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Completion Engineers: Decision Making with Cross Discipline Integration

By Dan Gibson
From add energy
a global consulting engineering firm
www.addenergy.no

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About the Author

Dan Gibson is a Senior Completions & Well Integrity engineer with over 35 years of experience. He has worked in Facilities, Production, and finally Completion Engineering. Dan and his wife have lived across the USA (Anchorage, Denver, Houston) and around the world in Gabon, Congo, Egypt, Scotland, and Australia. He understands both low cost, tight margin and high value, high cost well environments and how to be successful in both.

Dan was an expert witness in the Deepwater Horizon/Macondo trial. He has authored or co-authored a number of papers ranging from polymer flood management to ice mechanics and most recently an innovative ICD system. He is one of the most active members of SPE Connect where SPE members can readily contact him and the entire SPE community with questions.

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Agenda

- Show a robust completion decision process
  - It is relatively quick
  - Powerful support for decision making
- Examine the Completion Decision Process for an Example Well
  - Introduce an effective method to work with other discipline drivers to select the best completion
- Look at a typical offshore problem, injection conformance, and see how the process can help
  - Evaluation of a new technology (ICD)

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Evaluation Method - 1

This decision process is based on Decision Matrix Analysis which is one of the simplest forms of Multiple Criteria Decision Analysis

- It provides a robust way to compare alternatives
- The key evaluation criteria, and their importance, are clear

Key Evaluation Fa			hoice 2	Choice 3
Safety				
Gas Mileage				
Seats				
Cup Holders				

eeds to determine
portant for this

takeholders in the
ese factors is critical

What are some of the key factors you might think about when buying a car?

Multiple Criteria Decision Analysis (MCDA) 5

Methodology

Decision Matrix Analysis is the simplest form of Multiple Criteria Decision Analysis (MCDA), also known as Multiple Criteria Decision Aid or Multiple Criteria Decision Management (MCDM). Sophisticated MCDA can involve highly complex modelling of different potential scenarios, using advanced mathematics. A lot of business decision making, however, is based on approximate or subjective data. Where this is the case, Decision Matrix Analysis may be all that's needed.

Methodology

- Decision Matrix Analysis helps you to decide between several options, where you need to take many different factors into account.
- To use the tool, lay out your options as Column Headings in a table. Set up the Rows to show the factors you need to consider. Weight the Evaluation Factors from Most Important (5) to Least Important (1). Force rank each option for each factor using the number of options from Worst (1) to Best (3). No ties are allowed.
- Multiply each score by the weight of the factor, to show its contribution to the overall selection. Finally add up the total scores for each option. The highest scoring option will be the best option.
- If there are a lot of factors to be considered evaluate them all but also look at the 3 or 4 most important to see which Option addresses those factors best.

Evaluation Method -2

Next prioritize the evaluation factors

- Team needs to agree to the ranking
- Different prioritization will result in different outcomes
- How powerful is it to agree on the criteria and their importance

Key Evaluation Factors	Importance 4 is High
Safety	4
Gas Mileage	3
Seats	2
Cup Holders	1

Second - the Team needs to determine the most important factors for this completion

These are Ranked by the Team as a Group which is important when trading off priorities

Evaluation Method -3

Chose the alternatives to be evaluated

- Limit the choices to real options for the problem

Key Evaluation Factors	Importance 4 is High	Compact Car	Pickup Truck	Minivan
Safety	4			
Gas Mileage	3			
Seats	2			
Cup Holders	1			

Third - list the options for this evaluation
These are provided by the person running the evaluation

Evaluation Method - 4

Fourth, the Integrated Team evaluates each option

Use of a forced ranking system is required

- High number = Most Important
  - No ties if at all possible
- Should Ignore Importance when scoring to ensure fairness
  - In practice I hide the ranking column and even shift the rows

Key Evaluation Factors	Importance 4 is High	Compact Car	Pickup Truck	Minivan
Safety	Hide the Importance Values	1	3	2
Gas Mileage		3	1	2
Seats		2	1	3
Cup Holders		2	1	3

Evaluation Method - 5

Finally, calculate the weighted scores to determine the best option

- Multiply Importance times Option Score
- Should Ignore Importance when scoring to ensure fairness
  - In practice I hide the ranking column and shift the rows

Key Evaluation Factors	Project Importance 4 is High	Compact Car	Pickup Truck	Minivan
Safety	4 →	1	3	2
Gas Mileage	3 →	3	1	2
Seats	2 →	2	1	3
Cup Holders	1 →	2	1	3
Weighted Ranking		19 = 4*1+3*3+2*2+1*2		

Evaluation Method - 6

Repeat and calculate the weighted scores to determine the best option

- Clear decision process
- Group Participation provides understanding for decision
- Easily documented for the record

Key Evaluation Factors	Project Importance 4 is High	Compact Car	Pickup Truck	Minivan
Safety	4	1	3	2
Gas Mileage	3	3	1	2
Seats	2	2	1	3
Cup Holders	1	2	1	3
Weighted Ranking		19	18	23

Decision Matrix Analysis

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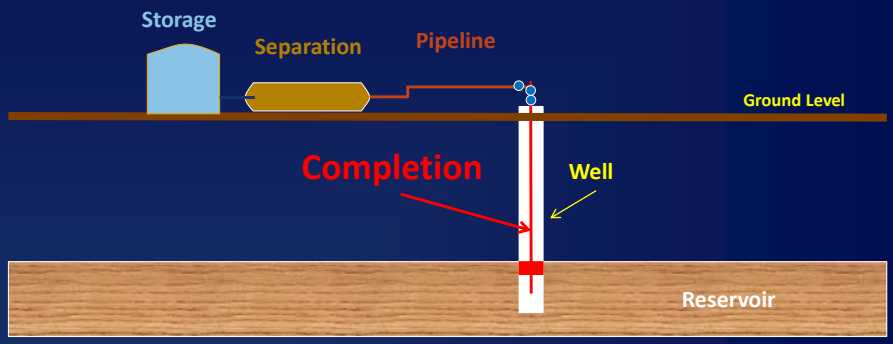
Well Completions Bring the Resource to the Surface for Processing



How many Disciplines are represented in this figure?

- How do completion decisions impact all of these other disciplines?

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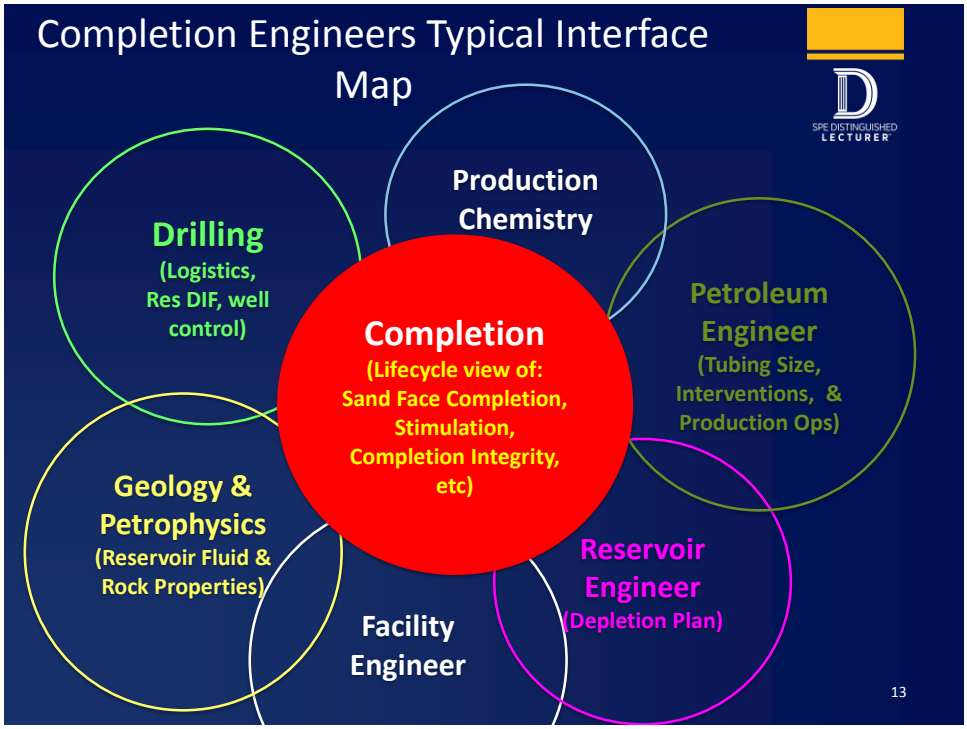
Completion Engineers Typical Interface Map
SPE DISTINGUISHED LECTURER
Drilling
(Logistics, Res DIF, well control)
Production Chemistry
Completion
(Lifecycle view of: Sand Face Completion, Stimulation, Completion Integrity, etc)
Petroleum Engineer
(Tubing Size, Interventions, & Production Ops)
Geology & Petrophysics
(Reservoir Fluid & Rock Properties)
Facility Engineer
Reservoir Engineer
(Depletion Plan)
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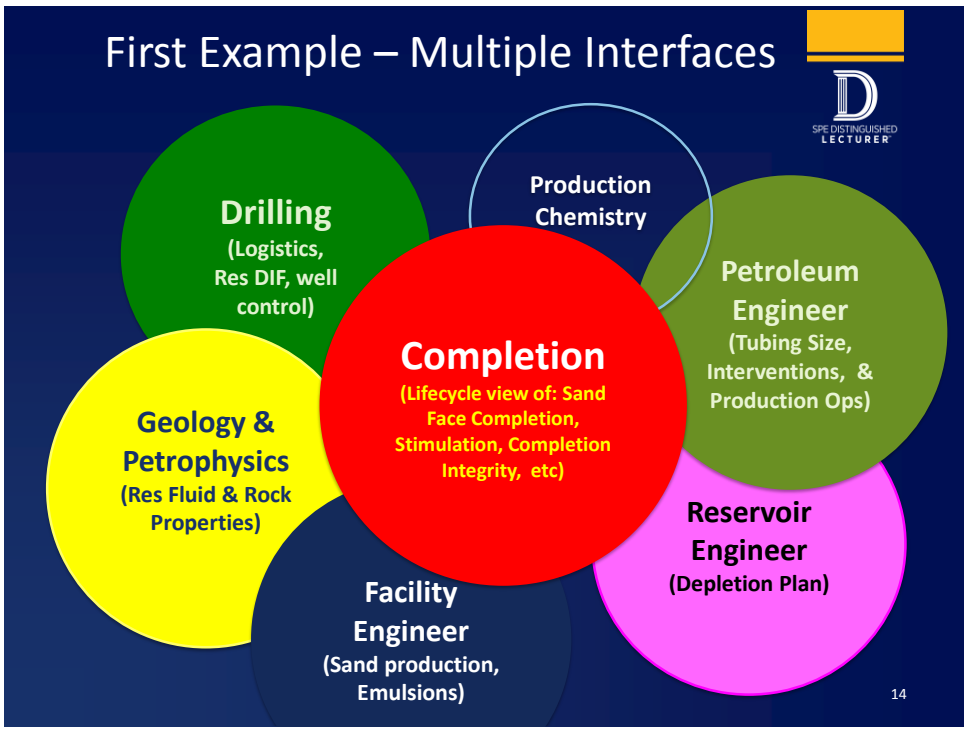
First Example – Multiple Interfaces
SPE DISTINGUISHED LECTURER
Drilling
(Logistics, Res DIF, well control)
Production Chemistry
Completion
(Lifecycle view of: Sand Face Completion, Stimulation, Completion Integrity, etc)
Petroleum Engineer
(Tubing Size, Interventions, & Production Ops)
Geology & Petrophysics
(Res Fluid & Rock Properties)
Facility Engineer
(Sand production, Emulsions)
Reservoir Engineer
(Depletion Plan)
14

Completion Selection Example

1. New Discovery, 50 ft net pay, Poor Perm
2. Pay is in two sands, thick 30 ft shale between
3. Reserves ~5 mmBO in offshore well
4. 75% of Reserves in the bottom sand with bottom water production risk (strong aquifer)
5. PI is 0.5 BOPD/psi without any stimulation
6. Weak sand with 1000 psi drawdown limit

What Kind of Sand Face Completion is Required?

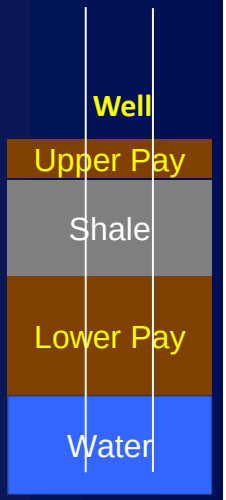

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Image: pet-oilblogspot.com

Calculate Well Life

Do some quick math and see how long it will take to get the oil out;

5mmBO / (0.5 BOPD/psi * 1000 psi) = 27 years!

- PI = 0.5 BOPD/psi
- Sand Strength Drawdown limit = 1000 psi

As Completion Engineers we need to find the right completion that will **improve the value by getting the oil out faster**

How?

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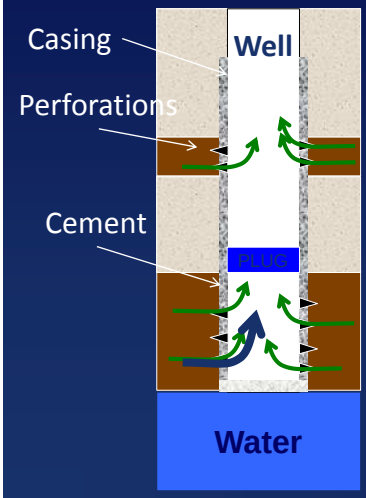
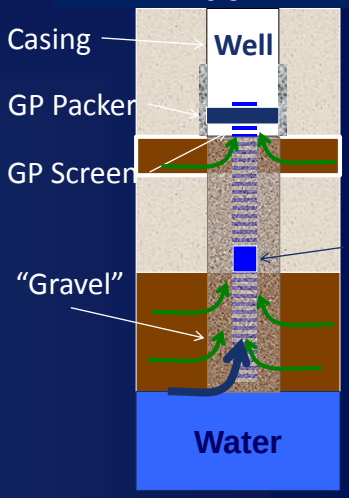
Completion Options – 1

Vertical Cased & Perforated



Vertical Gravel Pack



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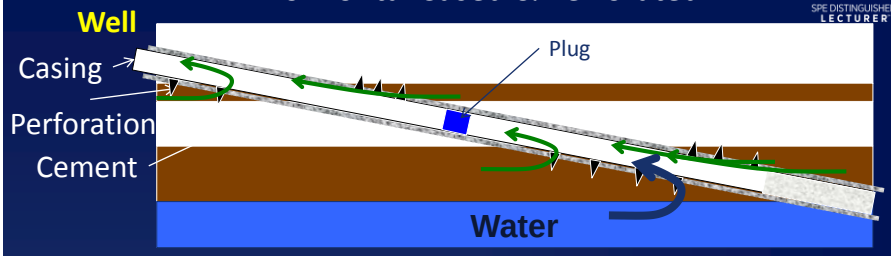
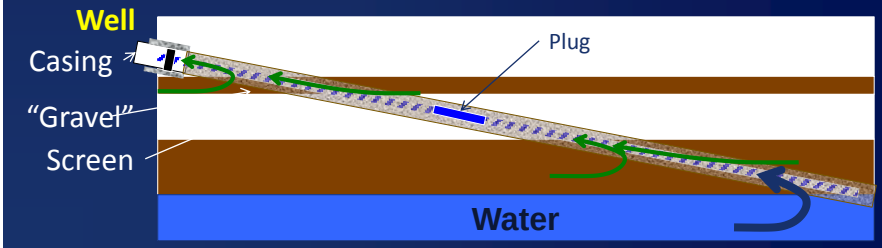
Completion Options – 2

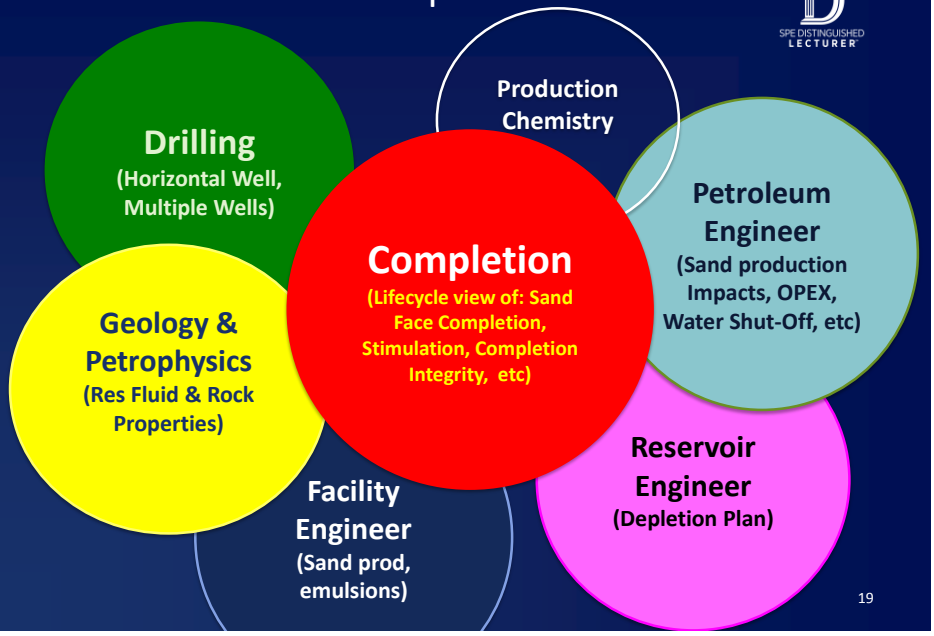
Horizontal Cased & Perforated



Horizontal Gravel Pack



How Can the Team Evaluate these Various Options?



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Evaluation Method - Factors

Each Completion Type will meet the Well requirements slightly differently

- It is now up to the CE to lead the discussion with the integrated team to determine the best type of completion for this well
  - Lets look at the **Decision Matrix Analysis**

Key Evaluation Factors				
Sand Prevention				
Production Rate				
Water Shut-Off/Reserves				
Contractor Capability				

First the Team needs to determine what factors are important for this completion

Getting the other stakeholders in the room to discuss these factors is critical

Decision Matrix Analysis

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Evaluation Method - Factors

Getting Folks to Agree on a Priority Ranking is critical to selecting the right completion to deliver your most important evaluation factors i.e. business value drivers

Note: This is an example only a real evaluation may have 20 evaluation factors considered but only 5- 8 key evaluation factors in my experience

Key Evaluation Factors	Project Importance 4 is High
Sand Prevention	4
Production Rate	3
Water Shut-Off/Reserves	2
Contractor Capability	1

Second the Team needs to determine the most important factors for this completion

These are Ranked by the Team as a Group which is important when trading off priorities

Evaluation Method - Options

Then Compare the Completion Options against the important factors

- This is an example only. A real evaluation may have many different completion options.
  - Note: OHGP = Open Hole Gravel Pack , C&P = Cased & Perfed

Key Evaluation Factors	Project Importance 4 is High	Vertical C&P	Vertical OHGP	Horizontal C&P	Horizontal OHGP
Sand Prevention	4				
Production Rate	3				
Water Shut-Off/Reserves	2				
Contractor Capability	1				

Third the Completion Engineer needs to determine the completion choices for this well

Evaluation Method - Evaluation

Fourth, the Integrated Team evaluates each completion option

- Use of a forced ranking system is required
  - High number = Most Important
- Should Ignore 'Importance' when scoring to ensure fairness

Key Evaluation Factors	Project Importance 4 is High	Vertical C&P	Vertical OHGP	Horizontal C&P	Horizontal OHGP
Sand Prevention	*Ignore (hide) Importance when Scoring*	1	3	2	4
Production Rate		1	2	3	4
Water Shut-Off/Reserves		4	3	2	1
Contractor Capability		4	2	3	1

Decision Matrix Analysis 23

Evaluation Method - Calculation

Finally, calculate the 'score' for each of the options using the Ranking of the Important Factors

- Each completion selection is a compromise against the Key Factors

Key Evaluation Factors	Project Importance 4 is High	Vertical C&P	Vertical OHGP	Horizontal C&P	Horizontal OHGP
Sand Prevention	4 →	1	3	2	4
Production Rate	3 →	1	2	3	4
Water Shut-Off/Reserves	2 →	4	3	2	1
Contractor Capability	1 →	4	2	3	1
Weighted Ranking		19 =4*1+3*1+2*4+1*4			

Decision Matrix Analysis 24

Evaluation Method - Result

- The 'best' option is a Horizontal Open Hole Gravel Pack
  - Vertical C&P clearly not the best option
- **Team** participation means that everyone has buy-in
- And the risks that jeopardize success (Contractor Capability, Water Shut-Off) are well identified and have to be managed

Key Evaluation Factors	Project Importance 4 is High	Vertical C&P	Vertical OHGP	Horizontal C&P	Horizontal OHGP
Sand Prevention	4	1	3	2	4
Production Rate	3	1	2	3	4
Water Shut-Off/Reserves	2	4	3	2	1
Contractor Capability	1	4	2	3	1
Weighted Ranking		19	26	24	31

Calculate Well Life

Of course, the calculation of the time to produce the reserves for each option matches the evaluation

Vert C&P = 5mmBO / (0.5 BOPD/psi * 1000 psi) = 27 years
Vert OHGP = 5mmBO/ (0.5 BOPD/psi * 2000 psi) = ~14 years
Horiz C&P = 5mmBO / (2 BOPD/psi * 500 psi) = ~14 years
Horiz OHGP = 5mmBO / (2 BOPD/psi * 2000 psi) = ~4 years

An economic evaluation will prove that the higher costs and higher complexity of the Horiz OHGP is justified

- **Economics are an outcome of the decision made – not an input**

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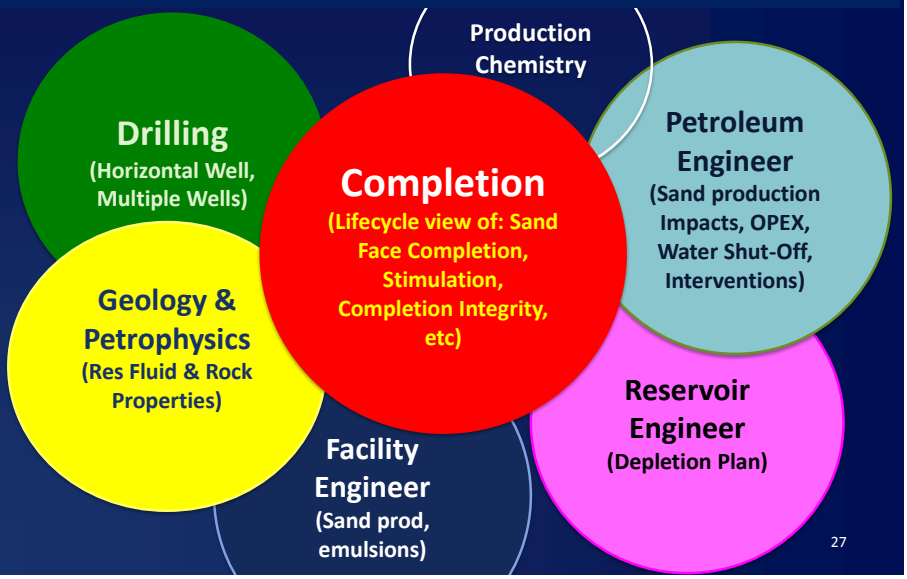
Use of a rigorous process, leads to the best completion that addresses each disciplines business drivers



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Lets Look at another Real Example

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Seismic shows two offshore fault blocks are not being drained

But the blocks are isolated from the aquifer and need water injection to maintain reservoir pressure and provide sweep

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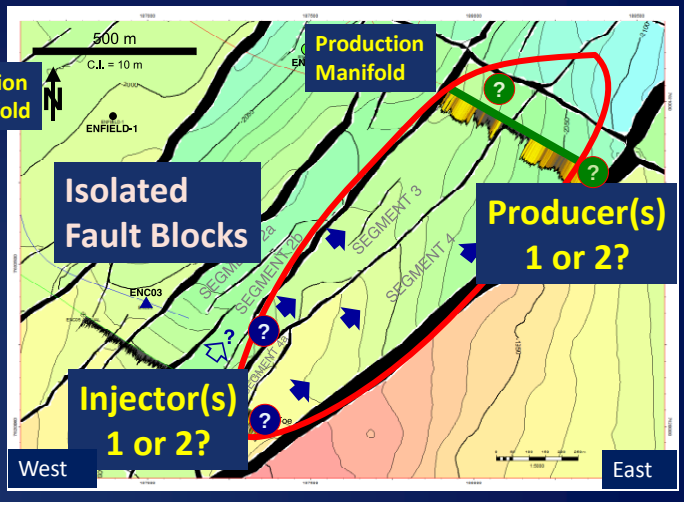
Offshore, Subsea, Example

Two Fault Blocks are isolated and undeveloped

- Most of Reserves in East fault block (right hand block)
- Unconsolidated, high perm (+1Darcy), reservoir sands
- Plan on 20,000 BWIPD with majority to East fault block (PWRI)



Ref: SPE 136539

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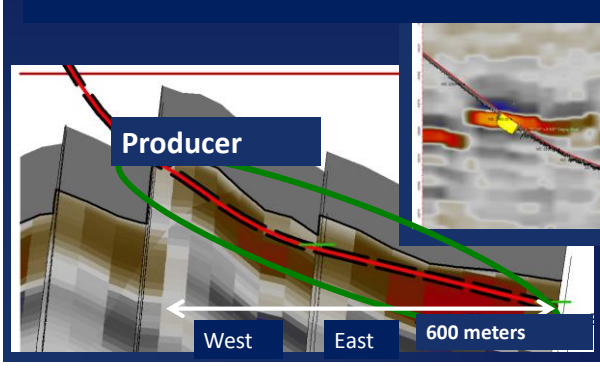
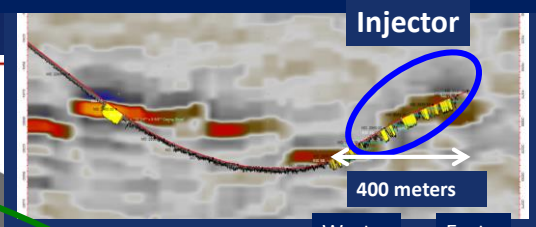
Horizontal Wells a Challenge

- Vertical Wells would be give the best injection and reserves but very high cost and delays to install new subsea tiebacks (production & injection subsea pipelines)
- Drilling can reach both injector and producer locations from existing manifolds but with difficult well paths (see figures)
- How do we best *complete* this complex injector?





Ref: SPE 136539

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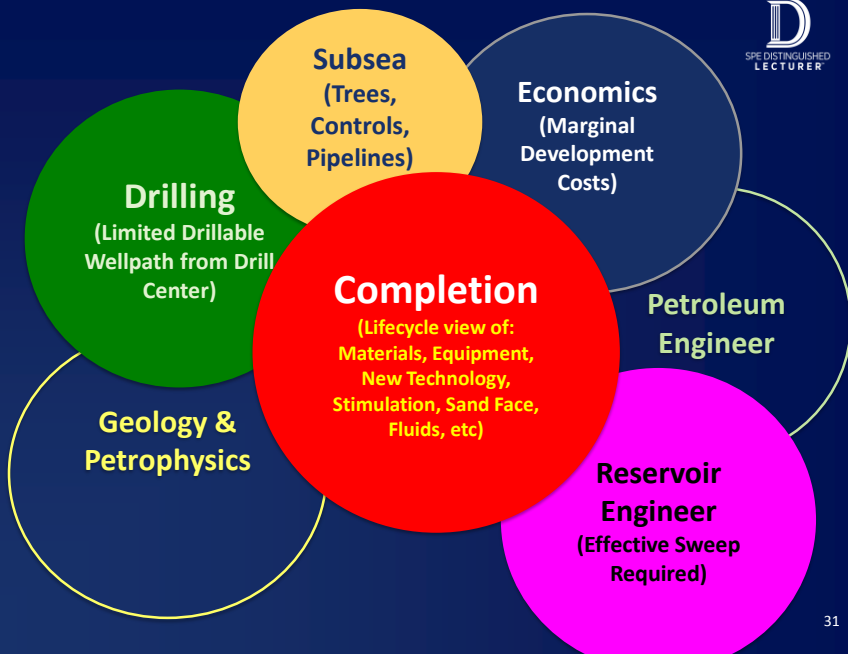
Not a Simple Decision with all these Factors



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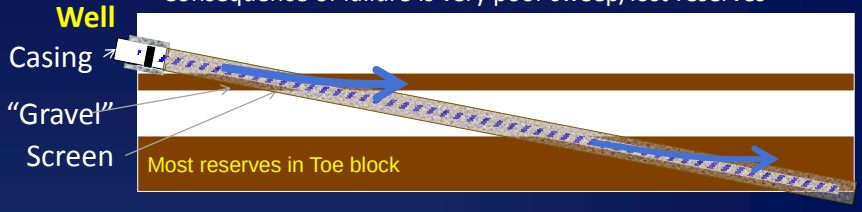
Injector Options

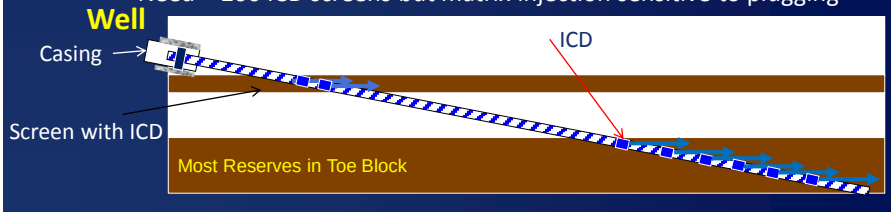
Horizontal OHGP (Like Producers)

- Difficult to design to allocate 20,000 BWIPD into two zones
- Consequence of failure is very poor sweep/lost reserves



Horizontal Injection Control Device (ICD)

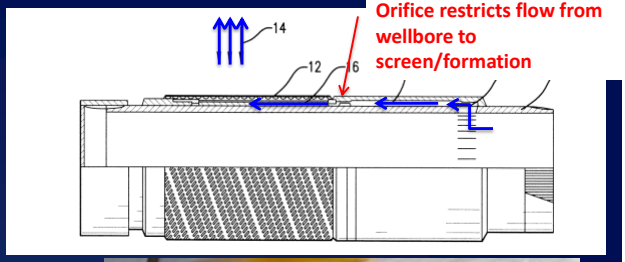
- Each ICD only ~50-100 BWIPD
- Need ~ 200 ICD screens but matrix injection sensitive to plugging

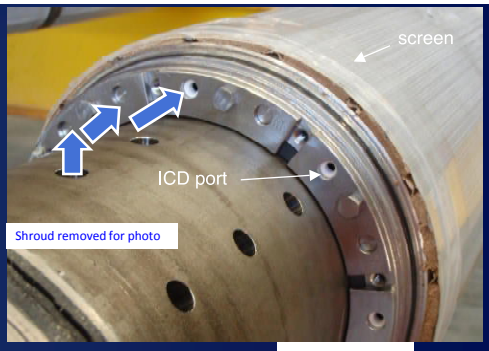


New ICD Design to Control Flow

Inflow is modified by changing the number of open ports at each screen

- Many different ways have been patented.
- This is just one way for this project.





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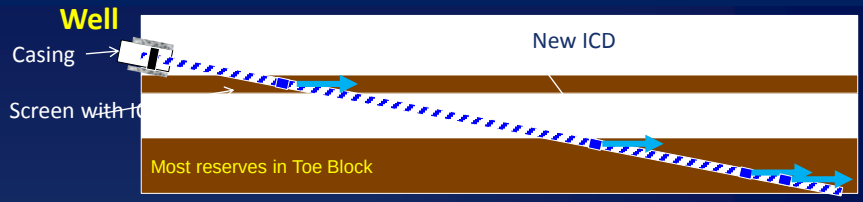
New Technology ICD Solution

Develop **'Frac'** Rate Injection Control Device (ICD)

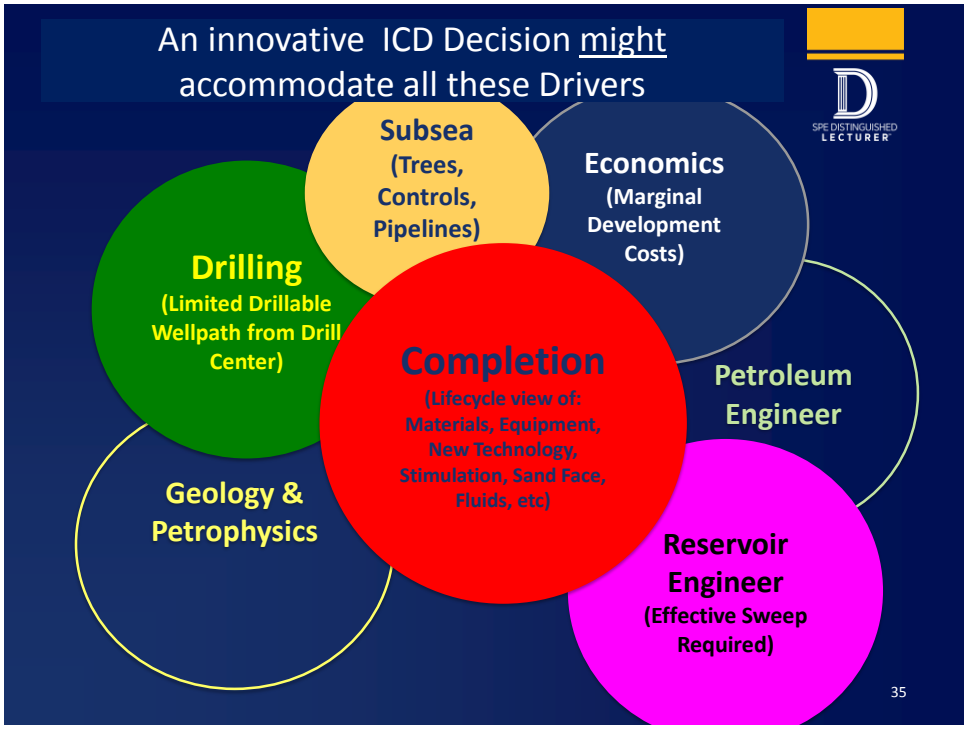
- Can a contractor develop an ICD Screen w/over 5000 BWIPD of capacity?
- Would only need ~ 5 ICD screens and have more control on injection



Never been done before and doesn't currently exist!

- Can Contractor Develop the new design in time for the project?

How do you evaluate this option compared to the options?



Injector Evaluation – Factors - 1

The Team got together and discussed all of the factors and which were the most important

These Discussions helped all the stakeholders to understand the tradeoffs with each completion design

Note: Example only

Key Evaluation Factors	Project Importance 5 is High				
		What are the key factors?			
Weighted Ranking					

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Injector Evaluation – Factors - 2

In a real analysis there may be many more factors.
List them all, and then rank them all.
In the end only the most important factors – top 5-8 really matter.

Key Evaluation Factors	Project Importance 5 is High				
Zonal Water Injection (Reserves)					
Cost					
Schedule					
Sand Control					
Installation Sensitivity (Two Fault Blocks)					
Weighted Ranking					

Injector Evaluation - Factors

In the end only the most important factors – top 5-8 really matter.
Re-rank the top factors after the team agrees which ones will be used for the analysis

Key Evaluation Factors	Project Importance 5 is High				
Zonal Water Injection (Reserves)	5				
Cost	4				
Schedule	3				
Sand Control	2				
Installation Sensitivity (Two Fault Blocks)	1				
Weighted Ranking					

Injector Evaluation - Factors

The Completion engineer provides the options.

Usually these have been worked up before and there may be reservoir model evaluations, cost estimates, and schedules for each of these options to consider.

Key Evaluation Factors	Project Importance 5 is High	Two Vertical OHGP	One Hoizontal OHGP	Horiz Conv'l ICD	New Frac ICD
Zonal Water Injection (Reserves)	Hide the factors and Shuffle the Rows in an Actual Evaluation				
Cost					
Schedule					
Sand Control					
Installation Sens. (Two Fault Blocks)					
Weighted Ranking					

Injector Evaluation - Factors

Once they have been discussed the calculate the scores and determine if there is a 'best' option

In this case three options appear similar but one has high costs and slow delivery schedule.

Key Evaluation Factors	Project Importance 5 is High	Two Vertical OHGP	One Horizontal OHGP	Horiz Conv'l ICD	New Frac ICD
Zonal Water Injection (Reserves)	5	4	1	2	3
Cost	4	1	2	3	4
Schedule	3	1	4	3	2
Sand Control	2	4	1	3	2
Installation Sens. (Across Two Fault Blocks)	1	4	1	3	2
Weighted Ranking		39	28	40	43

Injector Evaluation - Factors

If, after discussion, one option should not be considered then drop it and rescore ----based on the prior scores

i.e. 4 => 3, 3=>2, etc

Do not change the numbers or allow the integrity of the original evaluation to be lost or modified

Key Evaluation Factors	Project Importance 5 is High	Two Vertical OHGP	One Horizontal OHGP	Horiz Conv'l ICD	New Frac ICD
Zonal Water Injection (Reserves)	5			2	3
Cost	4			2	3
Schedule				2	1
Sand Control			1	3	2
Installation Sens. (Two Fault Blocks)			1	3	2
Weighted Ranking			21	33	36

Be Flexible and Adapt as Necessary
But maintain integrity in evaluation--do not change the numbers.

Injector Evaluation - Factors

The best one required new technology but had the most upside on reserves and rates

- This had to be worked harder to see if it was possible'

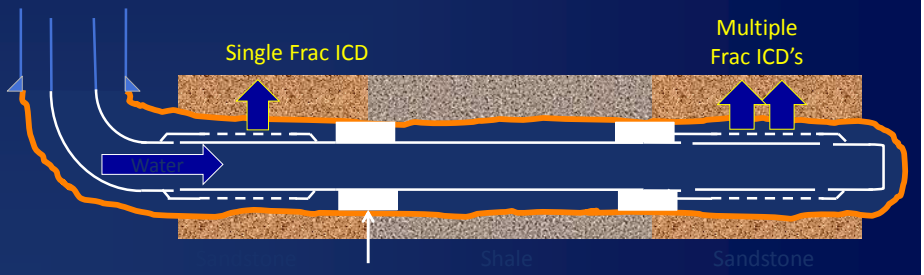
The other, lower option, used on conventional technology with more sensitivity to water quality and damage reserves

Key Evaluation Factors	Project Importance 4 is High	Two Vertical OHGP	One Hoizontal OHGP	Horiz Conv'l ICD	New Frac ICD
Zonal Water Injection (Reserves)	5		1	2	3
Cost	4		1	2	3
Schedule	3		3	2	1
Sand Control	2		1	3	2
Installation (Two Fault Blocks)	1		1	3	2
Weighted Ranking			21	33	36

New Sand Face Injector Design

The Completion Team and Contractor developed a **new** Frac-Thru ICD Injector well design to meet everyone's requirements

- Sufficient water injection in both zones (RE's)
- Could be installed in complex well path (DE/CE's)
- Use existing Subsea Injection & Producer manifolds (SSE's)



Ref: SPE 136539

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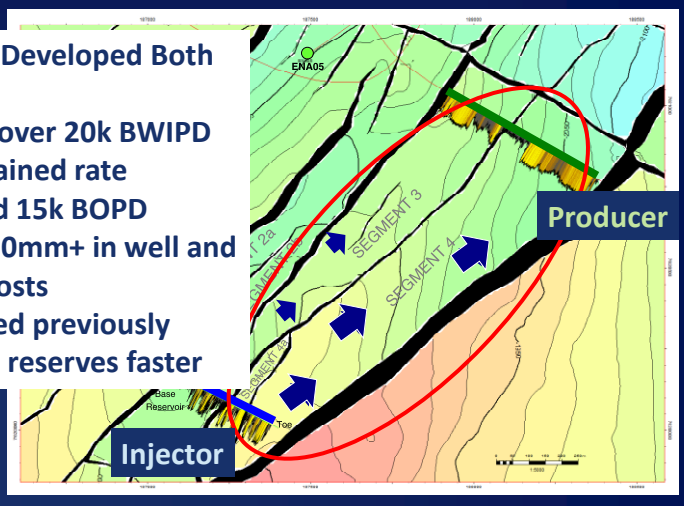
Offshore, Subsea, Example

Completion Innovation effectively met needs of Reservoir sweep, Subsea infrastructure, and Drilling well paths to deliver a successful project quickly

Successfully Developed Both Fault Blocks

- ✓ **Injected over 20k BWIPD at a sustained rate**
- ✓ **Produced 15k BOPD**
- ✓ **Saved $80mm+ in well and subsea costs**
- ✓ **Developed previously stranded reserves faster**



Ref: SPE 136539

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Conclusions

- Completion Engineers help integrate various business drivers from each discipline to maximize value
  - Completion Engineers manage the decision process during completion selection
  - Other Disciplines can use this process to help their decision making for critical choices
- Engagement of stakeholders a key function of this process
  - Discussions and buy-in to the decision the real value
- Interplay and Assessment of the various factors vary by context of the field/well
- A review of some examples show how the process really works to improve decision making and deliver business value

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