Development of Donghae-1 Gas Field, Offshore Korea

30 March 2004

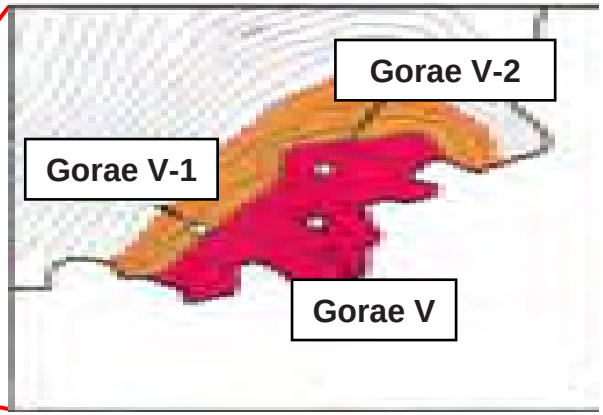
KIGAM (Korea Institute of Geoscience & Mineral Resources)

KNOC (Korea National Oil Corporation)

The 3rd Workshop of the Cambodia PPM Case Study

Donghae-1 Gas Field

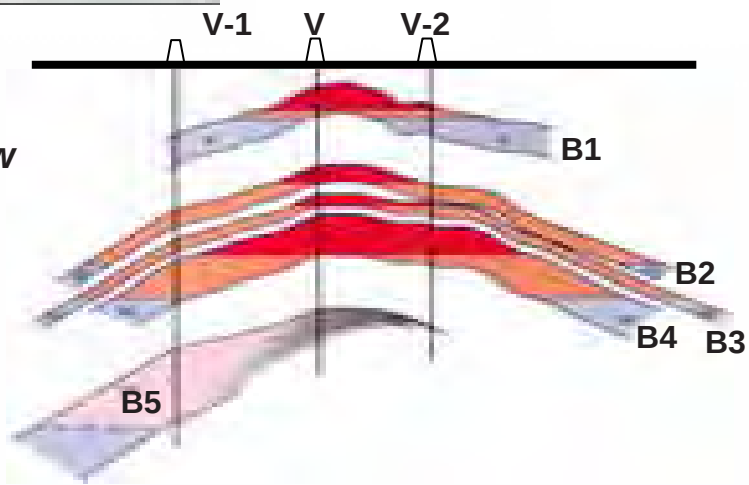
Reservoir Location



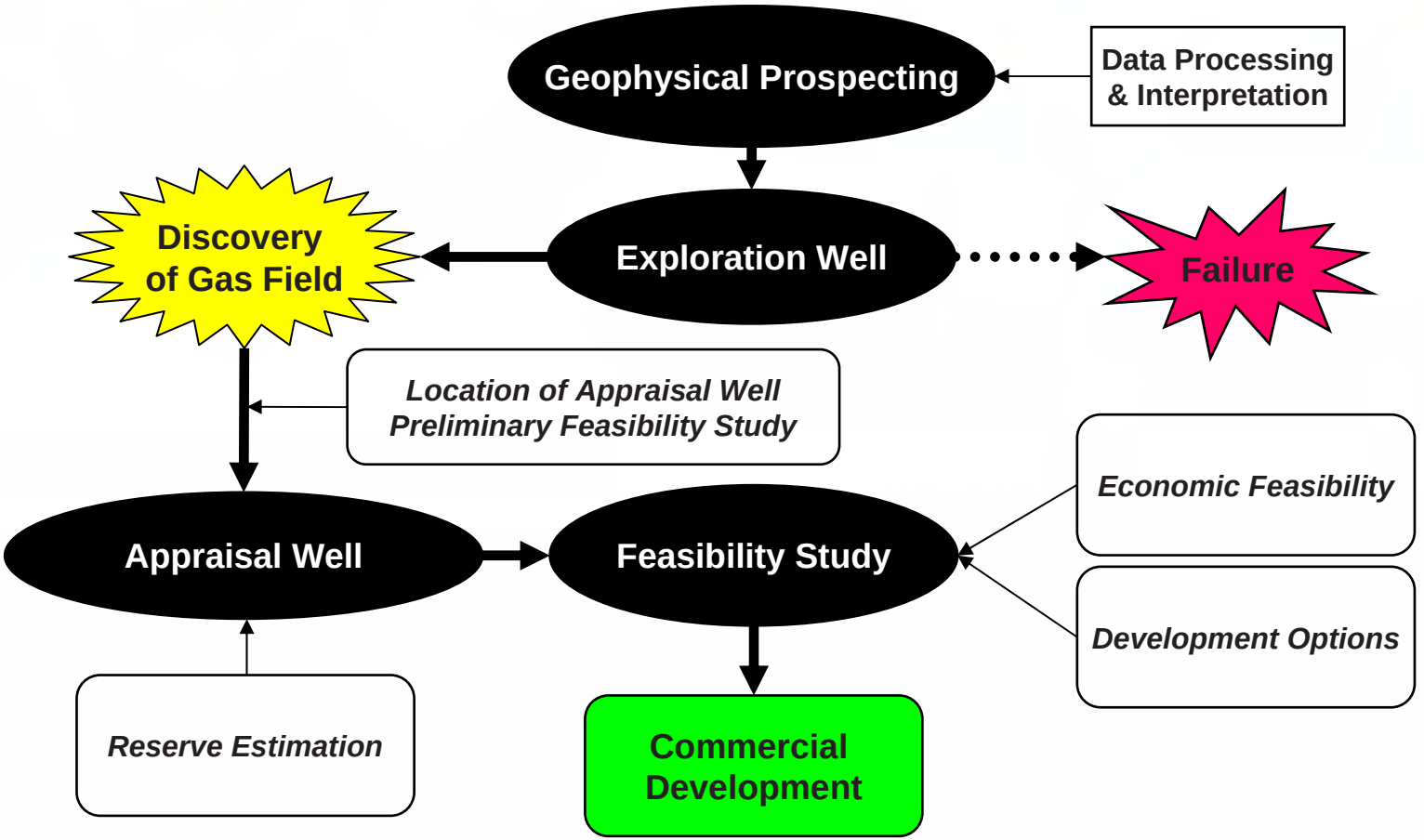
Water Depth

Distance from Shore

Sectional View



DEVELOPMENT OF DONGHAE-1



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- Development Options
- Compositional Simulation
- Production Optimization
- Production Facilities
- Concluding Remarks

DELIVERABILITY ANALYSIS

DST Data Analysis

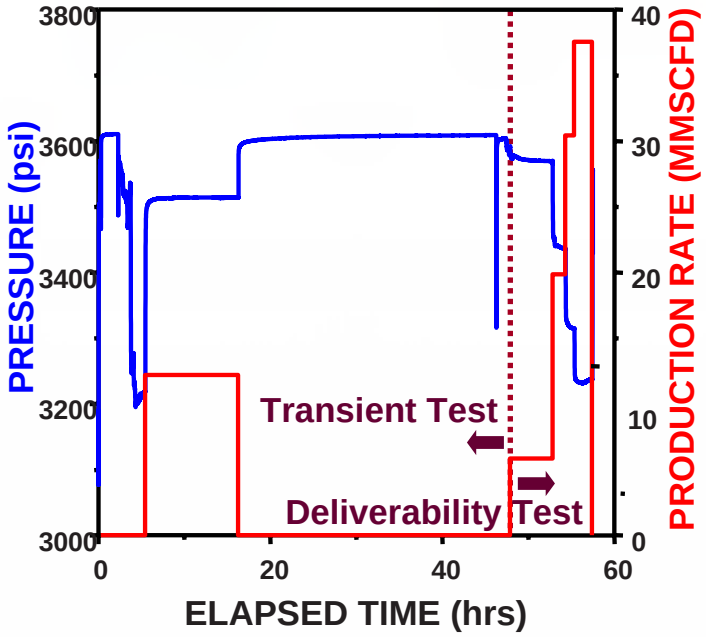
- **DST & Deliverability Analysis**
  - ✓ **DST Data**
  - ✓ **Reservoir Properties**
    - Horner Plot
    - Type Curve Matching
  - ✓ **Radius of Investigation**
  - ✓ **Wellbore Storage Effect**
  - ✓ **Estimation of Deliverability**

DST No.	Target Layer	Gauge Depth (ft)	Net Pay Thickness (ft)	Deliverability Test
V DST#2	B4	8366.14	103.8	Flow After Flow Test
V DST#3	B2	7685.83	51.7	
V-1 DST#2	B3, B4	7868.44	137.4	
V-1 DST#3	B2	7781.27	48.4	
V-2 DST#1	B4	8014.07	92.7	Modified Isochronal Test
V-2 DST#2	B3	7923.85	28.3	
V-2 DST#3	B2	7843.44	42.3	

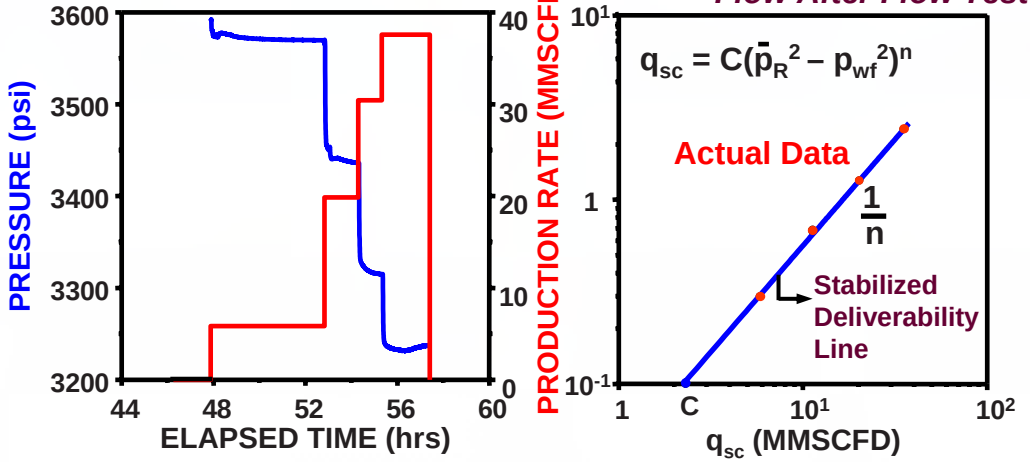
DELIVERABILITY ANALYSIS

Gorae V (DST#2)

TRANSIENT PRESSURE TEST



DELIVERABILITY TEST



Flow After Flow Test

Pressure Transient Test		Deliverability Test	
k (md)	37.49	n	0.865
s´	4.50	C	1.07e-4
p* (psi)	3608.79	AOF (MMSCFD)	152.80
r_{inv}. (ft)	853.92	Late time deviation: shale effect	
t_{ws} (hrs)	0.0021	Wellbore storage effect is not significant	

DELIVERABILITY ANALYSIS

DST Results

- **Excellent agreements between *type curve matching method* and *Horner method***
  - ✓ **Permeability: moderately ranged from 23.0 to 65.3 md**
  - ✓ **Skin factor: 4.64 to 21**
  - ✓ **AOF: 21.2 to 152.8 MMSCFD**
- **Substantial productivity: more than 60 MMSCFD**
  - ✓ **V-2 (DST #2): 21.2 MMSCFD**

DEVELOPMENT OPTIONS

Considerations

- **Engineering Data**
  - ✓ Reserve, Rock and Fluid Properties
- **Gas Sales Specifications**
  - ✓ Marketplace, Supply, Price
- **Design Specifications**
  - ✓ Temperature, Pressure, Processing Capacity of Facilities
- **Environmental Data**
  - ✓ Weather, Subsea Condition
- **Economic Parameters**
  - ✓ Cost of Capital, Operating Expenses

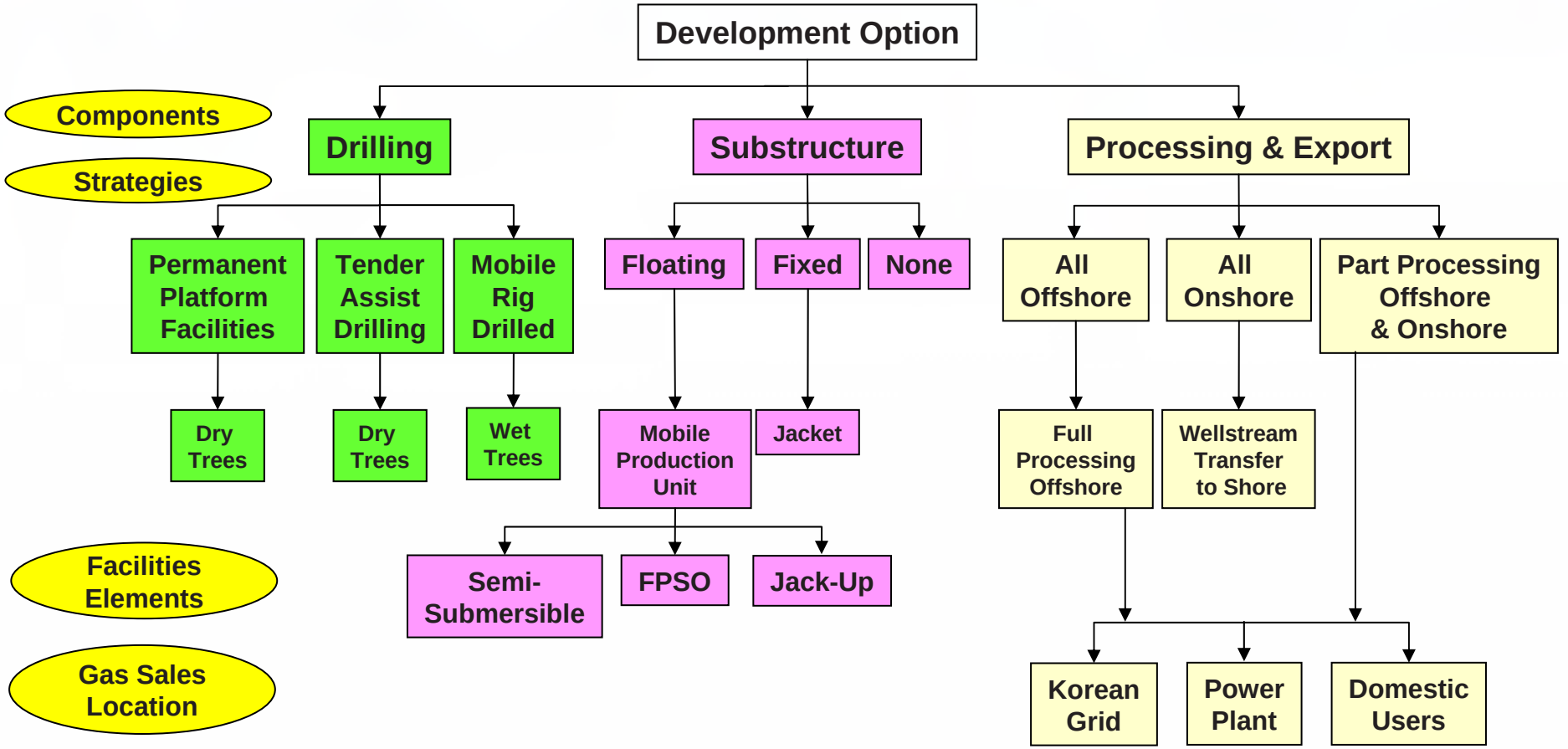
DEVELOPMENT OPTIONS

Selection Process

- 1st Stage : Identification of All Feasible Development Options
  - ✓ Substructure System Type
  - ✓ Drilling Methods
- 2nd Stage : Selection of Favorable Process
  - ✓ Option Screening
  - ✓ 24 Production Options
- 3rd Stage : Optimized Development Concept
  - ✓ Selection of Preferable Process Option

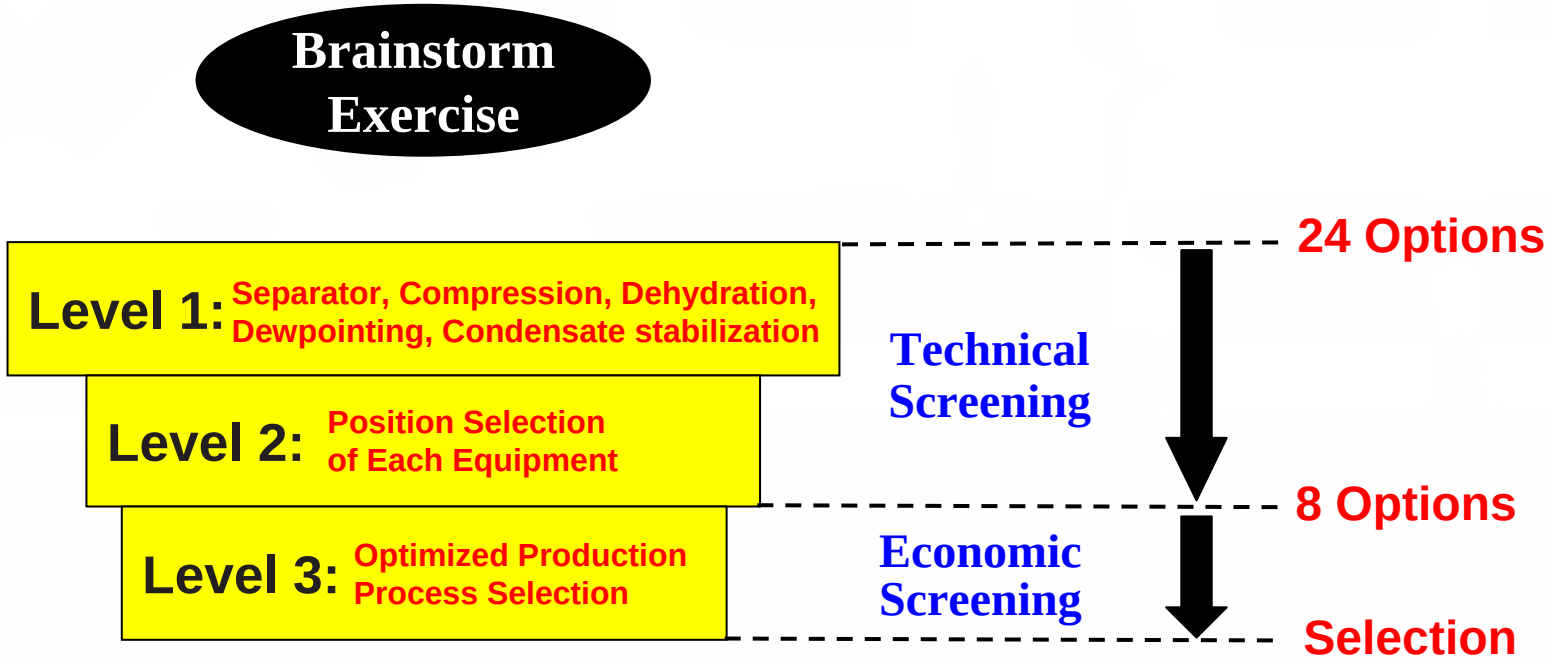
DEVELOPMENT OPTIONS

1) Identification of Development Options



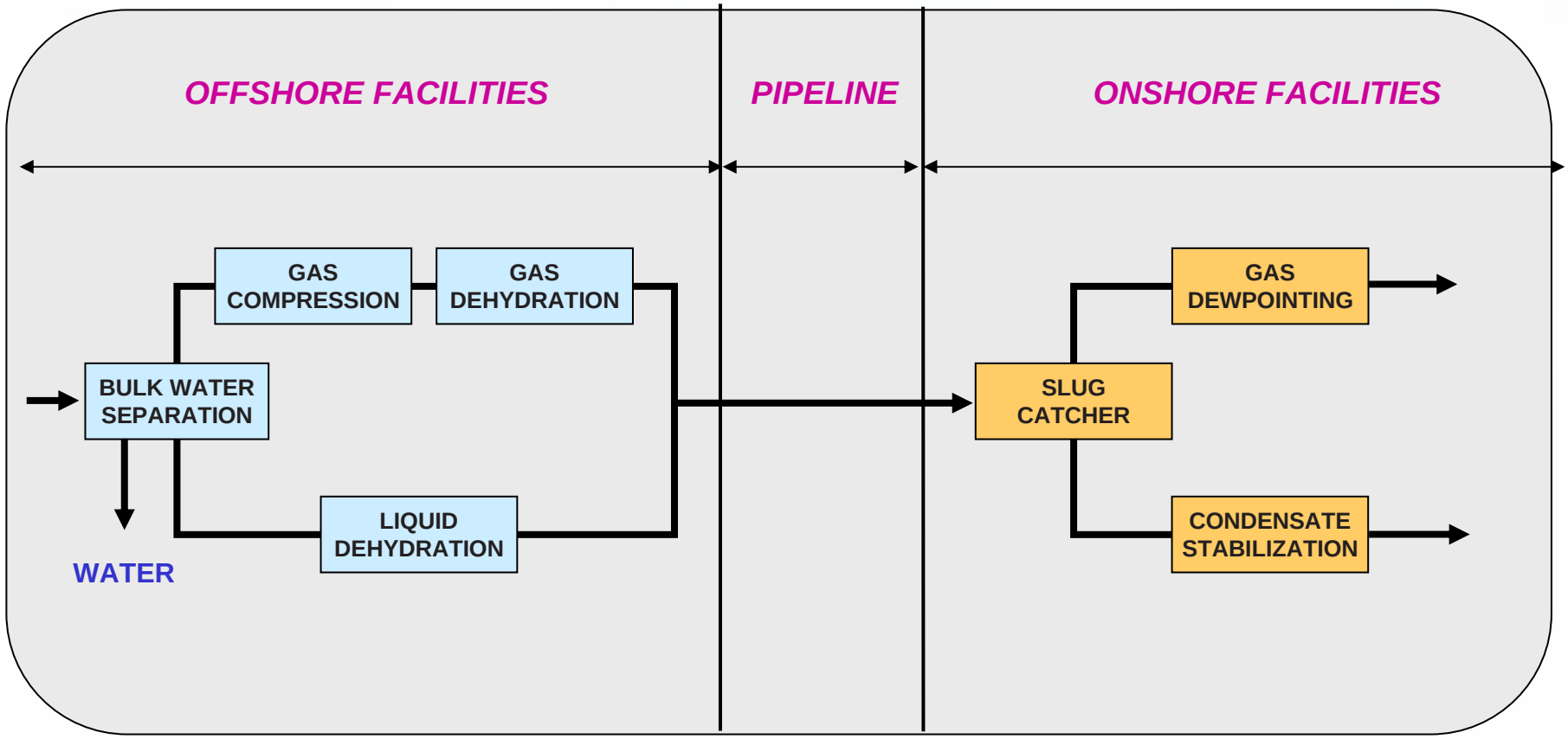
DEVELOPMENT OPTIONS

2) Screening



DEVELOPMENT OPTIONS

3) Diagram of Preferred Process Scheme



COMPOSITIONAL SIMULATION

Objectives

- **Phase I**
  - ✓ **Estimation of the gas and condensate reserves (GIIP) of Donghae-1 Gas Field**

- ***Phase II***
  - ✓ **To evaluate the field's development including optimal well locations, various sensitivities and water coning & partially penetrating wells**

COMPOSITIONAL SIMULATION

Reservoir Properties

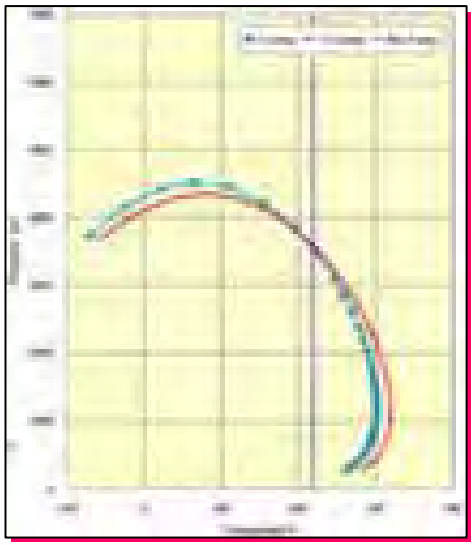
EOS Modeling

- 11 Components (CO2, N2, C1~C6, C7+)
- 5 Pseudo-Components
  (Non-HC, C1, C2/C3, C4/C5, C6+)

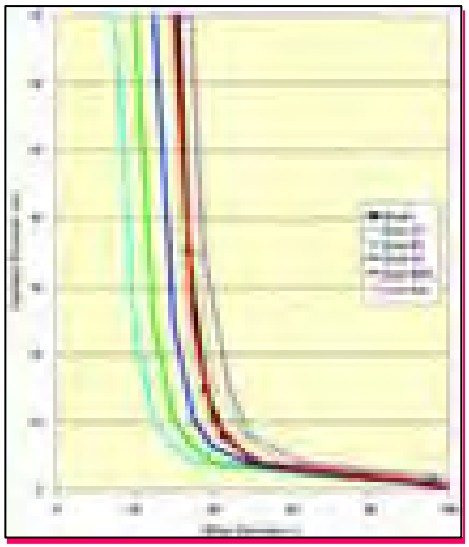
Capillary P (P_c) : SCAL

Relative Permeability

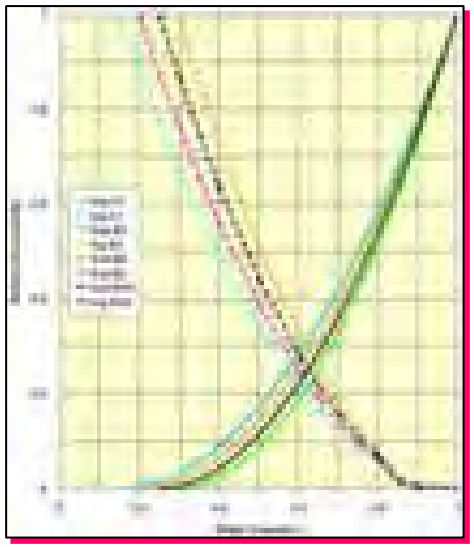
Dew-point Phase Diagram



Gas Water Pc



Gas Water kr (Corey Eq.)

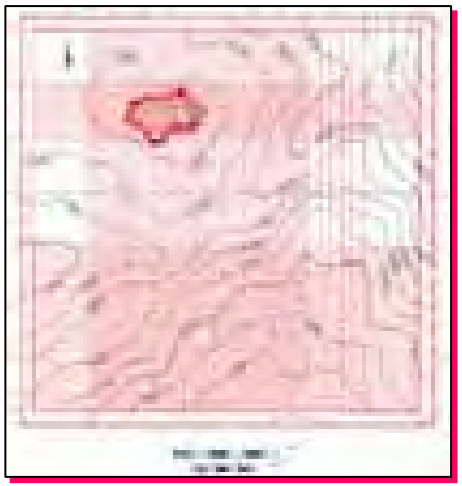


COMPOSITIONAL SIMULATION

Model Grid System

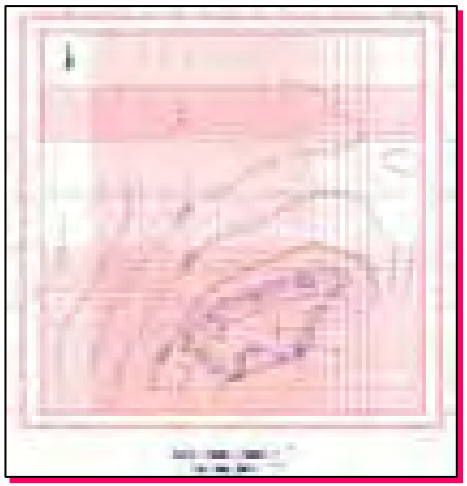
- Grid : 47x43x15
- Layers : C1, B1, B2, B3/4
- Constant Thickness

C1: Structure/Isopach/Grid



B1 Reservoir

B2 Reservoir

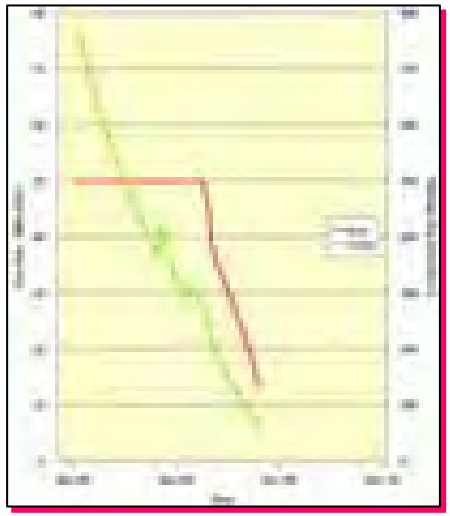


B3/4 Reservoir

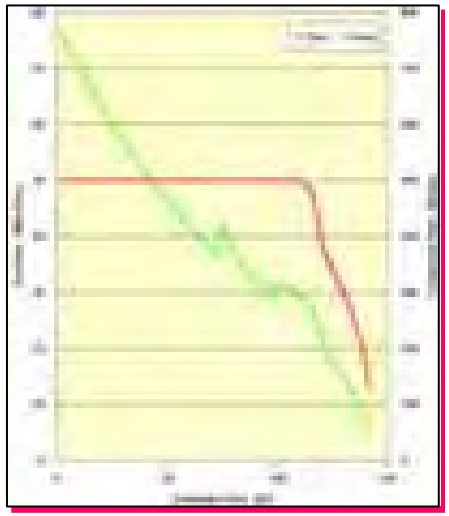
COMPOSITIONAL SIMULATION

Base Case Run

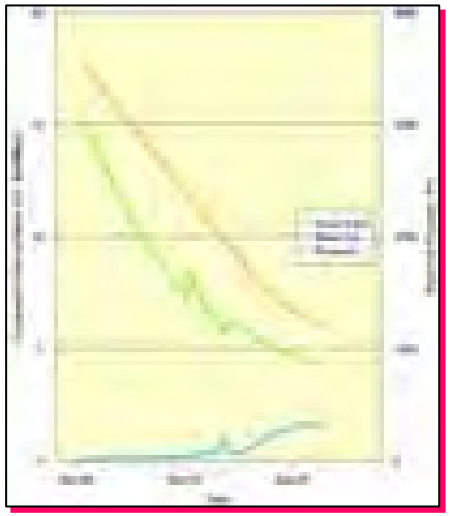
Gas & Condensate Production vs. Time



Gas & Condensate Rate vs. Cumulative Gas Production



Condensate Yield, Water Cut & Average Reservoir Pressure



Base Case Results

- **Ultimate Gas Recovery : 142 Bcf (68% of GIIP)**
- **Period of Production Plateau : 6 years**
- **Condensate Recovered : 1.2 MMbbl (37% of In-Place)**
- **Water Production Less Than 1.7 bbl/MMscf**

COMPOSITIONAL SIMULATION

Sensitivity Analysis – 13 Cases

- **Permeability**
  - ✓ Production Performance vs. Horizontal Permeability
- **Gas Initially In-Place**
  - ✓ Production Performance vs. GIIP
- **Surface Operating Pressure**
  - ✓ Production Performance vs. FWHP
- **Plateau Production Rate**
  - ✓ Production Performance vs. Field Rate
- **Strength of Aquifer**
  - ✓ Aquifer Strength Sensitivity
  - ✓ Effect of Aquifer Strength & Rate on Recovery
- **Effect of k_v and Selective Well Completion**

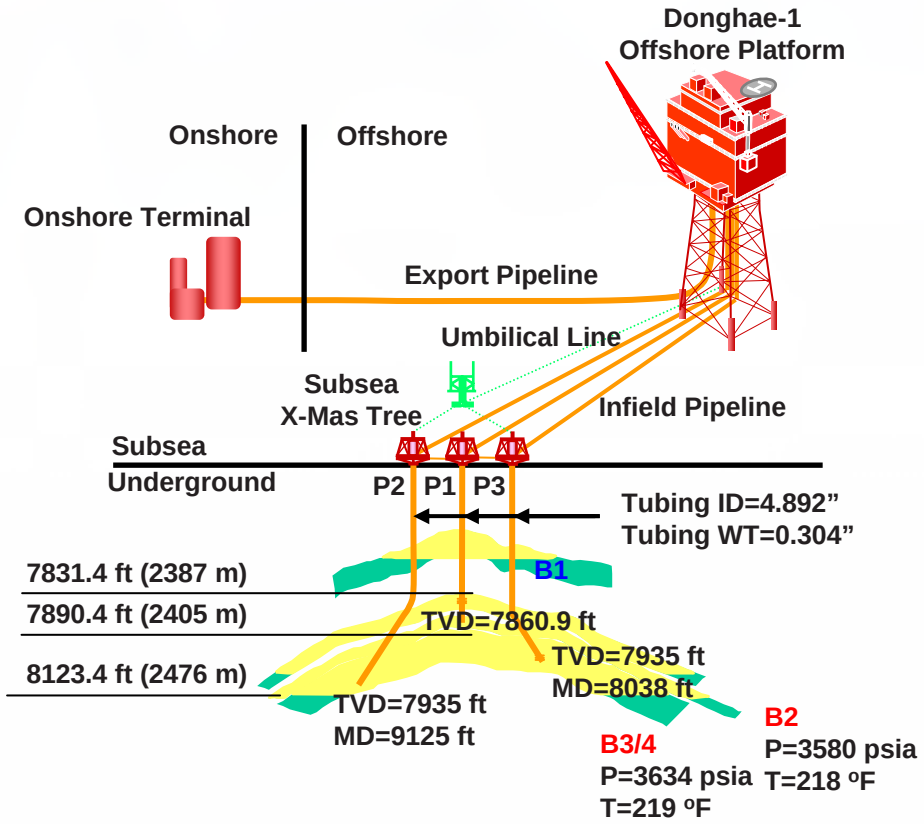
COMPOSITIONAL SIMULATION

Compositional Simulation Results

- **Probable Reserve of Donghae-1 (Gorae V & V-3 Field) :**
  - ✓ *208 Bcf of Gas, 1.77 MMbbl of Condensate*
  - ✓ Minimum FWHP of 700 psi & Minimum Allowable Gas Well Rate of 5 MMscf/day Assumed
- **4 Wells Required in the 4 Zones :**
- **Retrograde Condensation :**
  - ✓ 2.5 MMbbl of condensate to remain in the reservoir in a liquid state at the end of primary depletion.
  - ✓ 1% of HCPV, immobile and no effect on gas deliverability
- **Due to the modest k, the Aquifer Strength Weak**
  - ✓ Insensitive to Plateau Rate, GIIP
- **Relatively high k_v/k_h**
  - ✓ No Effect on the Ultimate Gas Recovery, regardless of penetration

PRODUCTION OPTIMIZATION

Integrated Network Model



PRODUCTION OPTIMIZATION

Integration of Reservoir and Surface Model

Compositional Fluid Model

- Gas-Condensate Flow
- Peng-Robinson Cubic EOS (1976)
- Flash Calculation
- Gas (g) & Condensate (L) Fugacity f_i

$$\ln\left(\frac{f_i^k}{z_i p}\right) = b_i \frac{z^k - 1}{b} - \ln(z^z - B) - \frac{A}{2.82843B}\left[\frac{2\Psi_i}{\Psi} - \frac{b_i}{b}\right]\ln\left[\frac{Z^k + 2.414B}{Z^k - 0.414B}\right]$$

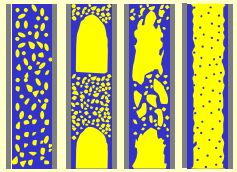
Subsurface Reservoir Model

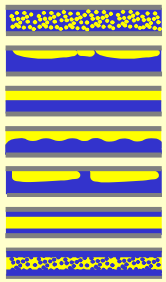
- Multi-Component Tank Model
- Assumptions
  - Homogeneous, Isotropic, Cylindrical Reservoir
  - No-Flow Boundary Condition
  - No Water & Condensate Flow
- Cumulative Gas Production

INTEGRATION

Multi-Phase Pipeline Flow Model

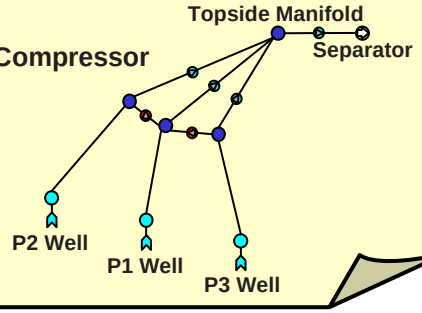
- Vertical Pipeline (Production Well) – PIPESIM
- Horizontal Pipeline – Multiphase Flow Model
- Vertical & Horizontal Flow Patterns





Pipeline Network Model

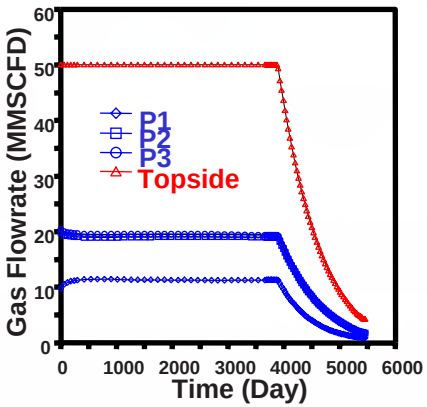
- PIPESIM (Build 26, 1999)
- Transport Pipeline, Production Line, Riser
- Branch System
- Modeling of Separator, Pump, Compressor



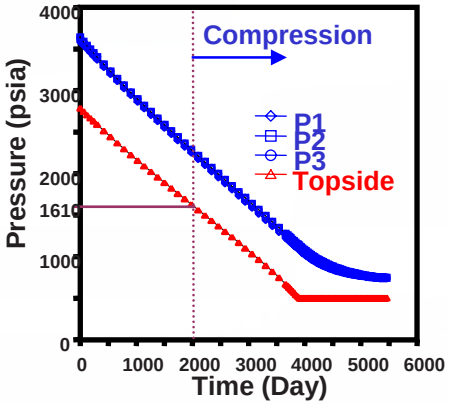
PRODUCTION OPTIMIZATION

Production Allocation & Compressor Installation

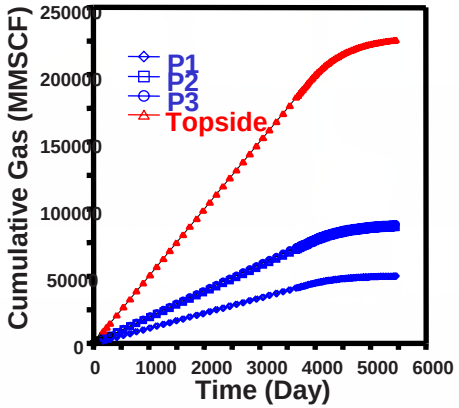
Allocation of Gas Production



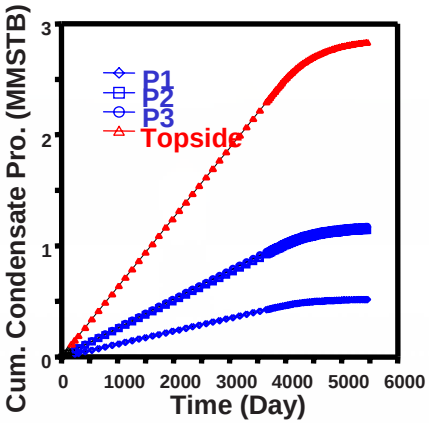
Pressure Profile at Separator



Cum. Gas Production at Separator



Cum. Condensate Pro. at Separator



- **Production Scenario**
  - Total Production Rate: 50 MMscf/D
  - BD12, BD13 Line: Detour Line for Emergency
  - Platform Minimum Pressure: 500 psia
  - Allocation of Optimized Gas Production Rate

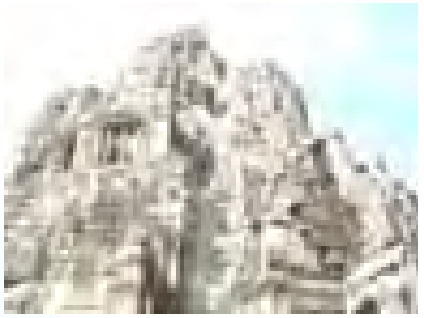
- **Optimized Production Rate**
  - Plateau Period: 3900 Days
  - Compressor Installation: 2000 Days (5.5 yrs)
  - Cumulative Gas Production (During Plateau Period)
  - Cum. Condensate Pro. (During Plateau Period)

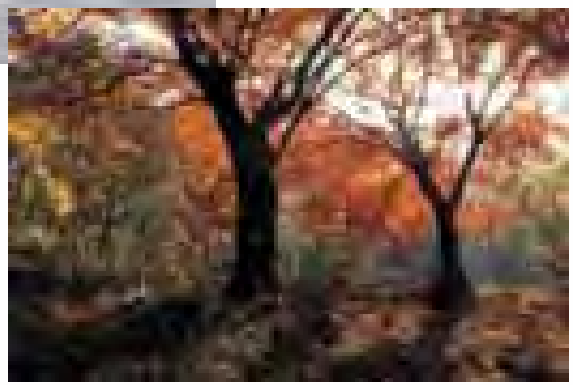
PRODUCTION FACILITIES

CONCLUDING REMARKS

- **Donghae-1 Gas Field, Offshore Korea**
  - ✓ **Production Options**
  - ✓ **DST**
  - ✓ **Reservoir Simulation**
  - ✓ **Integrated Network Modeling**
  - ✓ **Facility Design**

→ ***Gas & Condensate Production (2004)***





- **We are willing to actively involve in PPM Case Studies: collaborative work with Host Countries**


The End
Thank You.