brunei Darussalam for gas cap development and production during two phases of hydrocarbon lifecycle (Figure 1) i.e. development and production.



Figure 1: Chart showing life-cycle phase of hydrocarbon resources with emphasis on the development and production phase for the Gas Cap Development guideline

For a proposed production of Gas Cap Gas, subject to assessment on the impact of oil development to the timing of the gas cap production or release, there are three (3) mechanisms identified which would be applicable to any request to the Authority by the operator for gas cap development approval:

1. Gas Cap Recategorization;
2. GOR Relaxation; and
3. No GOR Constraint.

Gas Cap Recategorization

The principal criterion for categorizing the proposed gas cap development is driven by the nature of the gas, the economics of producing the oil rim associated with the gas caps and its remaining oil production life. Hence it is critical to fully assess the impact on the oil rim development relative to the timing of the gas cap production prior to any request made to the Authority for gas cap recategorization and subsequently the release of the Gas Cap Gas. Gas cap category and recategorization workflow can be referred to Section 2 in these guidelines.

GOR Relaxation

Applying GOR Constraint or limit to a field and reservoir at specific conditions are fundamental to optimize the management of available energy in the oil reservoirs and thereby maximise economic ultimate oil recovery. If the operator can demonstrate that it can maximise or enhance the oil ultimate recovery prior to any gas cap release application through relaxing or elevating the GOR Constraint or limit of a particular zone of a well then, a request can be made to the Authority. GOR Relaxation minimum requirements can be referred to Section 3 in these guidelines.

No GOR Constraint

There are scenarios where no GOR Constraint or limit is applied to the specific reservoir and/or well. For instance, if that particular well is the last or the only drainage point with limited oil rim column then in order to maximize the ultimate oil recovery from that reservoir, a GOR Constraint or limit may not be required. It is necessary for the operator to include in its submission to the Authority the assessment and evidence in support of its representations.

2. Gas Cap Category and Recategorization Workflow

2.1 Gas Cap Category

Gas categorization is driven by the nature of the gas, its development i.e. the economics of the oil rims associated with gas caps and the remaining oil production life.

Table 1 below describes all gas categories and provides guidelines designed to promote consistency in evaluation of gas development.

No.	Category	Description
2.1.1	Category I	Non-associated Gas accumulations can be categorized in this category if technical data analysis indicates a high degree of confidence that the gas resources are Non-associated Gas.
2.1.2	Category II	Associated gas cap resources that can be estimated with reasonable certainty to have uneconomical oil development There is no potential for ongoing or future economic development of the oil at the time of the evaluation. This may apply to an undeveloped oil rim that is too small for operator's economic oil development, or to a fully developed oil rim that is depleted.
2.1.3	Category III	Associated gas cap resources that support oil recovery that is expected to be fully depleted in less than five (5) years . The in-place volume of oil supported by associated gas cap is minor and is also expected to be fully depleted in less than five (5) years . After depletion, there is no potential for future economic development of any remaining oil through associated gas cap drive mechanisms.
2.1.4	Category IV	Associated gas cap resources that support oil recovery that is expected to be produced for more than five (5) years . The in-place volume of oil supported by associated gas cap is significant and is expected to be produced for more than five (5) years . There is potential for future economic development of remaining oil through associated gas cap drive mechanisms.

Table 1: Category Descriptions in Gas Cap Development

2.2 Gas Cap Recategorization Workflow

The flow chart in Figure 2 below identifies different gas cap category in accordance with impact of oil and remaining oil production time.

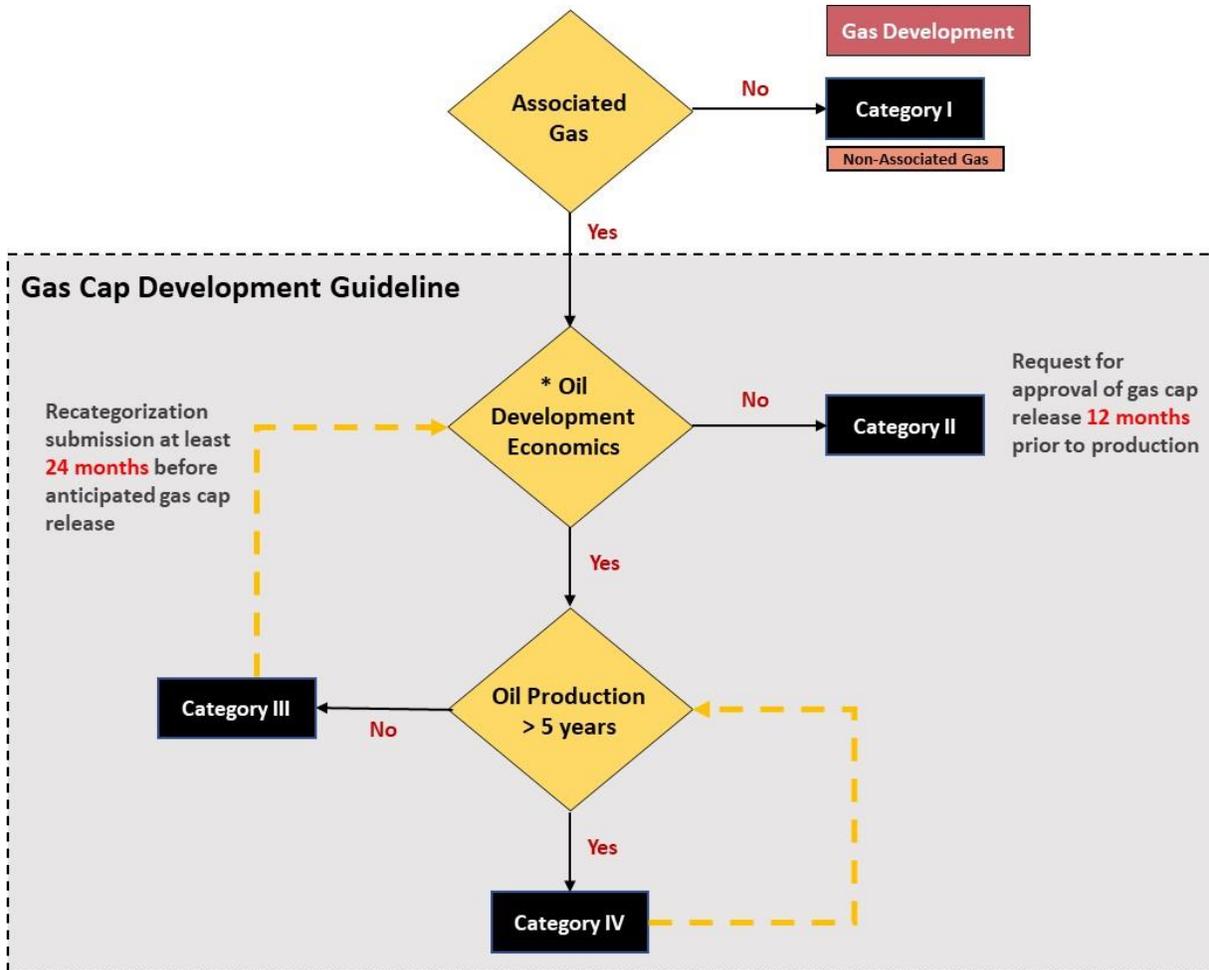


Figure 2: Gas Cap Recategorization Workflow

* Oil Development Economics - The operator is required to demonstrate to the Authority the economic assessment of producing the remaining oil rim independent of the gas production from the gas cap.

3. GOR Relaxation for Maximising Oil Rim Recovery

Applying GOR Constraint or limit to a field and reservoir at specific conditions are fundamental to optimize the management of available energy in any given oil reservoir and thereby maximise economic ultimate oil recovery.

Any request for GOR Relaxation shall be assessed by the Authority based on the following:

- (i) In the case of any GOR Relaxation that does not deviate from parameters in an approved development and production plan, **written notification** is required to be given to the Authority including all relevant data and supporting documents, unless otherwise directed by the Authority, in which case an approval shall be sought from the Authority accordingly. Notification shall be submitted **at least six (6) months** prior to GOR Relaxation with assurances providing data that the Oil Ultimate Recovery is on track to be achieved as per the approved development and production plan.
- (ii) In the case of any GOR Relaxation that deviates from parameters in an approved development and production plan, **prior written approval** from the Authority will be required, with justification and evidence including all relevant data and supporting documents. A request for approval shall be submitted to the Authority **at least six (6) months** prior to GOR Relaxation.
- (iii) In all cases other than the above, **prior written approval** from the Authority with justification and evidence including all relevant data and supporting documents must be obtained, such request for approval to be submitted **at least six (6) months** prior to GOR Relaxation.

Continuous production from a well beyond its agreed GOR Constraint is not allowed without the prior written approval of the Authority. If the operator can demonstrate that oil production can no longer be sustained, the production from the well should be stopped and the Authority shall be notified immediately together with the GOR trend data and recommended remedial action.

Minimum GOR Relaxation application requirements are provided in Table 2 of Section 5 below.

4. Workflow for Approval Process

The approval process as outlined in Figure 3 below is intended to provide sufficient time for the Authority to consider the gas cap development application by operators in adherence to Section 2 and 3 above. The operator shall ensure that it makes an engagement request to the Authority prior to any submissions under these guidelines.

The figure below refers to workflow for the approval process for any proposed gas cap development:

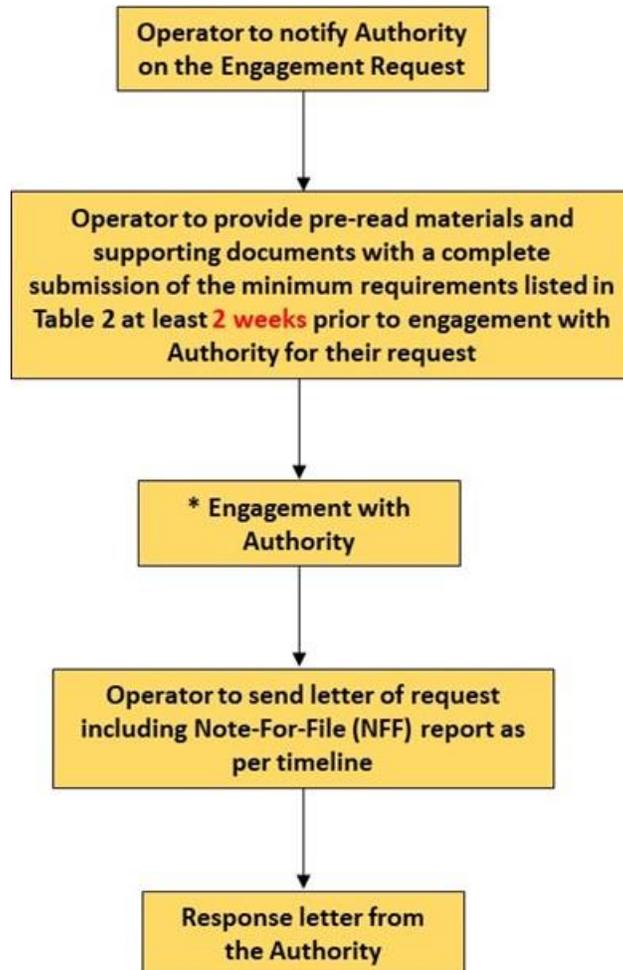


Figure 3: Workflow for Approval Process

Note: The Authority may request for additional information/data or clarification as required

5. Minimum Requirements for Submission of Gas Cap Development

Any gas cap development application submitted by the operator to the Authority must provide technical and economic evaluations in support. The Authority will then conduct an independent assessment on the impact that the proposed gas cap development would have on the ultimate oil recovery prior to any decision made by the Authority.

Below are the minimum data/information requirements for Operators to submit to the Authority in support of the proposal for gas cap recategorization, GOR Relaxation and no GOR Constraint. The submission must contain all, but is not limited to, the following information described in Tables 2 and 3 below:

No	Items	Minimum Requirements for Submission of Gas Cap Development	Gas Cap Recategorization	GOR Relaxation Approval	GOR Relaxation Notification	No GOR Constraint
3.1	Gas Cap Category	<ul style="list-style-type: none"> To identify and state the current gas cap categories according to the criteria set out in this document (Table 1) 	✓	✓	✓	✓
3.2	Gas Market and Utilisation	<ul style="list-style-type: none"> Confirmation of the market for produced gas and that all gas will be conserved including for its usage. E.g. for gas lift gas or as gas sales 	✓	✓	n/a	✓
3.3	Reserves and Resources	<ul style="list-style-type: none"> An estimate of the initial and current oil volume and gas volume initially in place. Initial estimate of the expected and range of oil and gas recovery factors under the existing depletion mechanism Description of the methods used in the determining all volumes above such as material balance, volumetric method or reservoir simulation Supporting data and calculations used e.g. FDP, decline curve analysis, OFM Data 	✓	✓	n/a	✓
		<ul style="list-style-type: none"> An estimate of the expected and range of oil and gas recovery factors under the proposed gas cap development project Breakdown of formation gas and Liquid Gas 			✓	

<p>3.4</p>	<p>Reservoir Description</p>	<ul style="list-style-type: none"> • A description of reservoir characteristics • Structure maps of each reservoir and cross section showing all hydrocarbon-bearing sands, fluid distributions, field limits and contours of initial and current contacts, well penetrations and their results • Well logs showing the lithology and fluid type of each reservoir, annotated with reservoir tops and; well-to-well correlation and base maps, if applicable. • Reservoir rock properties (permeability, mobility, log interpreted data including porosity and saturation, net to gross, reservoir temperature and formation water salinity, core data, average reservoir characteristics, mechanical properties, drainage and imbibition capillary pressure) • Reservoir fluid data (PVT data, initial reservoir conditions, saturation pressure, reservoir temperature, saturated oil density, API, viscosity, formation volume factor, Solution GOR at saturation pressure and thermal expansion and reservoir gas PVT) • Pressure plots showing fluid connectivity at initial and depleted stage of reservoir • Initial and current sizes/thickness of gas cap sizes and oil rim of individual reservoir unit and to indicate if any analogues or correlation is used 	<p>✓</p>	<p>✓</p>	<p>✓</p>	<p>✓</p>
<p>3.5</p>	<p>Drive Mechanism</p>	<ul style="list-style-type: none"> • Estimate of the gas cap drive mechanism with supporting data and calculations • Estimate of gas cap segregation drive index and m-factor with supporting data and calculations 	<p>✓</p>	<p>✓</p>	<p>n/a</p>	<p>✓</p>

<p>3.6</p>	<p>Development Strategy</p>	<ul style="list-style-type: none"> • State the development objectives • Clear completion schematic of all wells penetrating the subject reservoir and any other reservoirs completed by those wells including any future drainage points. Zonal annotation should be clearly indicated. • Proposed Gas Cap Gas development including requirements of drilling additional well(s) • Timing of gas cap production and a discussion of any time-critical aspects of the project. • To include comments on the feasibility of enhanced oil recovery and gas cycling, if applicable. • Technical evaluation of technology intended to be applied to increase the ultimate recovery (for example, installing new gas lift valve system optimization devices, etc). 	<p>✓</p>	<p>✓</p>	<p>n/a</p>	<p>✓</p>
		<ul style="list-style-type: none"> • Potential operational changes planned for the reservoir between now to gas cap development (e.g. additional infill drilling, CTU job, changes in well production strategy, etc.) 			<p>✓</p>	
<p>3.7</p>	<p>Production Strategy</p>	<ul style="list-style-type: none"> • A description and justification on the selected production strategy • Short term and long-term plans including impact on different production rate versus recoverable reserves • Annual historical oil, gas and water production data • Annual historical pressure data (flowing and shut-in WHP, flowing and shut-in BHP) • Annual oil, gas and water production forecast profile and its production philosophy • GOR/CGR Data (control, limit and monitoring plan as in Table 5) • Justification on the concurrent oil and gas production, if unavoidable • Indicative of zones the operator does not plan to produce under the proposed development but which could be profitable if assumption changes such as extent of reservoir or oil price. 	<p>✓</p>	<p>✓</p>	<p>✓</p>	<p>✓</p>

3.8	Economic	<ul style="list-style-type: none"> • Economic evaluation for the status quo and for the proposed gas cap development project, NPV, VIR, IRR at discounted and non-discounted scenarios • Economic sensitivity on the GCBD timing and the total NPV against the different GCBD timing • Assumptions used in the economic evaluation including the range of sensitivities e.g. oil price • Economic evaluation if oil production continued • Economic and commercial risk and opportunities • Volume cut-off • Project economic cut-off 	✓	✓	n/a	✓
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Table 2: Minimum Requirements for Submission of Gas Cap Development

6. Documentation and Timeline

Prior to and following any gas cap development engagement, the operator shall provide the following documentation as provided below:

No.	Document	Document and Submission Details
6.1	Presentation Slides or Pre-read Materials	Presentation Slides or Pre-read Materials with a complete submission of the Minimum Requirements for Gas Cap Development (Table 2) to be submitted to the Authority at least two (2) weeks prior to the engagement.
6.2	Note for File (NFF) report and other supporting documents	NFF report and other supporting documents with a complete submission of the minimum requirements for Gas Cap Development (Table 2) to be submitted to the Authority at least two (2) weeks after the engagement.
6.3	Application Letter / Notification	Application letter and notification with a complete submission of the minimum requirements for Gas Cap Development (Table 2) to be submitted to the Authority at least two (2) weeks after the engagement.

Table 3: Required Documentation for Gas Cap Development Engagement

7. General Reporting

7.1 Gas Cap Development Database

For any gas cap development activity, operators are required to submit **by not later than end of February of each calendar year**, historical gas cap development requests and gas cap development proposal to the Authority in a spreadsheet format prior to any gas cap development within the time frame stated in Figure 2. This database comprises of, but not limited to, the information and data in Table 4 below.

Date of Request	Operator Reference	Previous Letter / Operator Reference	Engagement Date	NFF Provided Date	Type of Request	Asset	Field	Group	Block	Reservoir	Wells	Approval Status	Authority Reference	Approval Date	Gas Cap Release Plan Date	Gas Cap Release Actual Date	Notification Reference	FDP Reference	Remarks	

Operator Reference	HCIIP (P50)			Initial Recovery Factor			Ultimate Recovery			Current Recovery Factor			Cumulative Production			Remaining Reserves			
	STOIIP	CIIP	GIIP	OIL	COND	GAS	OIL	COND	GAS	OIL	COND	GAS	OIL	COND	GAS	OIL	COND	GAS	
	MLN M3	MLN M3	BCM	%	%	%	MLN M3	MLN M3	BCM	%	%	%	MLN M3	MLN M3	BCM	MLN M3	MLN M3	BCM	

Operator Reference	Gas Cap Potential	Oil Gain	Gas Gain	Oil Regret	CAPEX	OPEX	ECONOMICS		
	MLN M3/D	M3/D	MLN M3/D	KM3	B\$ MLN	B\$ MLN	NPV	IRR	VIR

Table 4: Gas Cap Development Database

7.2 GOR Relaxation and No GOR Constraint Data

GOR data and status update as for the purpose of GOR relaxation and No GOR Constraint or limit applied for all applicable wells are to be shared and submitted to the Authority in a spreadsheet format **by not later than end of February of each calendar year.**

Other information includes reservoir details and the GOR data comprising of the produced GOR, initial GOR in solution (R_{si}), initial GOR limit and the proposed GOR limit as stated in Table 5.

Asset												
Field/Block												
Date	Reservoir	Well	Cumulative Production, N_p	Final Oil Ultimate Recovery	Final Gas EUR	Oil Rate	Gas rate	Produced GOR	Solution GOR	Initial GOR Limit	Current GOR Limit	Remarks
			Oil MLN M3	MLN M3	BCM	M3/D	MLN M3/D					

Table 5: GOR Data Table

References

In this guideline, the following references are referred:

1	Gas Cap and Oil Rim Development Regulatory Framework prepared for Energy Business Division, Prime Minister's Office, November 2015 by Gaffney, Cline & Associates Project No: PS-14-2015.05
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Appendices

In this guideline, the following appendix is referred:

A	Upstream Directive No. 1/2011: - Field Development Plan for Maturing Hydrocarbon Development Projects
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Appendix A



UPSTREAM DIRECTIVE NO 1/2011:- FIELD DEVELOPMENT PLAN FOR MATURING HYDROCARBON DEVELOPMENT PROJECTS.

In order to ensure that the hydrocarbon resources of Brunei Darussalam are appropriately explored, developed and managed to maximize its value for the sustained economic benefits of the nation, the Government of His Majesty the Sultan and Yang Di-Pertuan of Brunei Darussalam hereby issues the Upstream Directive No 1/2011: Field Development Plan for Maturing Hydrocarbon Development Projects.

Field Development Plan (FDP) for maturing hydrocarbon development projects must be submitted by each operator to Energy Department at Prime Minister's Office (EDPMO) and are required to meet the following requirements as follows with the exception of well reservoir management (WRM) activities like workovers, repairs and simple re-completion :-

1. Every discovered field in the acreage under the operatorship of an operator should have the **complete full life cycle opportunities as per the SPE Petroleum Resource Maturation System (SPE-PRMS) (Attachment 1) i.e. from reserves up to the contingent resources evaluated and justification for the remaining volumes deemed unrecoverable needs to be provided.** This assessment should be done with a certain degree of rigor and quality inline with proper reservoir management practices. Operators are required to submit plans on how the contingent and prospective resources will be matured and prudently produced. These plans will be visited on an annual basis to track progress and to identify obstacles that prevent progress.

2. **The operator needs to demonstrate that the development project has the objective of maximizing economic ultimate recovery from the target field, blocks or reservoirs.** The plan must first evaluate the Technical Limit recovery taking into account the full reservoir life cycle and must cover secondary recovery

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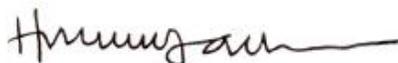


e.g. water-flooding at start of production and tertiary recovery schemes. It should clearly show where the economic limit is and what is the corresponding recovery factor achieved.

3. For gas development projects, the emphasis should be same, demonstrating how to maximize economic ultimate recovery of the total hydrocarbon fluids inline with proper reservoir management practices, for not just the natural gas but also its condensate. In the case of condensate gas fields, if the depletion of the reservoirs results in reservoir pressure decline causing condensate to drop out in the reservoirs resulting in unrecoverable condensate, alternative schemes such as dry gas recycling needs to be considered and presented as an option with the economics fully evaluated.

4. Overall, in the studies operators are required to come up with **holistic, life cycle area development plan**, which include the complete exploration programme, that synergies with the development plans or options of the existing discovered fields. Small discovered accumulations that may not seem to justify anything else other than primary depletion may be part of a cluster development with secondary and tertiary schemes if the exploration prospects and other discovered blocks nearby are taken into consideration.

5. At all time operators are required to demonstrate **high standard of safety, asset integrity and environmental** considerations are in-place in the Field Development Plan.

Issued by: 
Office of the Minister of Energy, Prime Minister's Office
Bandar Seri Begawan, BRUNEI DARUSSALAM

Issued on: **22** September 2011



Attachment 1

SPE-PRMS (SPE Petroleum Resource Maturation System) :-

