PETROLEUM ENGINEERING

Consideration of Gas Hydrate Production Well Technology

August 17, 2005

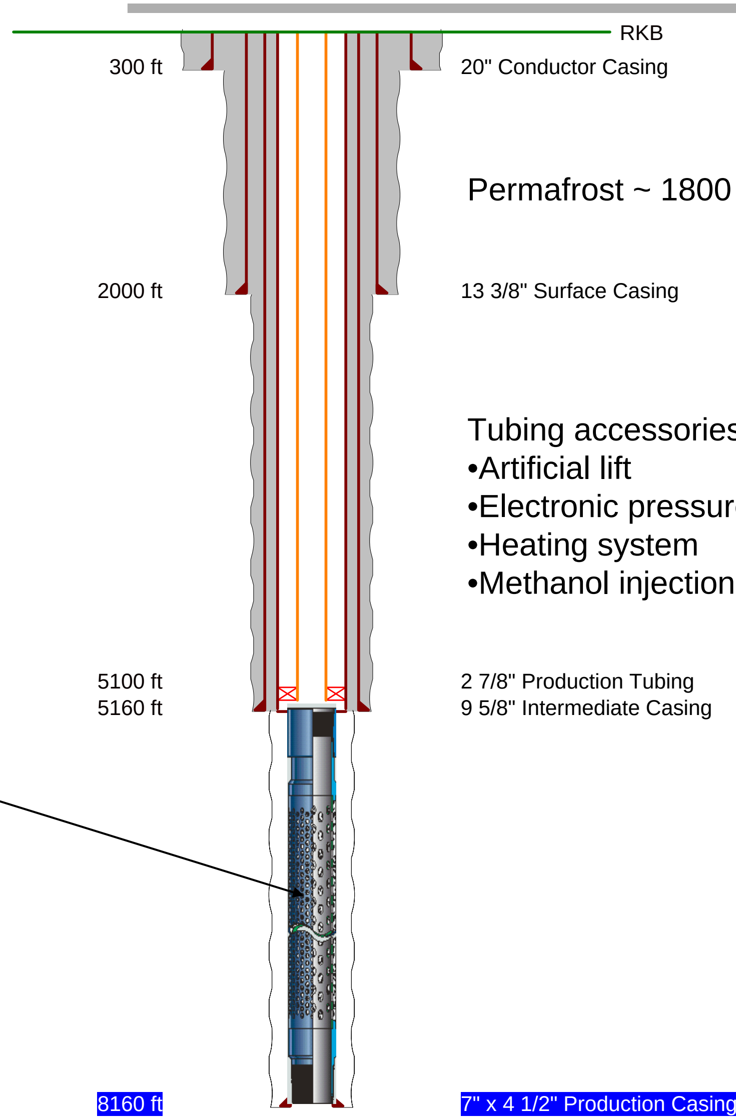
PRACTICAL SOLUTIONS
TO COMPLEX PROBLEMS

Gas Hydrate Production Well Technology

- Drilling & completion issues
- Well performance issues
  - Flowing pressures
  - Water production
  - Other flow assurance issues
- Field development review based on Mallik

Typical Well Completion

Sand screen shroud will incorporate fibre optic loops with distributed temperature and several discrete pressure sensors

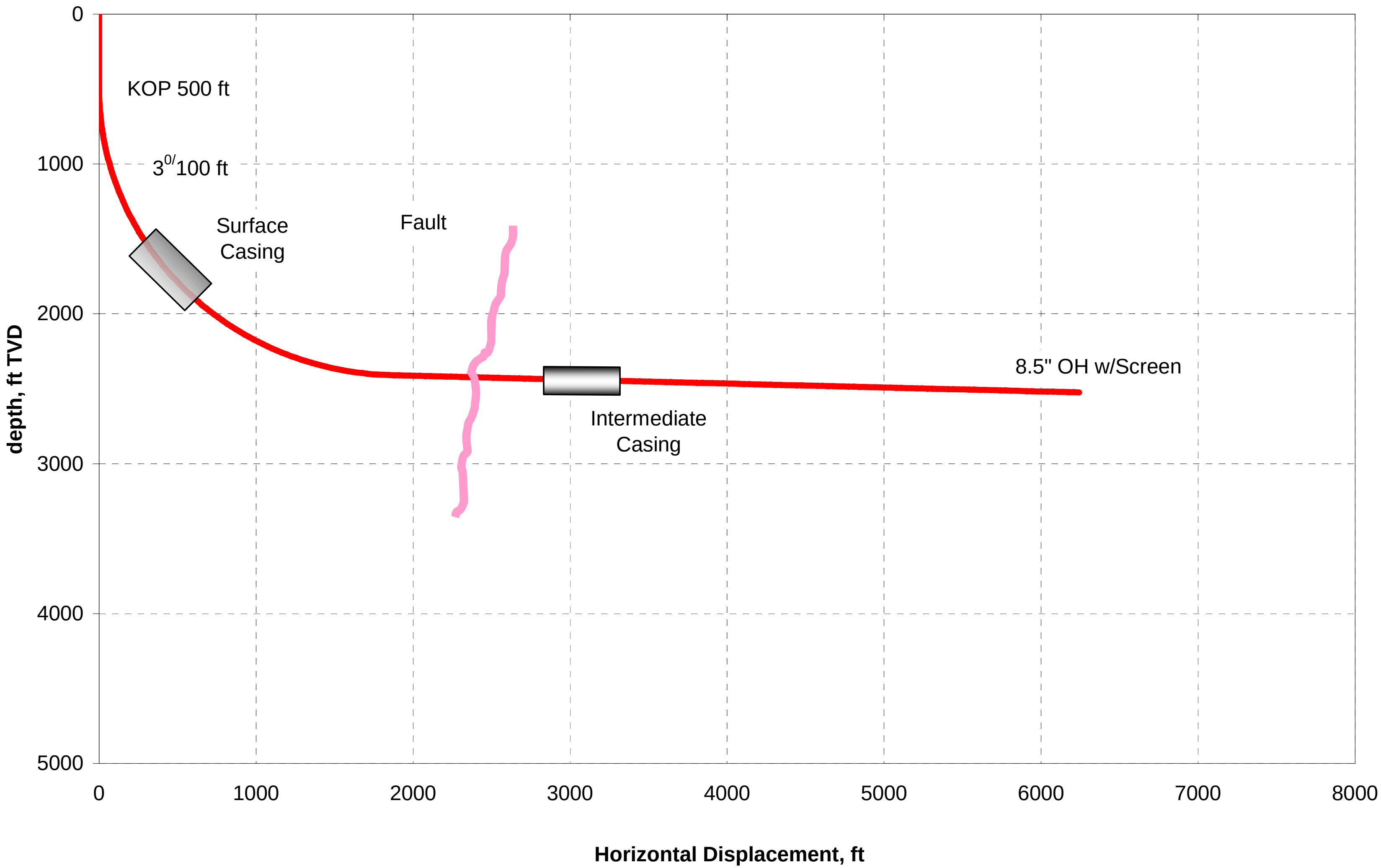


Permafrost ~ 1800 ft TVD

Tubing accessories:

- Artificial lift
- Electronic pressure gauge
- Heating system
- Methanol injection sub

Typical HZ Well Profile



Well Performance - Pressure

Conventional Gas Reservoir

- Typically normal or higher initial reservoir pressure
- FBHP controlled by:
  - Drawdown limitation (borehole stability, water production etc.)
  - Surface pressure constraint
  - Rate constraint
- Compression typically staged later in life of field

Gas Hydrate Reservoir

- Initially normally pressured (water phase pore pressure)
- FBHP controlled by dissociation (say 350-500 psi)
- Production rate must equal dissociation rate
- FWHP controlled by FBHP and production rate (gas & water)
- Compression required throughout life of project

Well Performance - Water

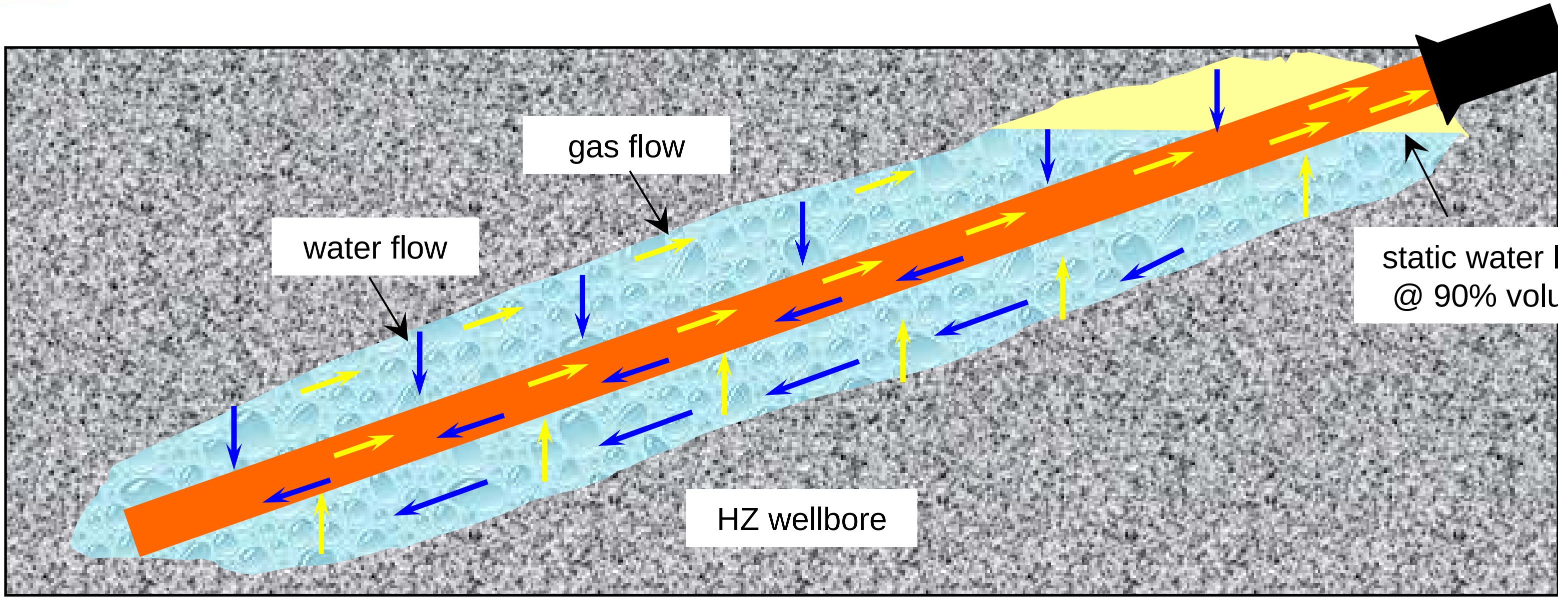
Conventional Gas Reservoir

- Water sources:
  - 1-2 bbls/MMscf condensation
  - Coning & cusping
  - Active aquifer
- Historical controls (low cost):
  - Cyclic operation
  - FWHP reduction
  - Water shut-off re-completions
  - Lift assist
- Other controls (high cost):
  - Sidetrack/horizontal well
  - Artificial lift (gaslift, PD pumps, jet pumps)

Gas Hydrate Reservoir

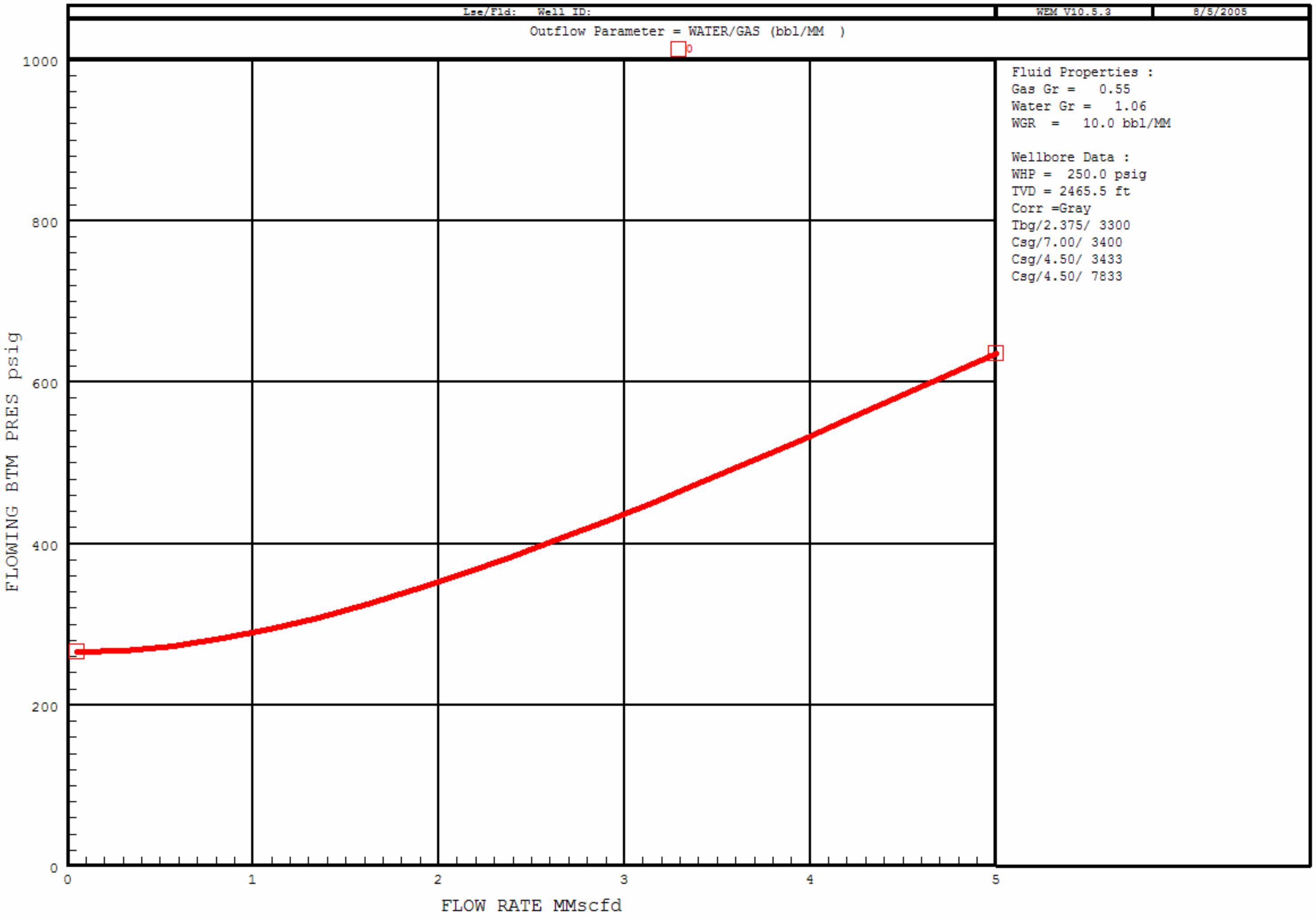
- 1 ft^3 of gas hydrate = 164 scf of gas & 0.9 ft^3 of water:
  - ~ 978 bbls/MMscf
  - Actual water production function of well geometry, reservoir drainage
- Low FBHP conditions provides stable tubing performance with relatively high watercuts
- Artificial lift required:
  - Well start-up
  - Continuous and/or intermittent basis
- Disposal or resource (low salinity)

Water Production



- No Free water
- Gravity effect dominate gas/water segregation
- Gas will accumulate along top of dissociated zone, expansion due to low pressure will drive gas towards wellbore
- No driving energy in free water phase – gas velocity only???

2 3/8” Tubing Performance



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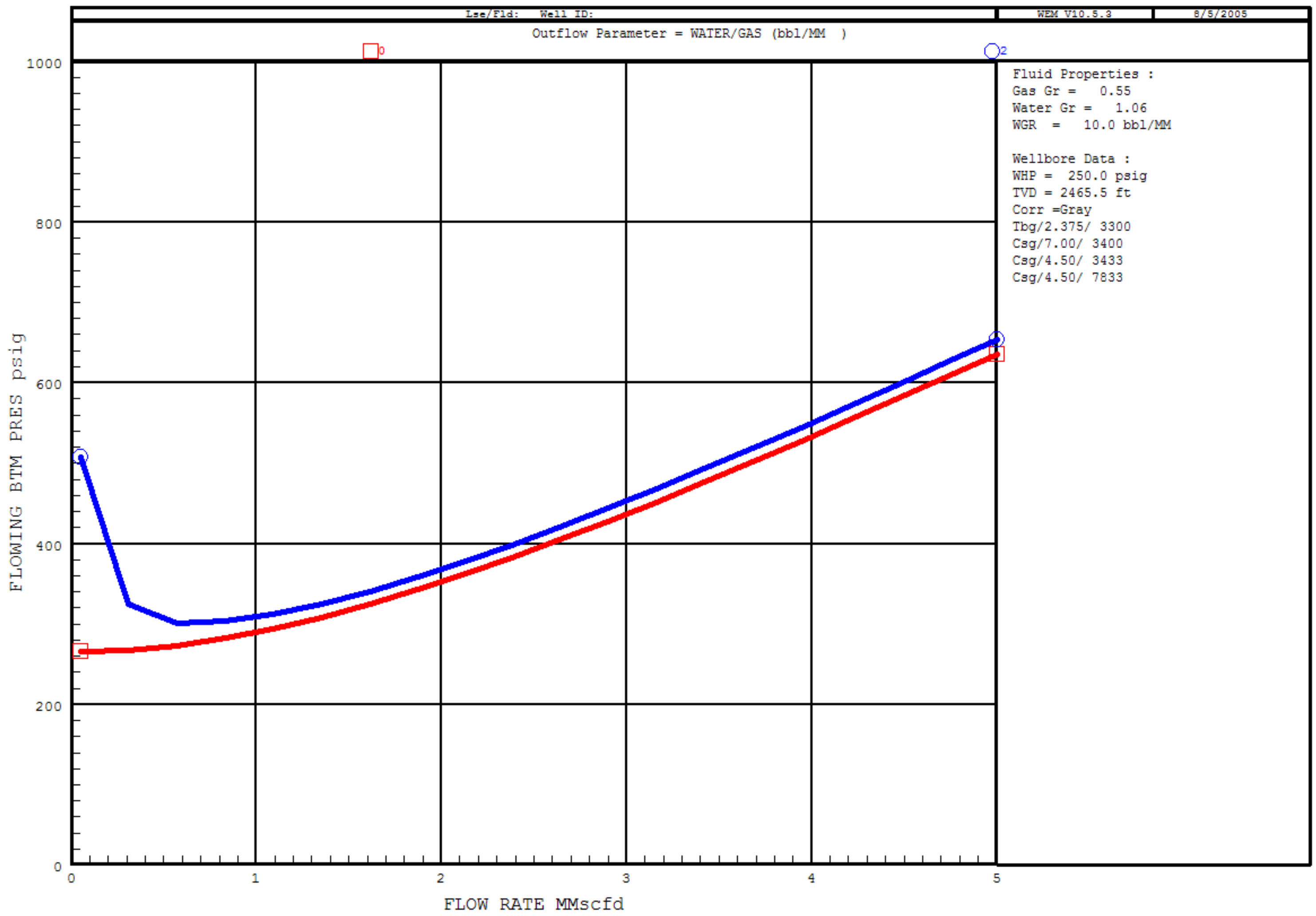

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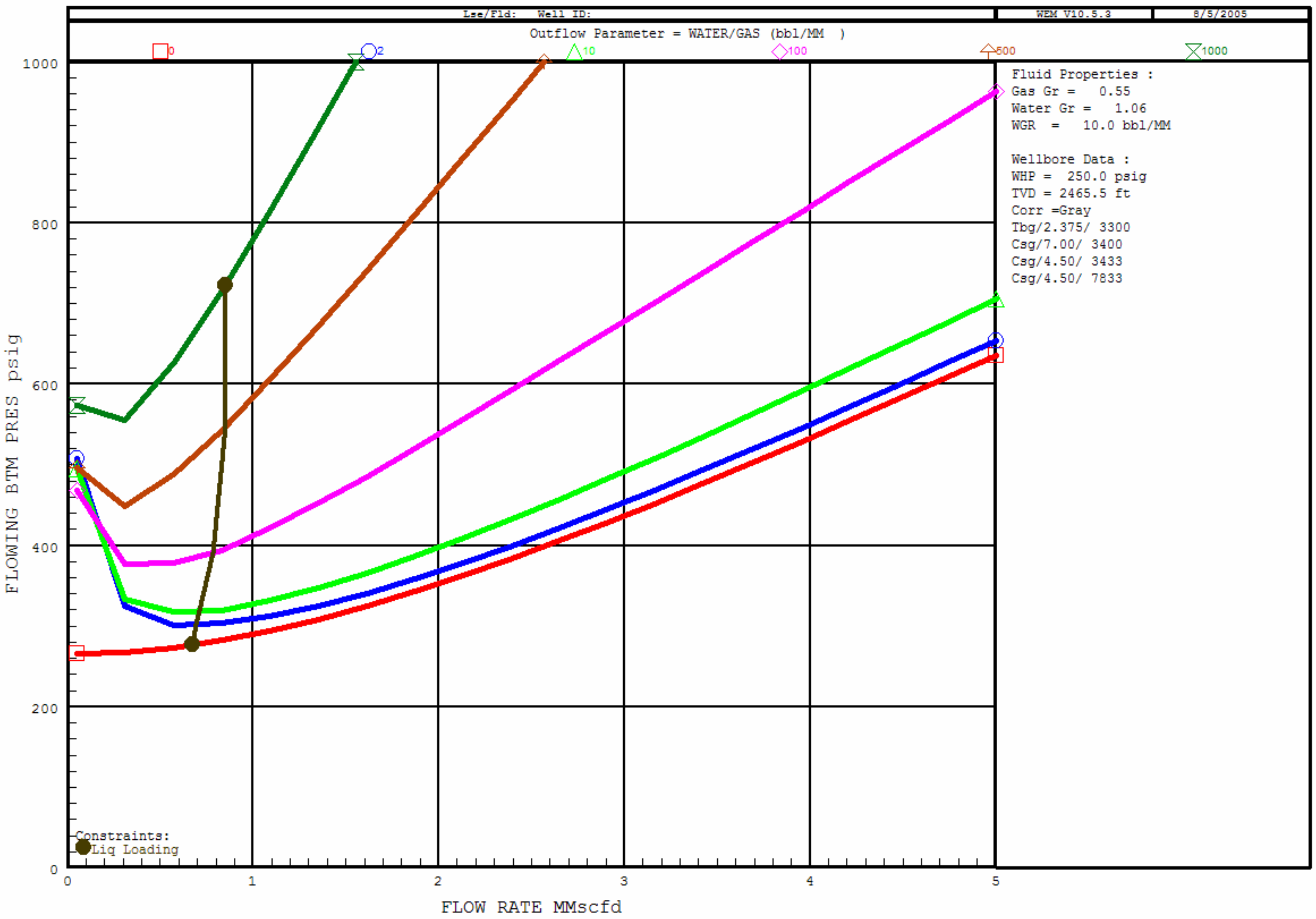

Well Performance – Flow Assurance

Conventional Gas Reservoir

- Hydrate formation prevention:
  - FWHT > 75 F depending upon gas analyses & pressure
  - Temporary heating or chemical injection
- Liquid loading
- Others:
  - CO_2 & H_2S (corrosion)
  - Scale (produced water)
  - Asphaltenes & paraffins (gas condensate)
  - Extreme high temperatures and pressures

Gas Hydrate Reservoir

- Hydrate formation prevention :
  - Low FBHP
  - Heat and/or chemical injection
- Freezing:
  - Geothermal < 32 F
  - Heat and/or chemical injection
- Water production
- Others:
  - No significant corrosion
  - No condensate liquids
  - No significant scaling

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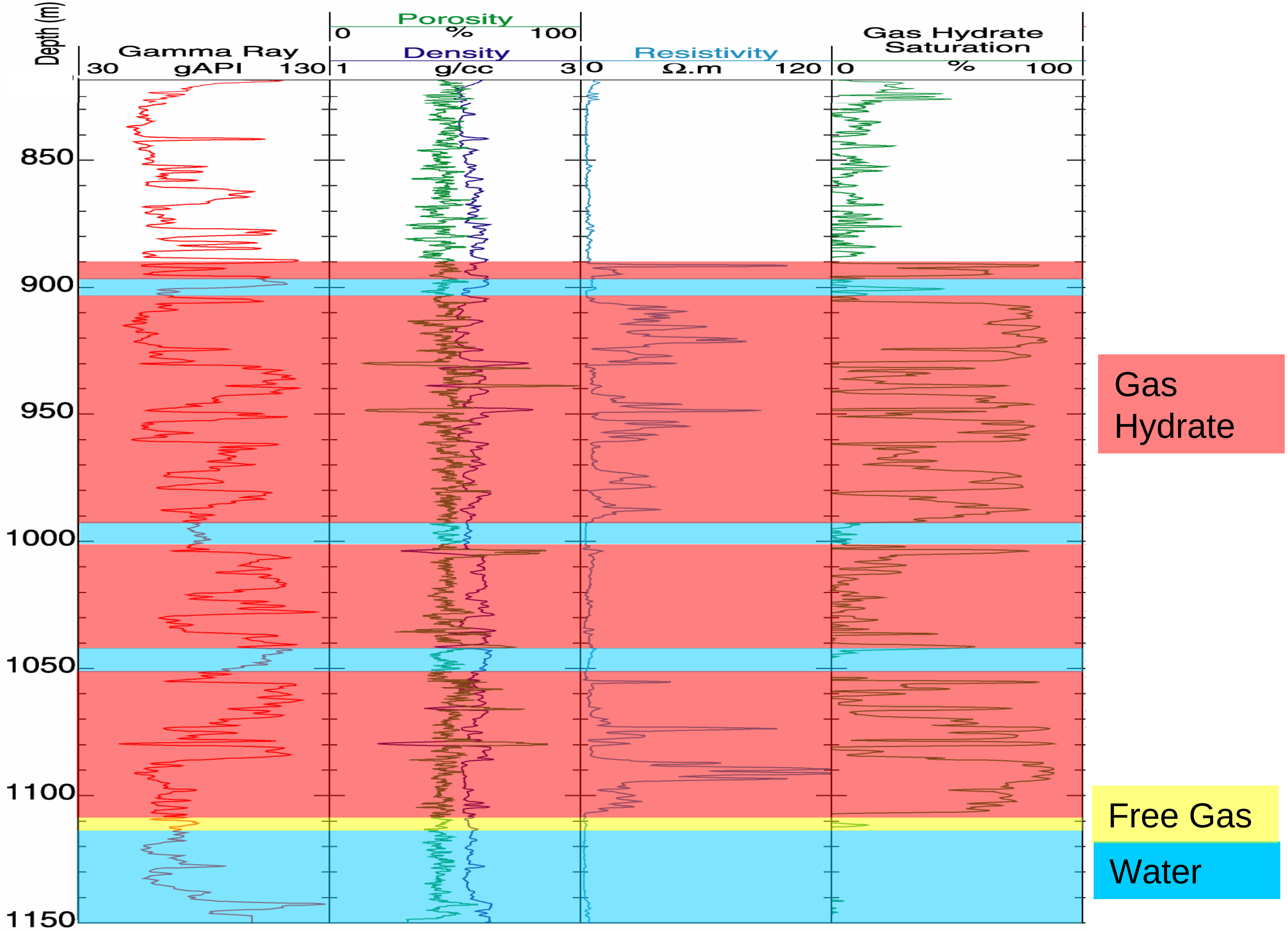
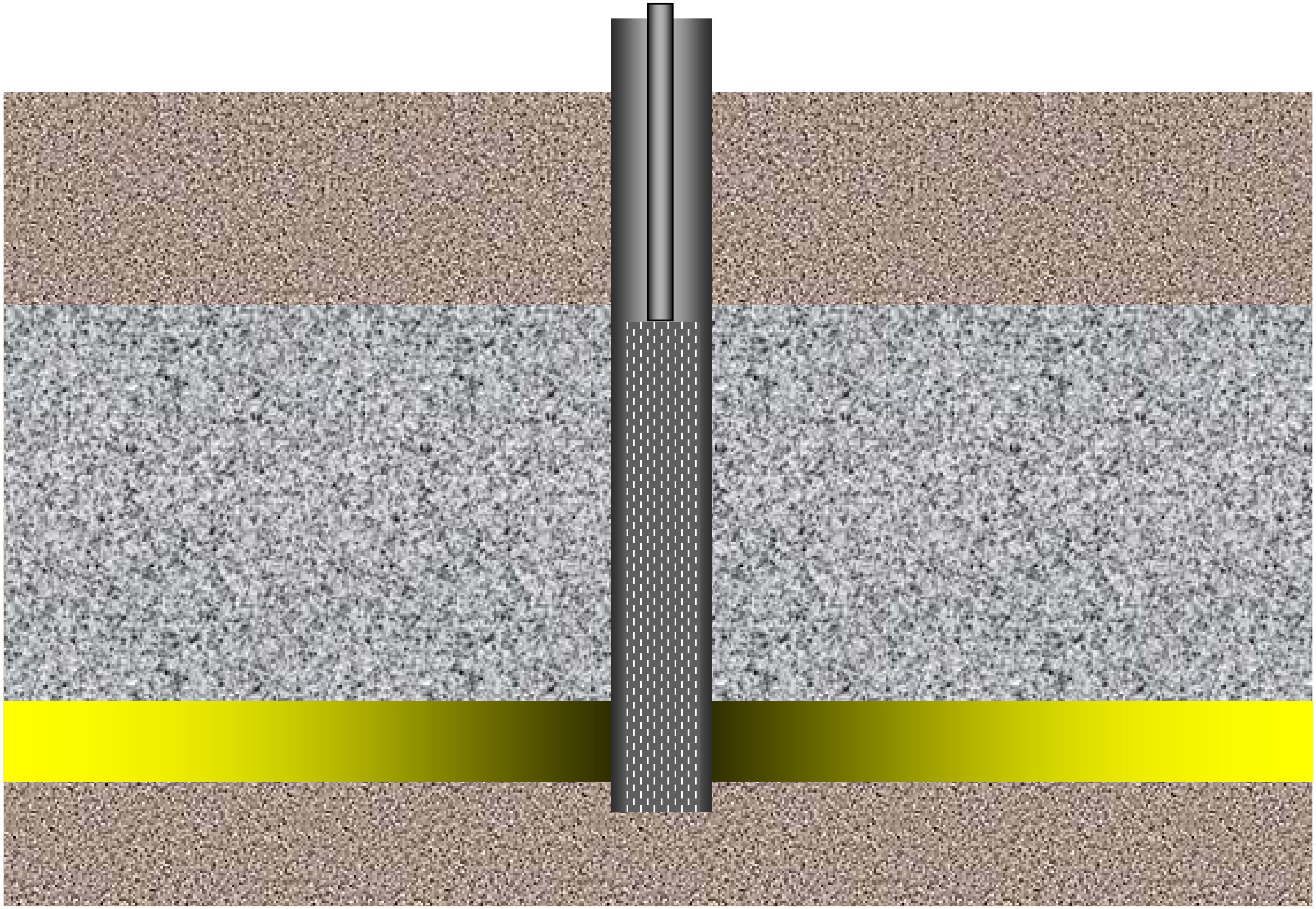
Well Performance - Conclusions

- Gas hydrate wells will have a relatively benign operating environment – long life and few interventions
- Technologies required to produce gas hydrate wells are currently used in conventional gas field operations
- Capital & operating cost impacts:
  - Compression requirement for gas hydrate wells represents additional costs compared to conventional gas wells
  - Artificial lift requirement and water disposal for gas hydrate wells represent additional costs compared to conventional gas wells
  - Must consider the above in context of field life and reserves recovery per well

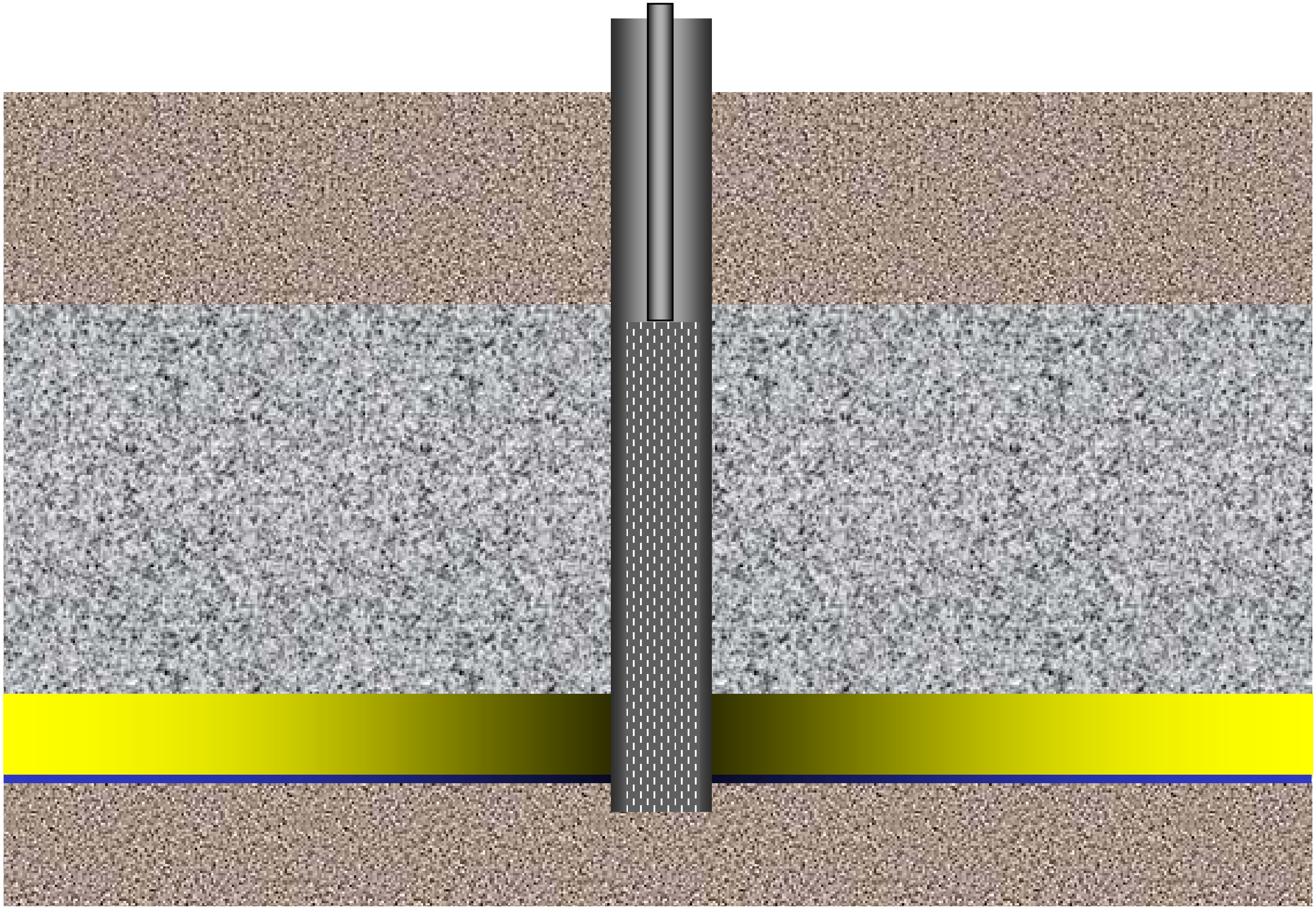
Mallik 5L-38 Hydrate Deposit



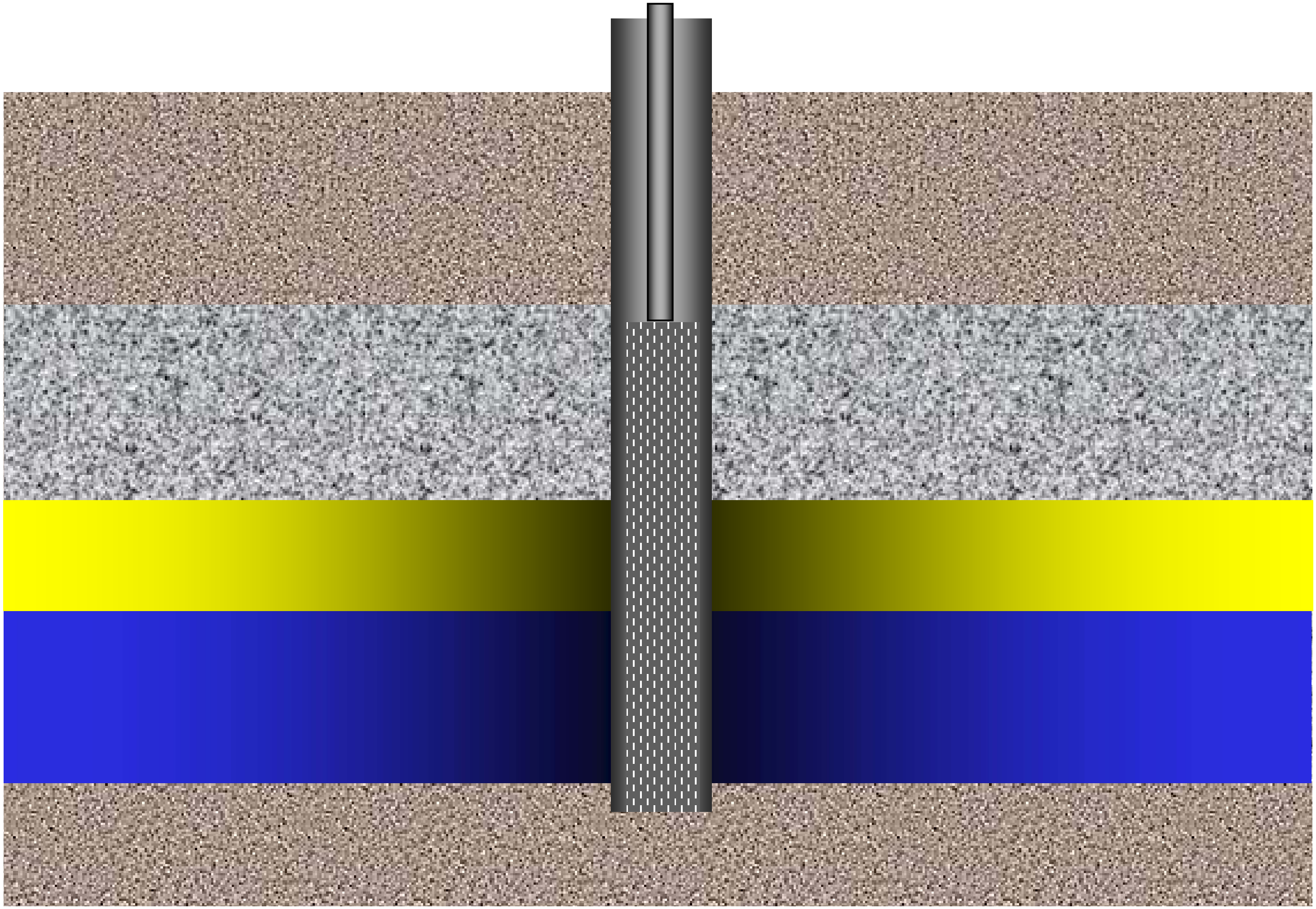
Case 1 – Gas Hydrate Over Free Gas



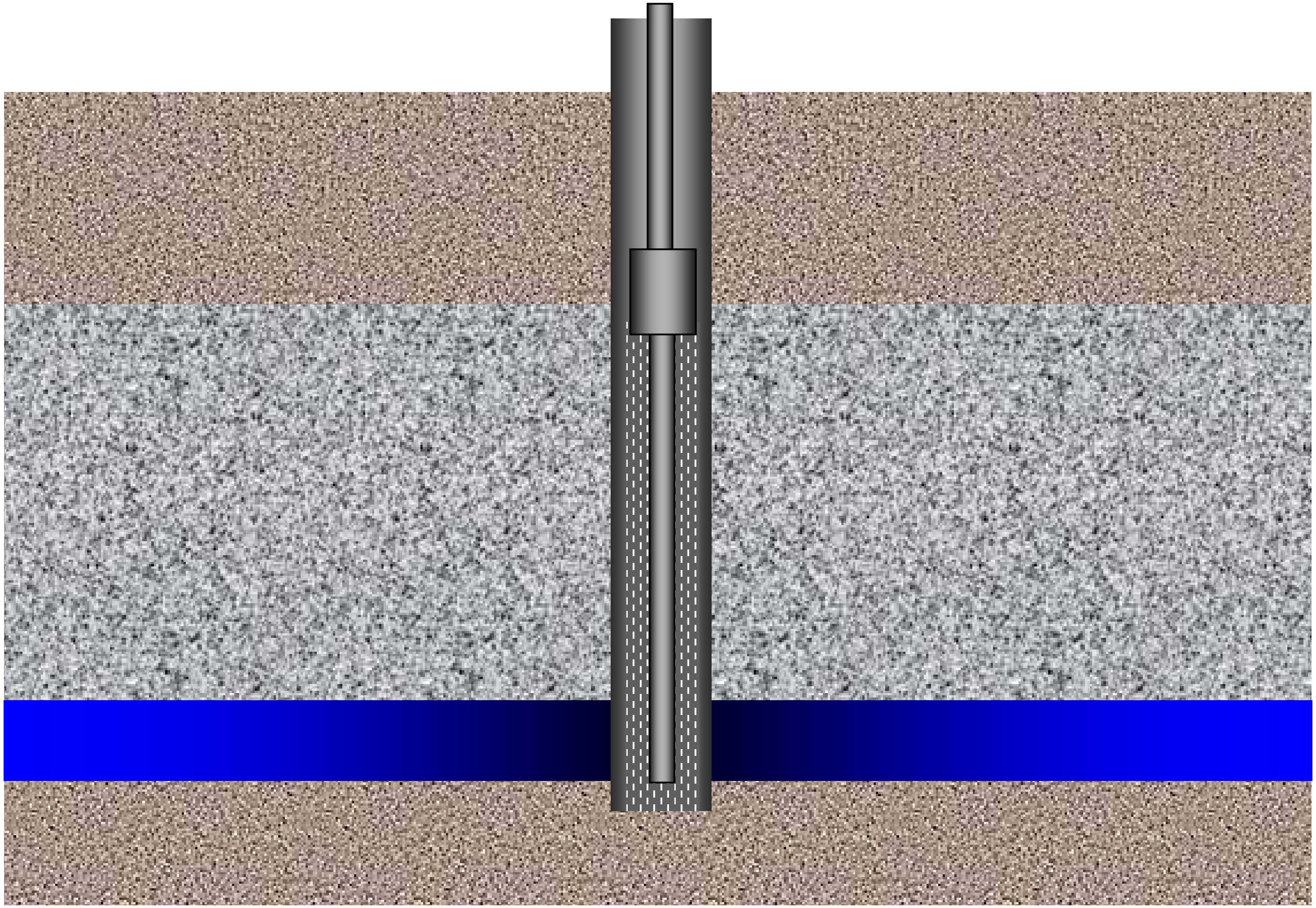
Case 1 – Free Water Established



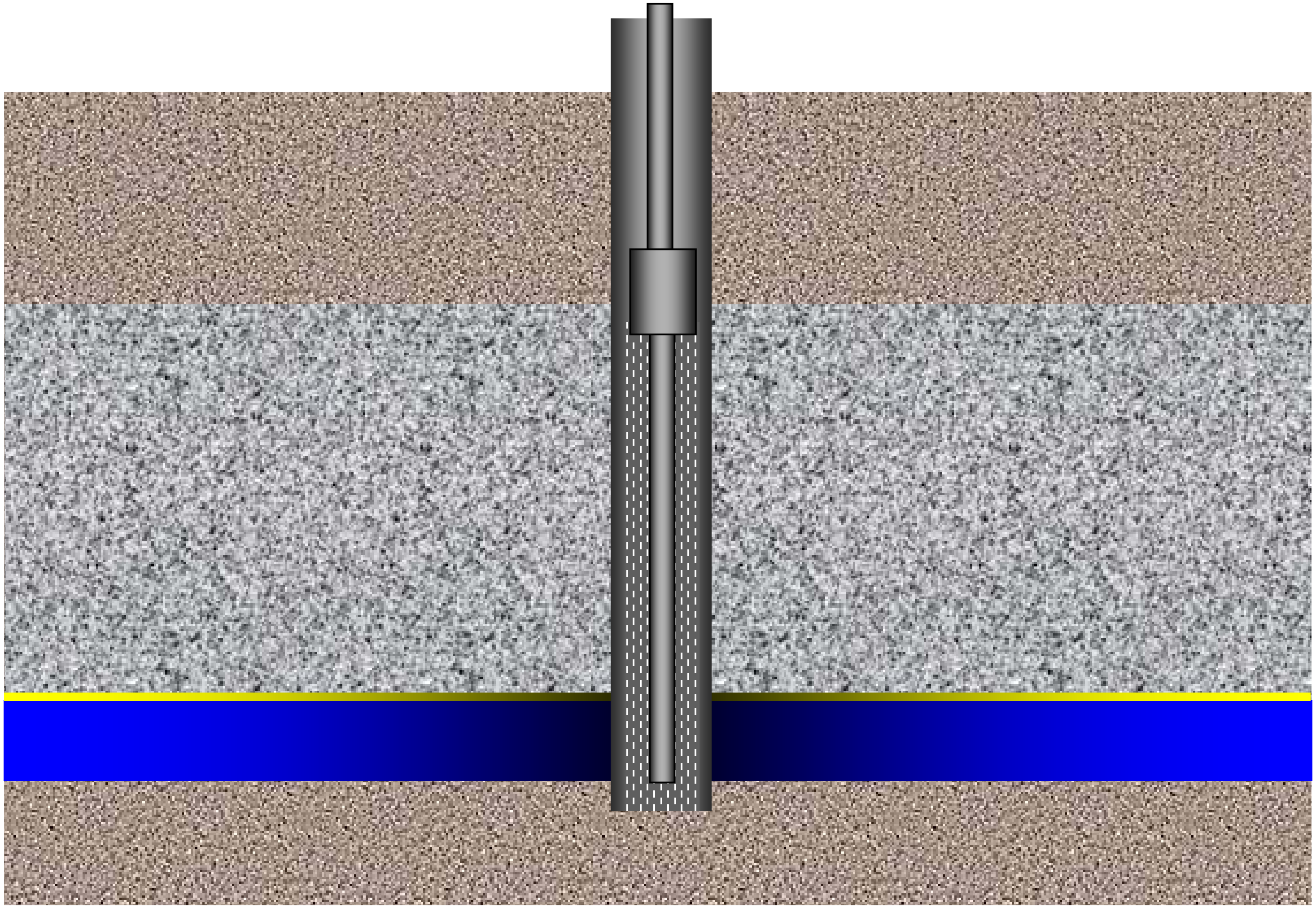
Case 1 – Cont'd Gas Hydrate Dissociation



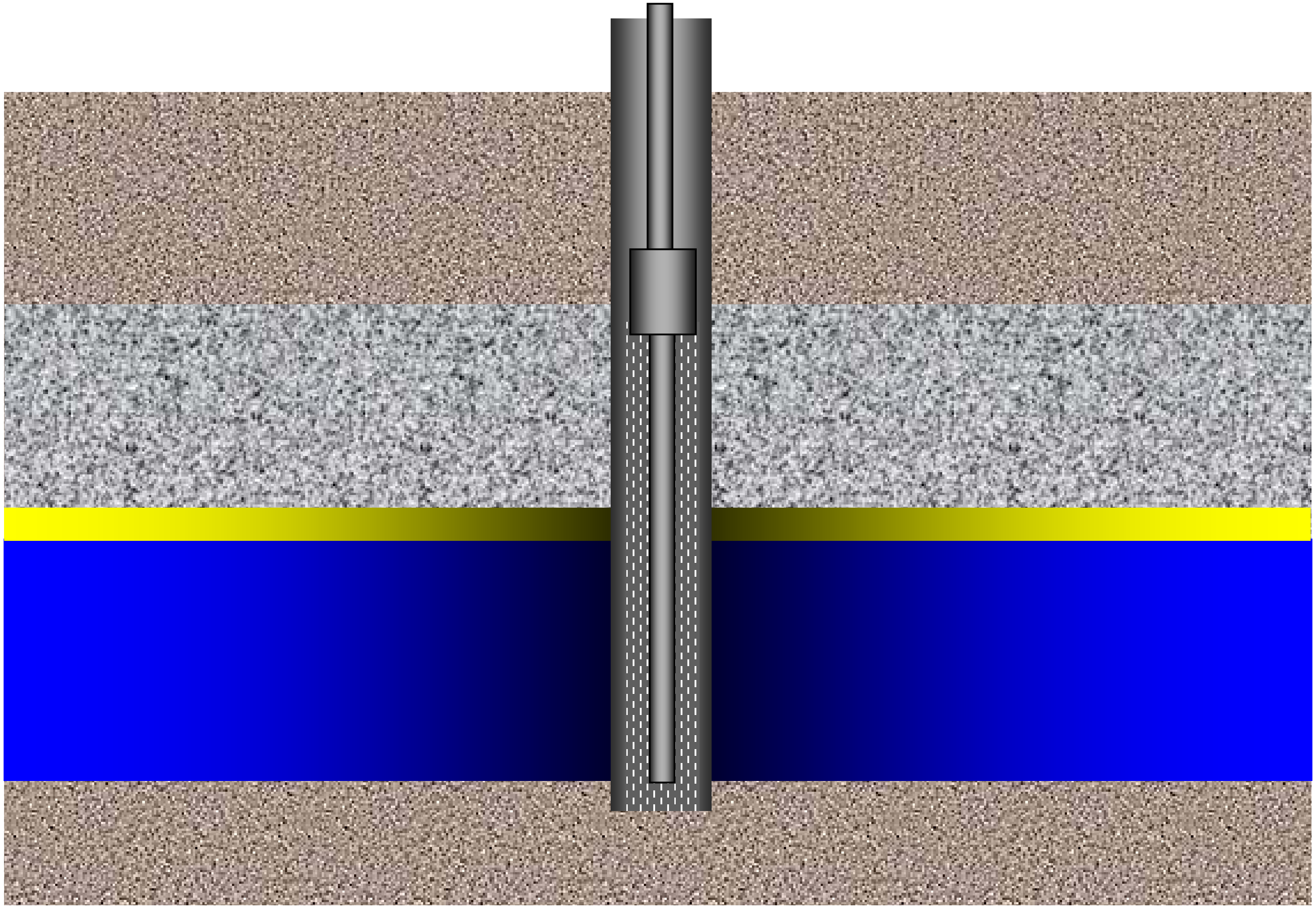
Case 2 – Gas Hydrate Over Water



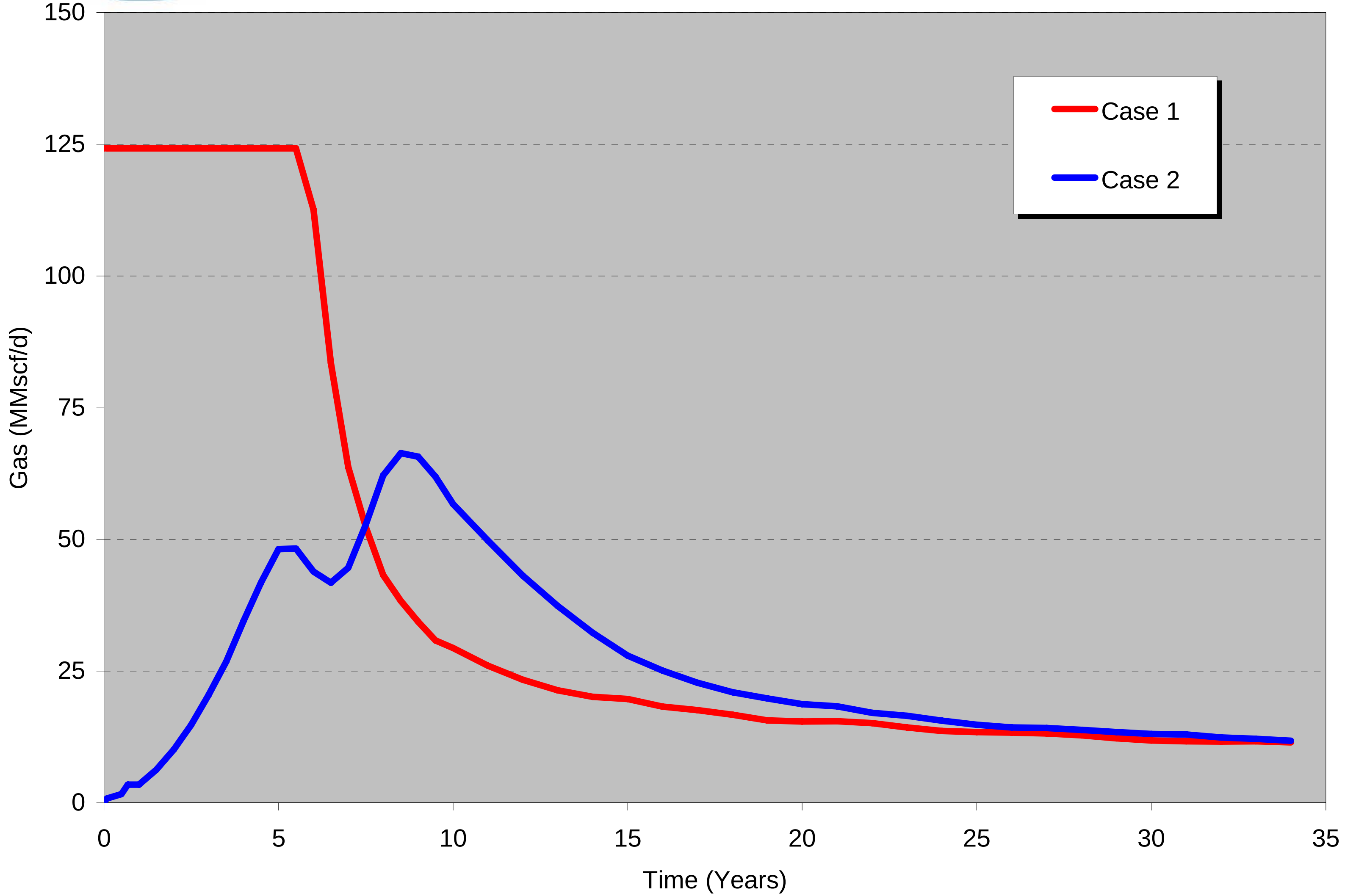
Case 2 – Onset of Gas Production



Case 2 – Continued Hydrate Dissociation



Production Comparison



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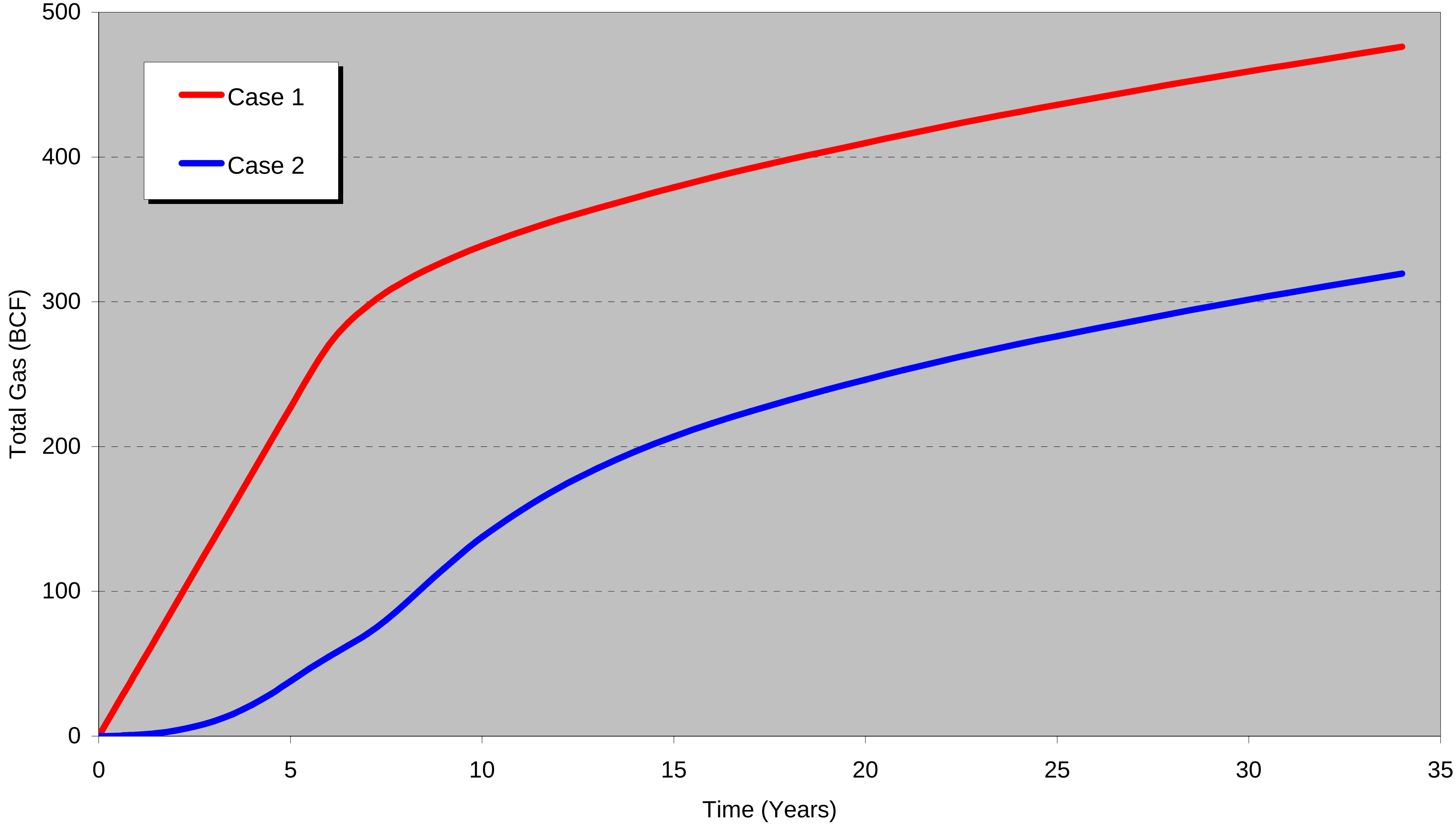
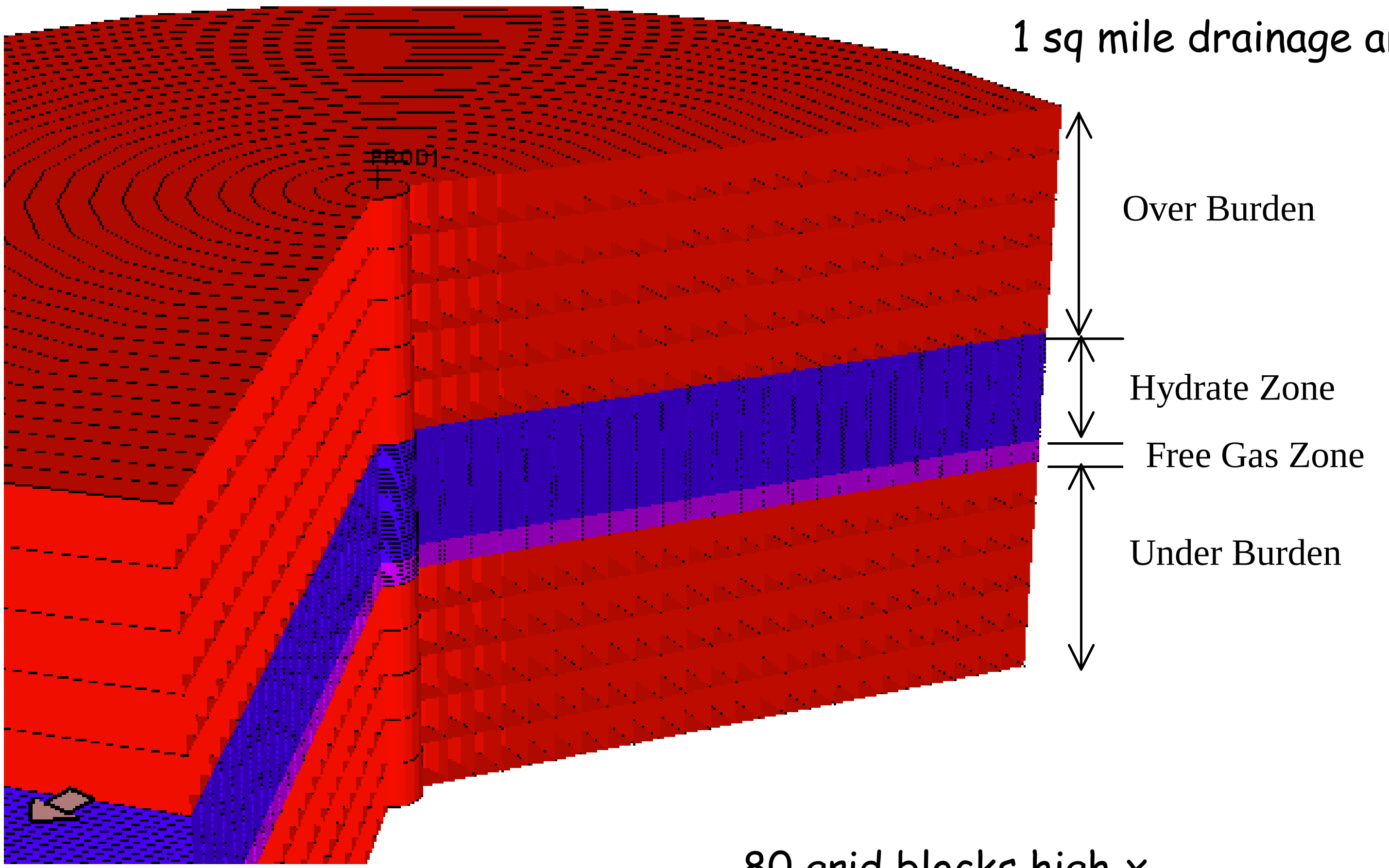


STARS Reservoir Model

Single well

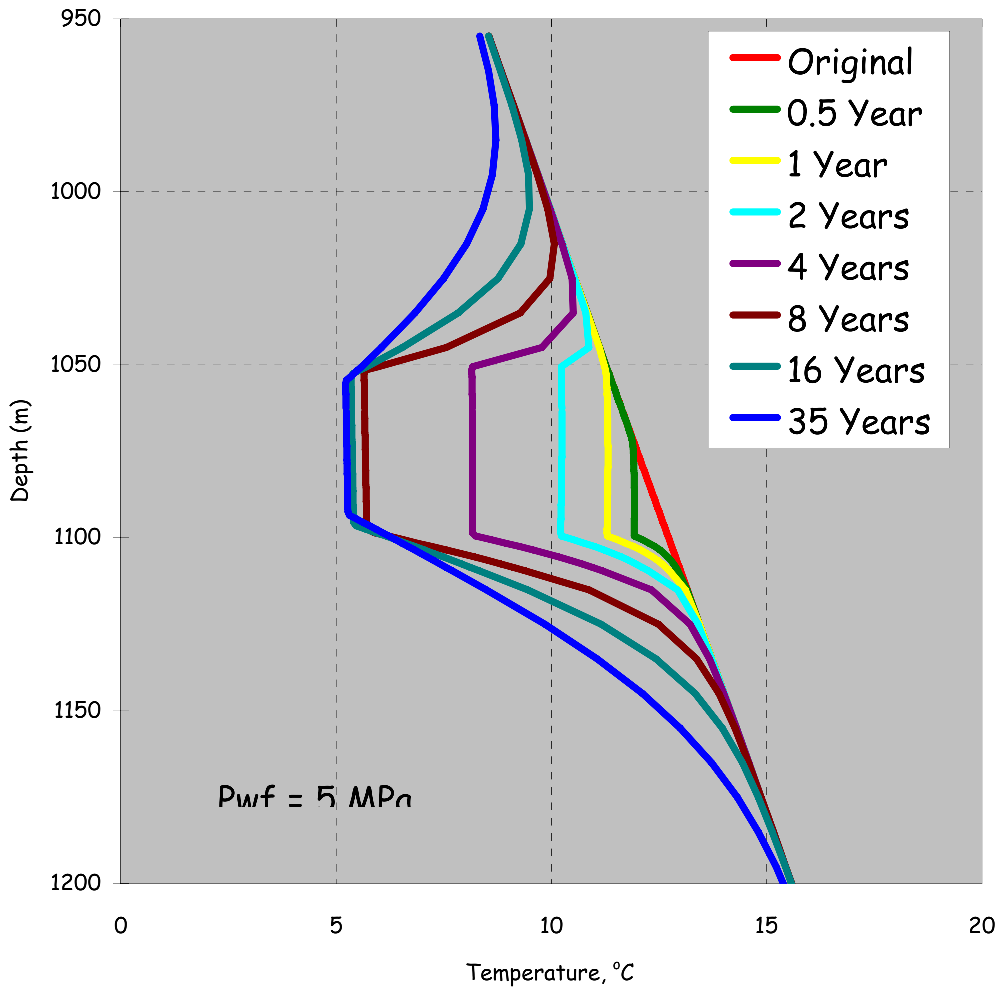
1 sq mile drainage area



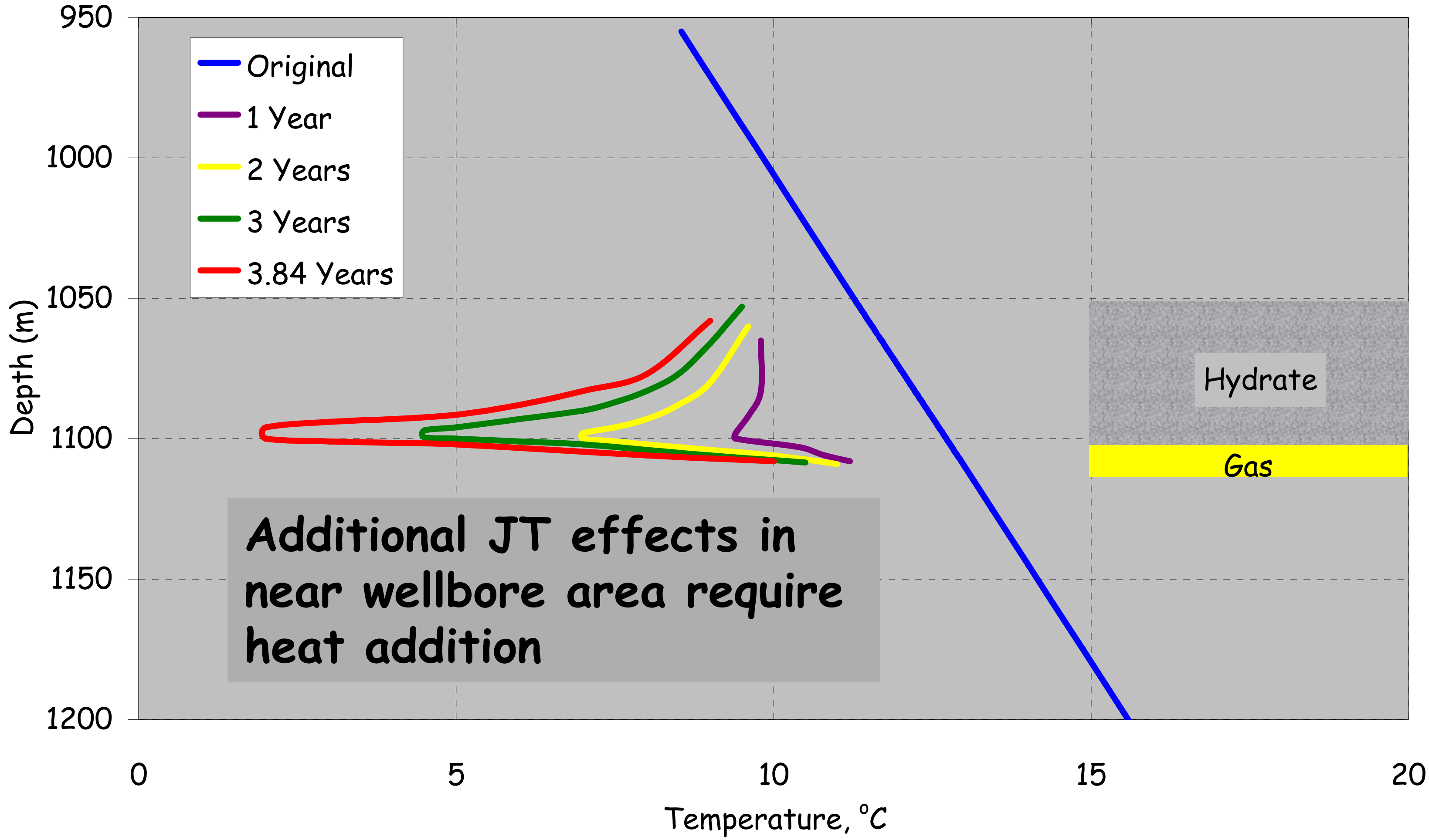
80 grid blocks high x

100 grid block radial

STARS Temperature Profile



TOUGH-Fx/Hydrate Temperature Profile



Cost Summary - $CDN 2004 MM

5 Wells, ~1 TCF GIP

Capital Costs	Case 1	Case 2
Drilling & Completions	$82	$87
Facilities & Pipeline	$288	$198
Sub-total	**$370**	**$285**

Operating Costs	Case 1	Case 2
Local Pipeline	$18	$18
Local Facilities	$374	$339
Gas Plant Process	$648	$431
Water Handling	$2	$26
Workovers	$13	$18
Pipeline Tariff	$1,512	$1,006
Sub-total	**$2,567**	**$1,838**
Total Capital & Operating	**$2,937**	**$2,123**

Economic Evaluation - Unit Technical Cost

		Case 1	Case 2
Total Capital & Operating, $ MM		$2,937	$2,123
Sales Gas, BCF		432.1	287.5
$CDN/Mscf	0% Discount	$6.80	$7.39
	10% Discount	$6.20	$8.01
	20% Discount	$5.78	$9.64