OFFSHORE FIELD DEVELOPMENT OPTIONS & STRATEGY

By: Nguyen Ngoc Hoan
M.Sc of Petroleum Engineering
Hoannn@pidc.com.vn

PRESENTATION CONTENT

▪ Field Development Consideration
▪ Field Development Options & Strategy
▪ Phased Development & Facilities Optimization
THE LIFE CYCLE OF A PETROLEUM RESERVOIR

PROJECT DEFINITION → DISCOVERY → APPRAISAL → DEVELOPMENT PLANNING

ONGOING DEVELOPMENT → PRODUCTION → DEVELOPMENT

DEPLETION → ABANDONMENT

GLOBAL CONSIDERATION

HIIP

Reserves

Risk & Economics

Production Rate

Facilities design

Capex

Opex
Gas Production depends on GSA, Plateau about 15 years

DEVELOPMENT OPTIONS & STRATEGY
DEVELOPMENT OPTIONS

Reservoir Management

Surface Facilities

Well completion

✓ Water injection: Higher oil recovery

✓ Gas injection: Higher oil recovery

✓ Gaslift, Submersible pump: Higher well prod rate
DEVELOPMENT OPTIONS

Reservoir Management  Gas Field

- Gas recycle: Higher condensate recovery
- Gas Compression: Higher gas recovery factor

Surface Facilities  Oil Field

- WHP + FPSO
- WHP + CPP + FSO
- WHP + CPP + Pipeline to Shore
- WHP + Pipeline to Shore + Processing Plant
- Subsea Well Head
DEVELOPMENT OPTIONS

Surface Facilities  Oil Field

✓ FPSO:  *New built & Conversion*

✓ FSO:  *New built & Conversion*

✓ CPP:  *Conventional sub-structure, Jack-up, TLP & Gravity Concrete foundation*

✓ WHP + FPSO
THE 3rd WORKSHOP OF PPM PHILIPPINES CASE STUDY
August 25-30, 2004, Baguio City

- WHP + CPP + FSO
- WHP + CPP + Pipeline to Shore
✓ WHP + Pipeline to Shore + Processing Plant

PHASE 1 – FIELD DEVELOPMENT PLAN
GAS FIELD DEVELOPMENT OPTIONS

- Two or single phase pipeline
- Wellhead Pressure
- Compressor phasing

Gas field

- Two phase pipeline
Gas Field

DEVELOPMENT OPTIONS

Well completion

✓ Subsea Wellhead

✓ Wellhead On Platform

✓ Single, selective or dual completion
FIELD DEVELOPMENT

SCARAB/SAFFRON DEVELOPMENT
GENERAL ARRANGEMENT

DEVELOPMENT OPTIONS

Well completion

Selective Completions

Multi-zone Completions
DEVELOPMENT OPTIONS

Well completion

- Selective Completions
  - Single zone at any one time

- Multi-zone Completions
  - Commingled completions
  - Segregated Tubing & Annulus flow
  - Multi-string completions
DEVELOPMENT OPTIONS

Well completion

Multi-zone Completions

- Commingled completions
  - Fluid composition different
  - High condensate content or sour gas
  - Zone pressures different
  - Differential depletion & cross flow
  - Water & break through

- Segregated Tubing & Annulus flow
  - Annulus corrosion & erosion
  - Liquid unloading from annulus
DEVELOPMENT OPTIONS

Well completion

*Multi-zone Completions*

- **Multi-string completions**
  - tubing size restricted & capacity limited
  - difficult to work over
  - need good cement jobs

Horizontal completion

For
- Thin reservoir
- Low permeability reservoir

Problem
- Well intervention: Logging, Perforation, completion
DEVELOPMENT STRATEGY

FIELD DEVELOPMENT

Make decision for:

- Facilities Capacities & Phasing
- Wells number, locations & Completion
- Drilling schedule
DEVELOPMENT STRATEGY

Make decisions in consideration of:

Down-Side risk & Up-Side potential
✓ Min reserve & Max reserve
Variation in Capex, Opex, Price

Optimization & Maximization
✓ Optimized production rate & maximized production rate
  (peak production & plateau duration)
✓ Optimized prod. reserve & maximized prod. Reserve
  (water injection ?)
✓ Company’s profit & Government profit
  (production bonus…)
DEVELOPMENT STRATEGY

Make decisions in the face of uncertainties:

1. Geological uncertainties:
   - ✓ Hydrocarbon Generation  ✓ Migration Path
   - ✓ Reservoir Seal  ✓ Reservoir Trap
   - ✓ Reservoir Rock Properties  ✓ Type of Hydrocarbon
   - ✓ Hydrocarbon IIP Volumes  ✓ Reservoir Fluid Properties
   - ✓ Reservoir Energy Mechanism
     (aquifer volume ? Gas cap volume ? GOR? ...)

2. Engineering Uncertainties:
   - ✓ Well Performance – Number of wells
   - ✓ Recovery factor – reserves – Production profile
   - ✓ Facilities Design  (*capacity, tech. Performance...*)
   - ✓ Project Start-up (delay in start-up)
DEVELOPMENT STRATEGY

Make decisions in the face of uncertainties

3. Commercial Uncertainties:

- Political
- Markets (oil & gas markets)
- Capex
- Opex

FOCUS OF DEVELOPMENT STRATEGY

- To avoid uneconomic development
- To ensure safety for Person, Environment & Reservoir
- To ensure adequate economic return
- To derive maximum benefit from available data sets
- To improve reservoir recovery
DEVELOPMENT STRATEGY

Emphasis on

- Reduction of uncertainties
- Reduction of influence of uncertainties
- Sub-optimal initial development *(detail next)*
- Opportunities for future optimization *(detail next)*

DEVELOPMENT MANAGEMENT PRINCIPALS

Project must be broken into phases

- Conceptual
- Feasibility
- Detail Design
- Material Procurement
- Construction, installation & Start-up
NORMAL FIELD DEVELOPMENT PLAN SCHEME

Discovery
↓
Preliminary Reserves Evaluation
↓
Outline Plan
↓
Appraisal Drilling
↓
Overall Reserves Evaluation
↓
Field Development Plan
↓
Work Design and Executive
↓
Development Drilling & Production
↓
Abandonment

EARLY FIELD DEVELOPMENT PLAN SCHEME

Discovery
↓
Reserves Evaluation For
Early Development Prospect
↓
Outline Plan
↓
Early Development Plan
↓
Appraisal Drilling
↓
Overall Reserves Evaluation
↓
Field Development Plan
↓
Work Design and Executive
↓
Development Drilling & Production
↓
Abandonment
DEVELOPMENT STRATEGY

Summary

- Reduce uncertainties & influence of uncertainties
- Sub-optimal initial development
- Opportunities for future optimization
- Ensure safety for Person, Environment & Reservoir
- Maximize benefit from available data sets

Example on Reservoir Uncertainty

Well #1 penetrated 25 m sand
Oil - 25 m
OIIP - 300 MMbbls

Before 3D interpretation

W#1 penetrated 25 m sand
Oil - 25 m
OIIP - 300 MMbbls
Example on Reservoir Uncertainty

Well #1

After 3D interpretation

Well #2

W#2 penetrated 22 m sand
Oil - 15 m
Gas - 7 m
OIIP - 250 MMbbls

Conclusion: Exp&Appr
Should based on understanding
of reason geology

Well #3

W#3 penetrated 20 m sand
Oil - 10 m
Water - 10 m
OIIP - 180 MMbbls
Example on Facility options
Gas condensate reservoir

- WHP
- Subsea WH
- WH pressure

New discovery

Reserve vs. Well head pressure

<table>
<thead>
<tr>
<th></th>
<th>WH Pressure (Psi)</th>
<th>Production MMscfpd</th>
<th>Reserve Bscf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Option 1</td>
<td>350</td>
<td>30</td>
<td>90</td>
</tr>
<tr>
<td>Option 2</td>
<td>750</td>
<td>30</td>
<td>65</td>
</tr>
</tbody>
</table>
Facility Options

Option A – WHP w/ minimum facility, Pwh = 750psi

Option B – WHP w/ minimum facility + small comp to produce w. Pwh = 350 psi

Option C - WHP w/ full facilities, Pwh = 350 psi

Option D – Sub sea WH
### Development Cost

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Well head pressure (psi)</td>
<td>750</td>
<td>350</td>
<td>350</td>
<td>750</td>
</tr>
<tr>
<td>Reserve (BCF)</td>
<td>65</td>
<td>90</td>
<td>90</td>
<td>65</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Expenditures (MMUSD)</th>
<th>Option</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAPEX</td>
<td>25.0</td>
</tr>
<tr>
<td>OPEX</td>
<td>17.7</td>
</tr>
<tr>
<td>Abandonment</td>
<td>4.5</td>
</tr>
<tr>
<td>Total Cost</td>
<td>47.2</td>
</tr>
</tbody>
</table>

### Project Evaluation

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRR</td>
<td>18%</td>
<td>14%</td>
<td>1%</td>
<td>16%</td>
</tr>
</tbody>
</table>
PHASED DEVELOPMENT & FACILITIES OPTIMIZATION

1. Introduction

2. Challenge Analyzing

3. Recommendation
INTRODUCTION

• Discoveries are more complex in structure, divided by regional and local Faults into Blocks

• Reservoir & Fluid properties are difficult to predict

• Information acquired during exploration & appraisal period is not sufficient to plan a full field development

• To minimize uncertainties, fields are developed by phases

CHALLENGES

• How to optimize production and processing facilities for the first phase

• Facilities for first phase should be installed with low cost to minimize risk, but flexible to upgrade for future field development and production
DESIGN OPTIMISATION

• FPSO

• In-Field Pipeline

• Well Head Platform

FPSO DESIGN OPTIMISATION

• Natural reservoir depletion has low recovery factor, which varies from 13% to about 23% depends on reservoir structures and properties

• Water injection application will increase oil recovery factor up to more than 40%
Key factor allows Contractor to apply water injection in next phase of field development is a number of swivel, pre-designed and installed on FPSO.

Some FPSO has been designed with only one production riser and swivel.

Dry dock for the FPSO to modify turret and install water injection, gas lift facilities, caused production shutdown for long time and big increase of investment.

Example: FPSO have been designed with one spare swivel for water injection, could save 42 MMUSD.

<table>
<thead>
<tr>
<th>Increased oil production</th>
<th>7 million barrels</th>
</tr>
</thead>
<tbody>
<tr>
<td>No dry dock</td>
<td>With dry dock and FPSO modification</td>
</tr>
<tr>
<td>1. Water injection facilities installation</td>
<td>20 mmUSD</td>
</tr>
<tr>
<td>2. Impact of production shutdown</td>
<td>50 mmUSD</td>
</tr>
<tr>
<td>3. Well drilling completion</td>
<td>140 mmUSD</td>
</tr>
<tr>
<td>4. Increased oil production</td>
<td>2 mmUSD</td>
</tr>
</tbody>
</table>
EXTERNAL TURRET MOORING SYSTEM

CROSS-SECTION INTERNAL & EXTERNAL TURRET
**FPSO DESIGN OPTIMISATION**

**Recommendation**

- FPSO to be designed with one or more spare swivel for crude oil, water injection or gas lift

- FPSO facilities layout should be considered to reserve space for future facilities installation with minimum modification of existing facilities

**IN FIELD PIPELINE DESIGN OPTIMISATION**

- Reservoir fluids produced & transported through infield pipeline usually are mix of fluids from different reservoirs with different physical and chemical properties

- Reduction in the pipeline flow rate could lead to reduction in fluid temperature and pipeline stack

- Pipeline reinstallation is costly operation
Pipe insulation depends on Wax deposition temperature

Viscosity as a function of temperature-Pumpe capacity design
INFIELD PIPELINE DESIGN OPTIMISATION

Conclusions

• Infield pipeline to be designed with carefully consideration of changes in reservoir fluid temperature, crude cloud point and changes of pipeline flow rate during field life.

• Infield pipeline to be insulated is strongly practical recommendation.

WHP DESIGN OPTIMISATION

Challenges:

WHP has been designed

• Without shelter for workers to stay overnight on platform
  ✓ When weather changed to severe condition person life under dangerous

• With crane of small capacity
  ✓ Operator have to use rig to do work over
WHP DESIGN OPTIMISATION

Challenges:

WHP has been designed

• With one board landing only
  ✓ In windy and strong current condition, supply board could damage to board landing and risers
  ✓ Take long time to wait on weather

WELL HEAD PLATFORM (WHP)
Recommendations:

- It is recommended to install crane with capacity at least 25 tone on WHP for wire line and coil tubing operation to be done

- Install shelter for workers to stay overnight on platform (four beds)

- Design and construct WHP with two board landing in opposite sides.

Conclusions:

- Design of production, processing facilities, FPSO, WHP and infield pipeline for phase 1 should take into account future field development plan, to allow:

  Facilities expansion and application of water injection & gas lift

  Optimized design results in resource conservation, increase oil & gas recovery factor, and significantly increases national revenue and operator’s benefit

  Learn to accept sub-optimal initial development
CONCLUSION

It is recommended

• FPSO to design with one or more spare swivels used for produced fluids, water injection or gas lift

• Reserve space on FPSO for future facilities installation

• Infield pipelines for crude oil transportation is strongly recommended to insulate.

CONCLUSION

It is recommended

• Crane capacity on Well head platform is 25 ton minimum

• Two board landing on WHP

• Shelter with four beds to be installed on WHP
**SUMMARY OF STOCK TANK CRUDE PROPERTIES**

<table>
<thead>
<tr>
<th>Fluid Property</th>
<th>Reservoir (Fingerprinting)</th>
<th>Baseement 15-1-SD-1x</th>
<th>Baseement 15-1-SD-2x</th>
<th>Baseement 15-1-SD-2x(2D)</th>
<th>Baseement 15-1-SD-1x</th>
<th>Baseement 15-1-SD-2x</th>
</tr>
</thead>
<tbody>
<tr>
<td>API @ 60°F</td>
<td>Hydrometer</td>
<td>35.5</td>
<td>37.0</td>
<td>36.0</td>
<td>35.9</td>
<td>35.5</td>
</tr>
<tr>
<td>Specific Gr</td>
<td>Hydrometer</td>
<td>0.9468</td>
<td>0.9358</td>
<td>0.9548</td>
<td>0.9453</td>
<td>0.9473</td>
</tr>
<tr>
<td>Cloud Point (wt%)</td>
<td>Parsified</td>
<td>67°C</td>
<td>71°C</td>
<td>73°C</td>
<td>68°C</td>
<td>71°C</td>
</tr>
<tr>
<td></td>
<td>Microscopy</td>
<td>71°C (157°F)</td>
<td>73°C (164°F)</td>
<td>68°C (175°F)</td>
<td>71°C (185°F)</td>
<td>73°C (195°F)</td>
</tr>
<tr>
<td></td>
<td>OUS Model</td>
<td>61°C (142°F)</td>
<td>61°C (142°F)</td>
<td>61°C (142°F)</td>
<td>61°C (142°F)</td>
<td>61°C (142°F)</td>
</tr>
<tr>
<td></td>
<td>API @ 98.5-95</td>
<td>29°C (85°F)</td>
<td>31°C (85°F)</td>
<td>38°C (100°F)</td>
<td>29°C (85°F)</td>
<td>18°C (65°F)</td>
</tr>
<tr>
<td>Gel Strength (Pa)</td>
<td>Easometer</td>
<td>411 Pa @ 22.3°C</td>
<td>338 Pa @ 25.0°C</td>
<td>451 Pa @ 22.1°C</td>
<td>307 Pa @ 25°C</td>
<td>185 Pa @ 22°C</td>
</tr>
<tr>
<td></td>
<td>Live Crude (Saturated with 200 psg C°H)</td>
<td>279 @ 21.6</td>
<td>193 @ 22.3</td>
<td>121 @ 23.7</td>
<td>112 @ 25.0</td>
<td>115 @ 22.0</td>
</tr>
<tr>
<td>HFGC</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
</tr>
<tr>
<td>Wax Contents (wt%)</td>
<td>OTOC (21°F)</td>
<td>13.1</td>
<td>6.4</td>
<td>16.5</td>
<td>13.2</td>
<td>9.6</td>
</tr>
<tr>
<td>Wax Deposition</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
</tr>
<tr>
<td>Viscosity 60°F</td>
<td>Easometer</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
<td>Completed</td>
</tr>
<tr>
<td>Viscosity (Saturated with 200 psg C°H)</td>
<td>Easometer</td>
<td>Completed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asphaltene Total</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
<td>Stable</td>
</tr>
<tr>
<td>Asphaltene Titer</td>
<td>0.49</td>
<td>0.44</td>
<td>0.35</td>
<td>0.24</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
INFIELD PIPELINE DESIGN OPTIMISATION

Wax deposition model result for WHP to FPSO oil pipeline

<table>
<thead>
<tr>
<th>Flow Rate</th>
<th>Thermal Mass (kJ/s)</th>
<th>Time to Deposit 4 mm Wax on Bare Stool Pipe Wall (days)</th>
<th>Only 50 mm Concrete Weight Coating</th>
<th>1&quot; of Insulation under 50 mm Concrete Weight Coating</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOPD</td>
<td>EWPD</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32,800</td>
<td>0</td>
<td>105</td>
<td>1.5</td>
<td>No Deposition</td>
</tr>
<tr>
<td>44,800</td>
<td>0</td>
<td>145</td>
<td>2</td>
<td>No Deposition</td>
</tr>
<tr>
<td>56,800</td>
<td>0</td>
<td>184</td>
<td>3</td>
<td>No Deposition</td>
</tr>
<tr>
<td>32,800</td>
<td>13,400</td>
<td>209</td>
<td>3.5</td>
<td>No Deposition</td>
</tr>
<tr>
<td>44,800</td>
<td>22,000</td>
<td>314</td>
<td>6</td>
<td>No Deposition</td>
</tr>
<tr>
<td>32,800</td>
<td>32,000</td>
<td>352</td>
<td>7</td>
<td>No Deposition</td>
</tr>
<tr>
<td>56,800</td>
<td>28,000</td>
<td>400</td>
<td>No Deposition</td>
<td>No Deposition</td>
</tr>
<tr>
<td>44,800</td>
<td>44,000</td>
<td>484</td>
<td>No Deposition</td>
<td>No Deposition</td>
</tr>
<tr>
<td>56,800</td>
<td>56,000</td>
<td>616</td>
<td>No Deposition</td>
<td>No Deposition</td>
</tr>
</tbody>
</table>

NATURE OF HYDROCARBON FIELD

Complexities

- Geological (faulted)
- Reservoir properties (Φ, K, So, Sw)
- Hydrocarbon reserves (reliability & distribution)
- Fluid properties (wax, H2S, CO2, salt, GOR...)
- Well completion (Single selected, dual completion)
This presentation will not focus on detailed theory and equations.

But, the emphasis is on what is being done, why it is being done, what technology exist and how well does it work.

Most of all, how does it relate to the practical decisions.
DEVELOPMENT PROCEDURE SCHEME

- **Appraisal program**
- **Appraisal drilling**
- **Reserves evaluation**
- **Field Development Plan (FDP)**
- **Implementing**
- **Drilling & Completion**
- **Early production**
- **Full field production**
- **Abandonment**

**Outline plan (OP)**

**Early production system (EPS)**

**Government approval**

**Data**

**Prod. report to O&G M**

**O&G M Approval**

**Temperature Profile simulation for: insulation, flow rate…**

INFIELD PIPELINE DESIGN OPTIMISATION
FIELD DEVELOPMENT