Evaluating the Integration of Reservoir and Surface Network Models

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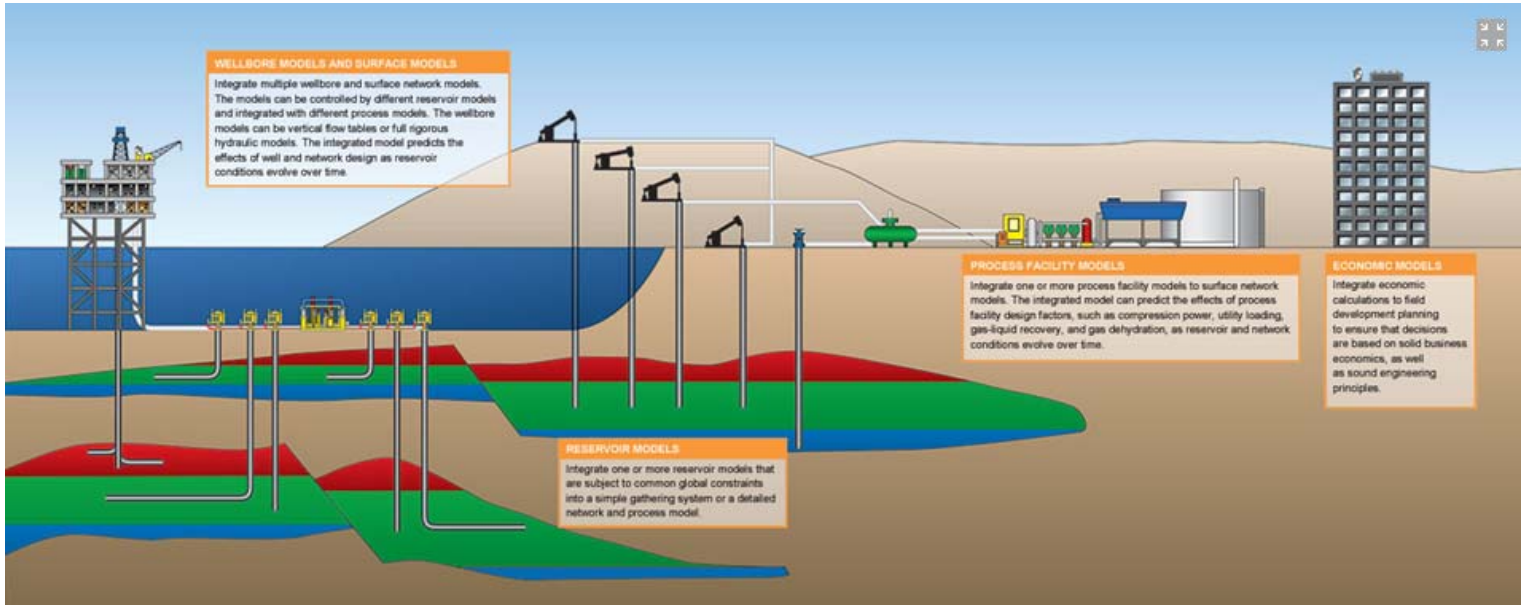
Objective

- Shed some light over the need and the development of integrating reservoir and surface network models.
- Evaluate, using a synthetic example, some of the integrating techniques when coupling is not needed or not possible.



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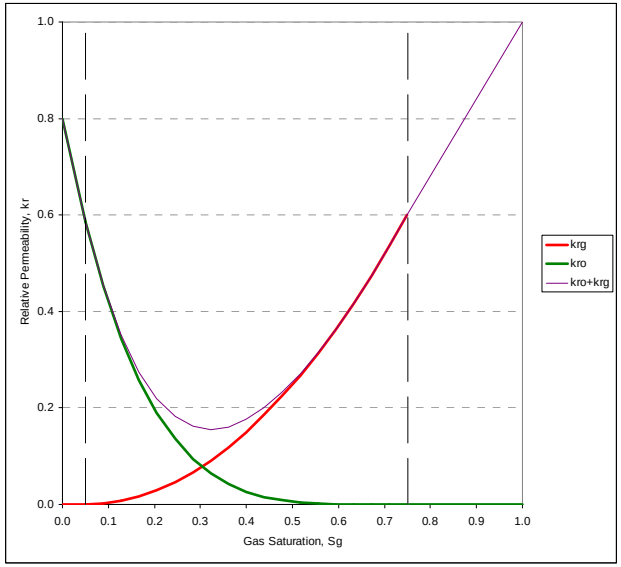
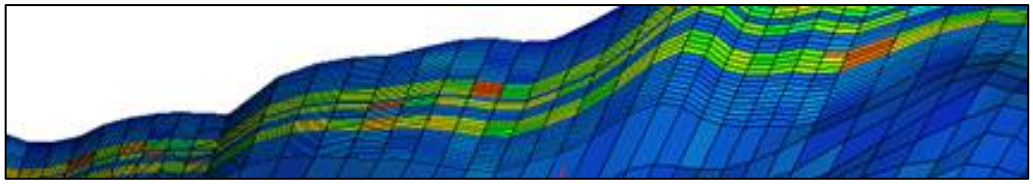
Outline

- Reservoir simulation models
- Wellbore and surface networks
- Types of coupling for reservoir and network models
- Coupling vs. separate models
- Case study of two separate models
- Evaluating error in two separate models
- Recommendations

Reservoir Simulation

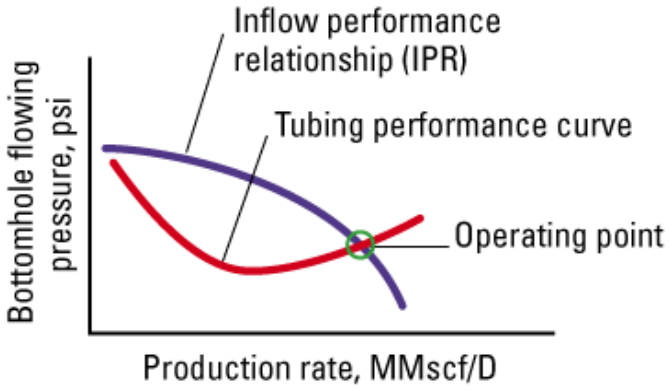
- Is a tool to model dynamic behaviour of the reservoir
- Based on numerical geologic model (honouring seismic well logs and cores)
- Based on material balance, studying fluid flow
- It operates under various production and injection conditions
- Tuned through history matching to account for uncertainty in petrophysics
- After history-matching the model predication scenarios are generated

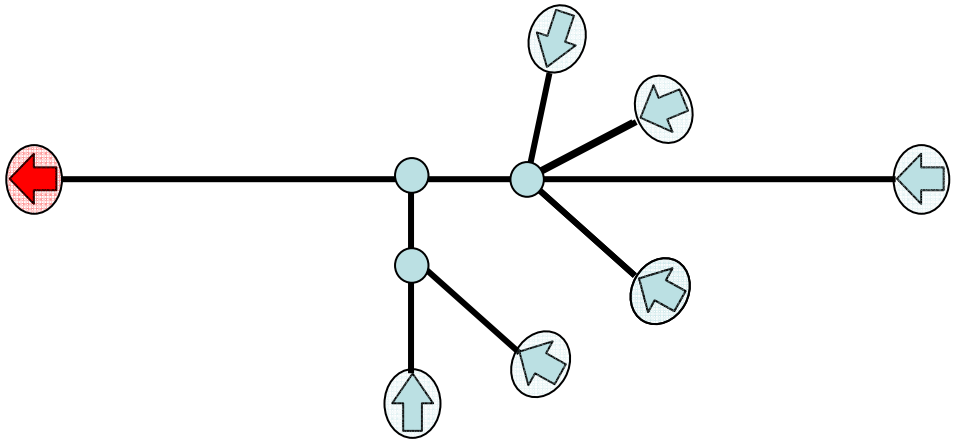




Network Simulator

- Models production downstream of the wells' completion, tubing string, surface choke and flowlines up to the separator.
- Performs nodal analysis by generating a set of mass and pressure balance equations at each node of the system and solve them (VLP/IPR intersections) for given boundary conditions such as separator pressure.
- Mainly steady-state models, single or multiphase flow, various compositional options
- Reservoir behaviour can be modelled directly through IPR curves relating sandface pressure to production rates





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Coupling Software Types

- Coupling was pioneered by Dempsey in 1971, for application in gas field development and production optimization
- Some years later Chevron extended the application to offshore oil fields
- Several other major companies developed their proprietary softwares
- Major service companies commercialised integrating software packages
- Advanced coupling software operates in compositional environment and incorporates financial metrics

Initial Integrating Techniques

- Mainframe Simulators
  - Single phase 2D model with surface facility option (for dry gas fields, long time ago)

- Simplified Network Integration
  - Based on replacing the well model (VFP) with generalised network model

- Simplified Asset Modeling with Proxy Models:
  - Simplify and upscale the reservoir model closer to a tank with simple material balance equations under certain drainage profile.

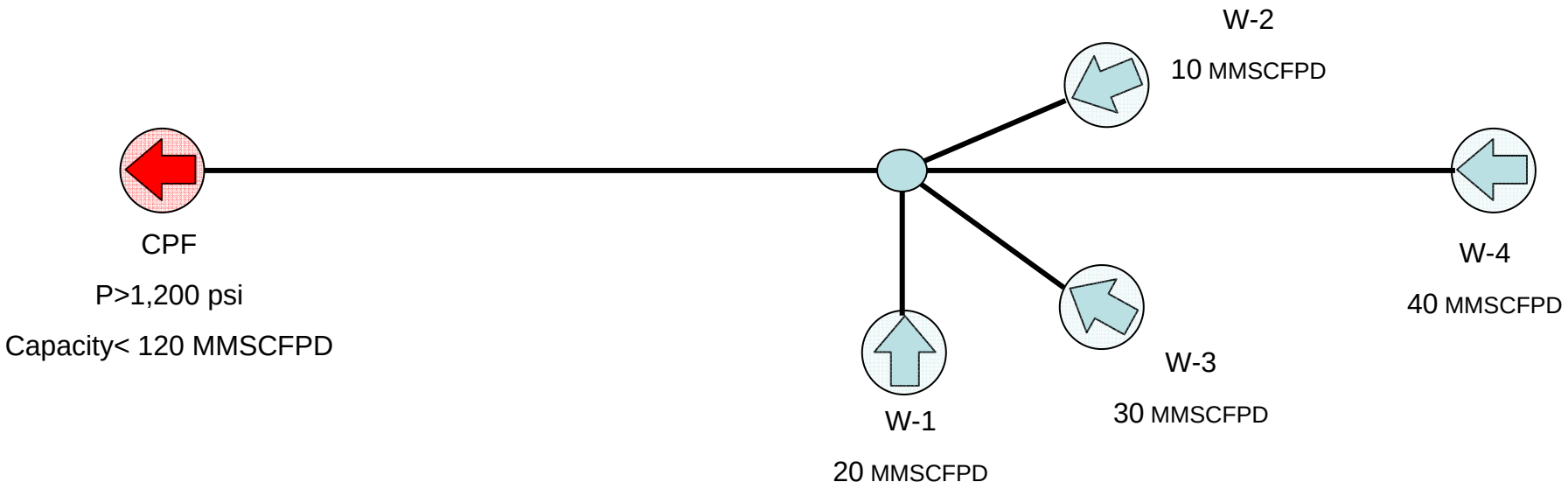
Different Coupling Software

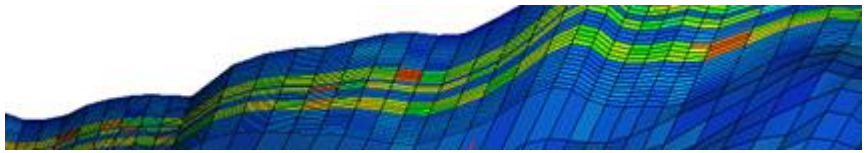
- Coupling location (surface, bottom hole or reservoir level with an IPR)
- Solution (explicit or implicit) and coupling at timestep or Newton iteration
- Full integration or interface software, given that it couples “open”

Coupled vs. Separate Models

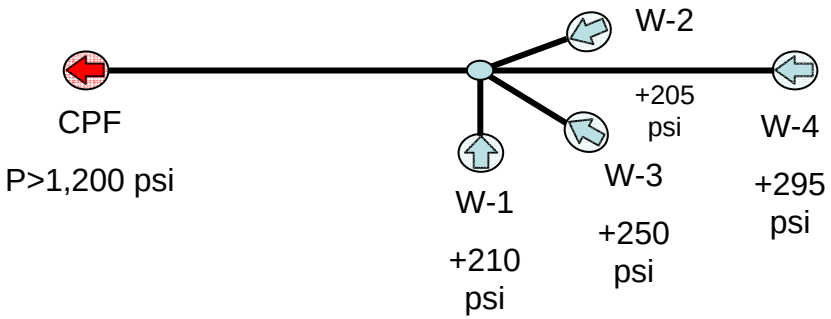
- It has been recognised that coupling is very helpful particularly when the surface facilities are shared amongst several fields at different pressure regimes
- Additional convergence required between the reservoir simulator and the network solver-optimizer result in longer running time for coupled simulation.
- The additional time depends on the efficiency of the optimizer and the number of iterations needed between the two models
- 10 times longer running time is not uncommon
- Convergence problem might be critical for already complicated reservoir models and coupling may not be an option

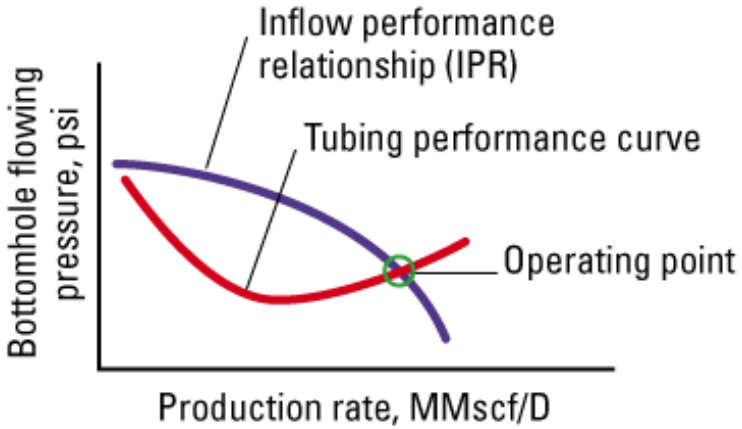
Example of Running Separate Models





Integrating Techniques 1





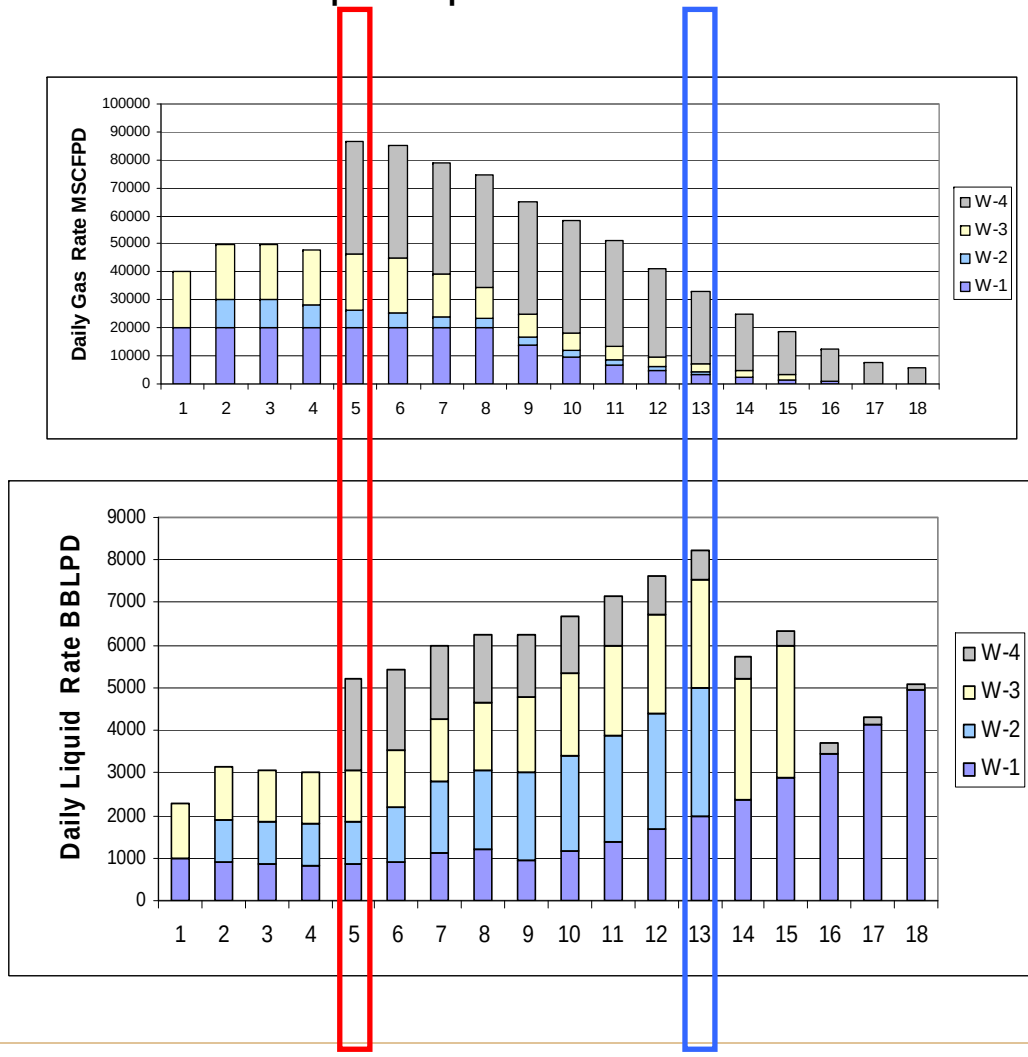
Courtesy of Schlumberger Oilfield Glossary

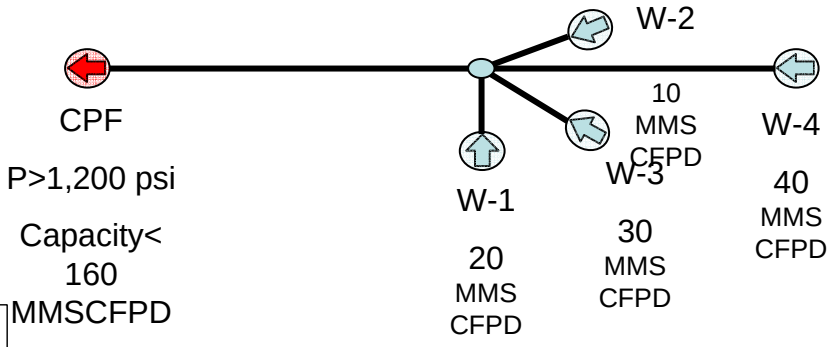
1. Initial estimation to pressure loss in the surface network e.g. 400 psi
2. Run reservoir simulator with min wellhead limit

   1,200 + 400 =1,600 psi
3. Use output well rates in the surface network and work out pressure loss at each wellhead
4. Run reservoir simulator with new wellhead limits
5. Produce initial production profiles from the reservoir model

Integrating Techniques 2

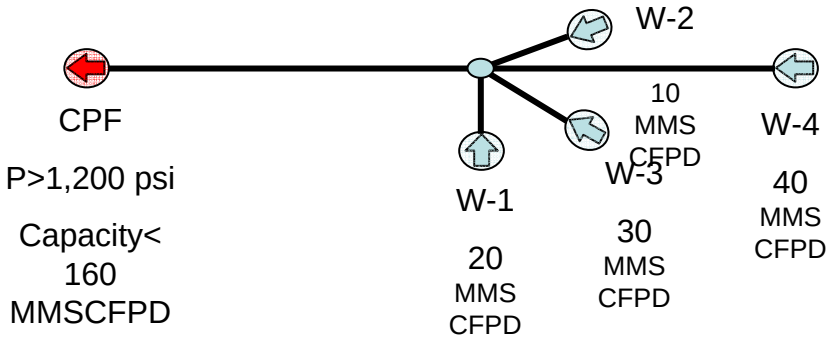
6. Run the peak production rates in the surface network

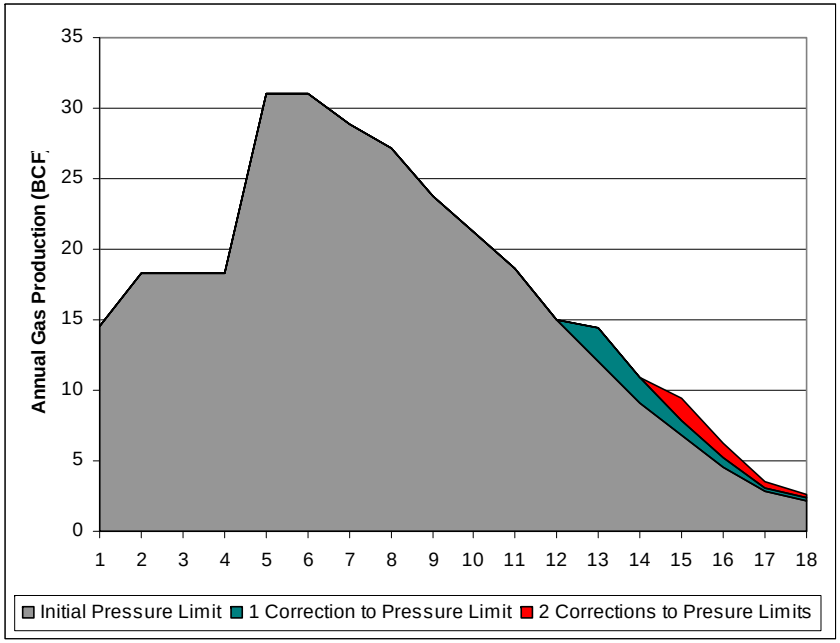




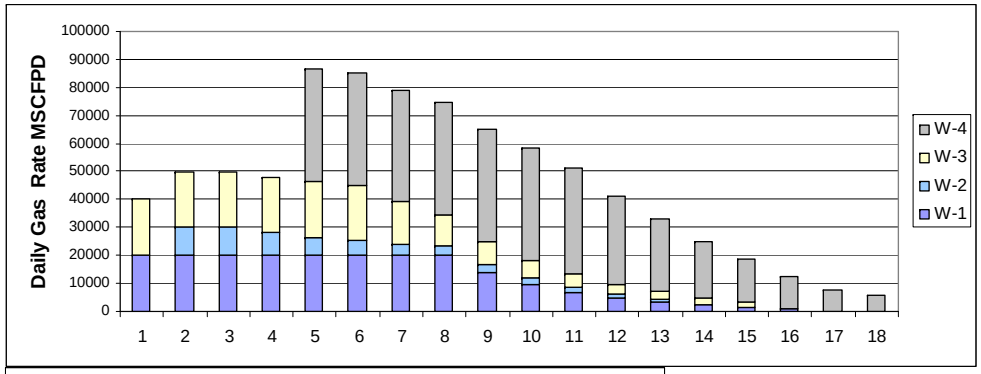
Integrating Techniques 3

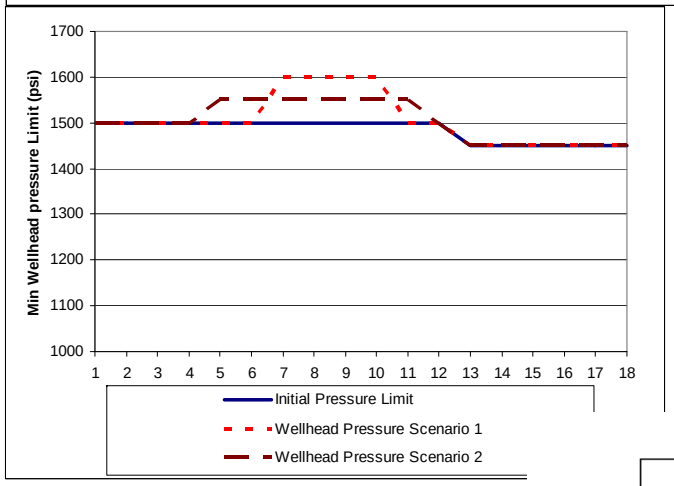
7. Identify the period where production is limited by wellhead pressure
8. Run the well rates at that year in the surface network and recalculate the wellhead pressures
9. Update the reservoir simulation wellhead pressure limits for that year
10. Workout the RF increment and the NPV improvement

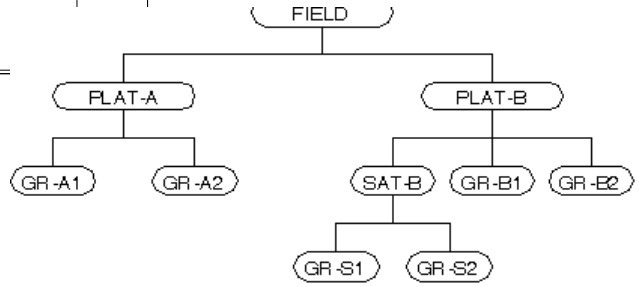


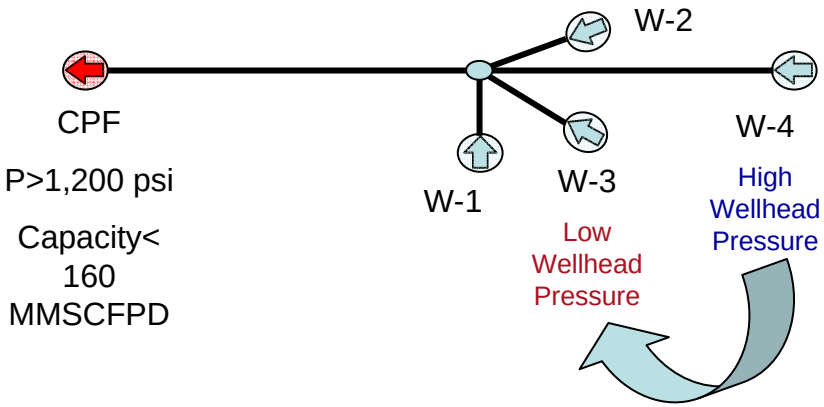


Integrating Techniques 4









- Accounting for backpressure and crossflow between wells
- Optimise individual well rates on the basis of individual well potential deliverability

Courtesy of Schlumberger ECLIPSE Manual

Recommendation

- Integrated should be after each discipline understands its model sensitivity
- The mutual understanding of the needs of each discipline in the integration of reservoir and surface is essential.
- New generation of coupling models have artificial intelligence and financial metrics which saves considerable time when updating the model
- The big time and efficiency saving when fully coupling is when updating model and wants to see the influence on end products like NPV
- Estimating additional running time in coupling is not a ready-made recipe
- Tuning the well deliverability could yield better ultimate recovery
- Not every field needs coupling especially when the surface network has a lot of spare capacity or could be reduced to simple branch after critical year
- When evaluating the need for coupling software look at:
  - Network complexity and ability to reduce it by time
  - Critical production (gas and liquids)
  - Years when well rates are capped by wellhead pressure limits

Thank You

References

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