Navigating the Changing World of Reserves and Resources in the Context of the PRMS

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part way

Unconventional Field – Prospective Resources ^ to Reserves per PRMS 2018

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Some material is based on slides provided by Creties Jenkins

The presentation material is the view of the collaborators in general, but not necessarily in detail, and not necessarily the view of their employer or SPE. The material is provided to promote discussion amongst the workshop attendees on better understanding of PRMS.

Topics

- Key Points
- “Full Project” vs “Ultimate Project(s)” area
- Overview of Process
- ED 1: PRs, Pg, Pd
- ED 2: Result of Discovery Test in Pod A
- ED 3: Results of TUD Process
- Questions!

Key Points

Key Points (1/3)

(1) Same as for Conventional accumulation PLUS

(2) Technology under Development (TUD) process ***for the Project*** likely to be required for Unconventionals

(Note: PRMS 2.4 Unconventionals does not mention this, neither does AG22 Ch10 Unconventional Resources Estimation!)

- Reserves must be based on EsT (Established Technology) for the Project
- CRs and PRs can be based on EsT or TUD for the project
- EsT is not the same as SEC Reliable Technology, it is a “subset”

Key Points (2/3)

(3) PRMS 2.4 Unconventionals

- Need for increased spatial sampling density (2.4.0.2)
- Direct technical evidence required for reservoir presence or productivity (2.4.0.3)
- Limited extrapolation from control point (2.4.0.4)
- A successful well test may be required to assign CRs where log and core data and nearby producing analogs have not provided evidence of potential economic viability (2.4.0.4)
- Pilot projects may be needed to define Reserves, which requires further evaluation of technical and commercial viability (2.4.0.4) – this is inadequate - should say Pilot projects may be needed to pass Discovery and/or progress through Discovered Unrecoverable, CRs to define Reserves -> PRMS improvement

Key Points (3/3)

4) Deterministic Incremental Method traditionally used BUT really NOT appropriate to comply with PRMS principles
   - No account uncertainty of outcome for same low, best and high project scope which is critical for understanding well(s) performance
     - Underlying geological and reservoir uncertainty, AND
     - Uncertainty in applicability and hence range of outcome of applied recovery technology (ie TUD) (which is a precursor to learning curve benefits)
     - Use of pilots or field trials; typically, each pilot or field trial relates to a separate investment decision for potential development around the pilot which is a separate <PRMS> project (pod)
       - The success situation of these, may lead to expansion of the area considered for development
   - Inconsistency with PRMS as project moves through PRMS framework
     - Especially use of “concentric rings” P1, P2, P3, C1, C2, C3 to describe maturity
     - Better to define project(s) in terms of pod(s) -> same # of wells -> range of recovery
     - Facilitate investment decisions - suitable for “pilots” and up to “developable” areas

“Full Project” vs “Ultimate Project(s)” area

What is meant by the term “full project”?

Jim Ross (author of Chapter 2, PRMS AG11 Applications Document) has clarified the term “full project” area as follows for unconventional accumulations:

> If a pilot project is planned and budgeted, discovered recoverable quantities from the full project, ***to the extent that the results of a successful pilot test can reasonably be assumed to be applicable in areas away from the specific area that is subject to the pilot test,*** may be classified as Contingent Resources.
>
> - This means there is some latitude in designating a Contingent Resources area using a planned and budgeted pilot project.
>
> - However, this decision should be based on the quality/quantity of the available data, a good understanding of the parameters controlling production, and the distribution of these parameters in the play area

➔ *It is unlikely that a “full project” area initially is the “ultimate project(s) area” -> discovery, step out, appraisal including TUD via pilots typically required*

➔ *Extending an analogy to another area without a positive TUD result from the original area should be avoided.*

Discovery -> CRs based on Planned & Budgeted Pilot(s)

For selected target:

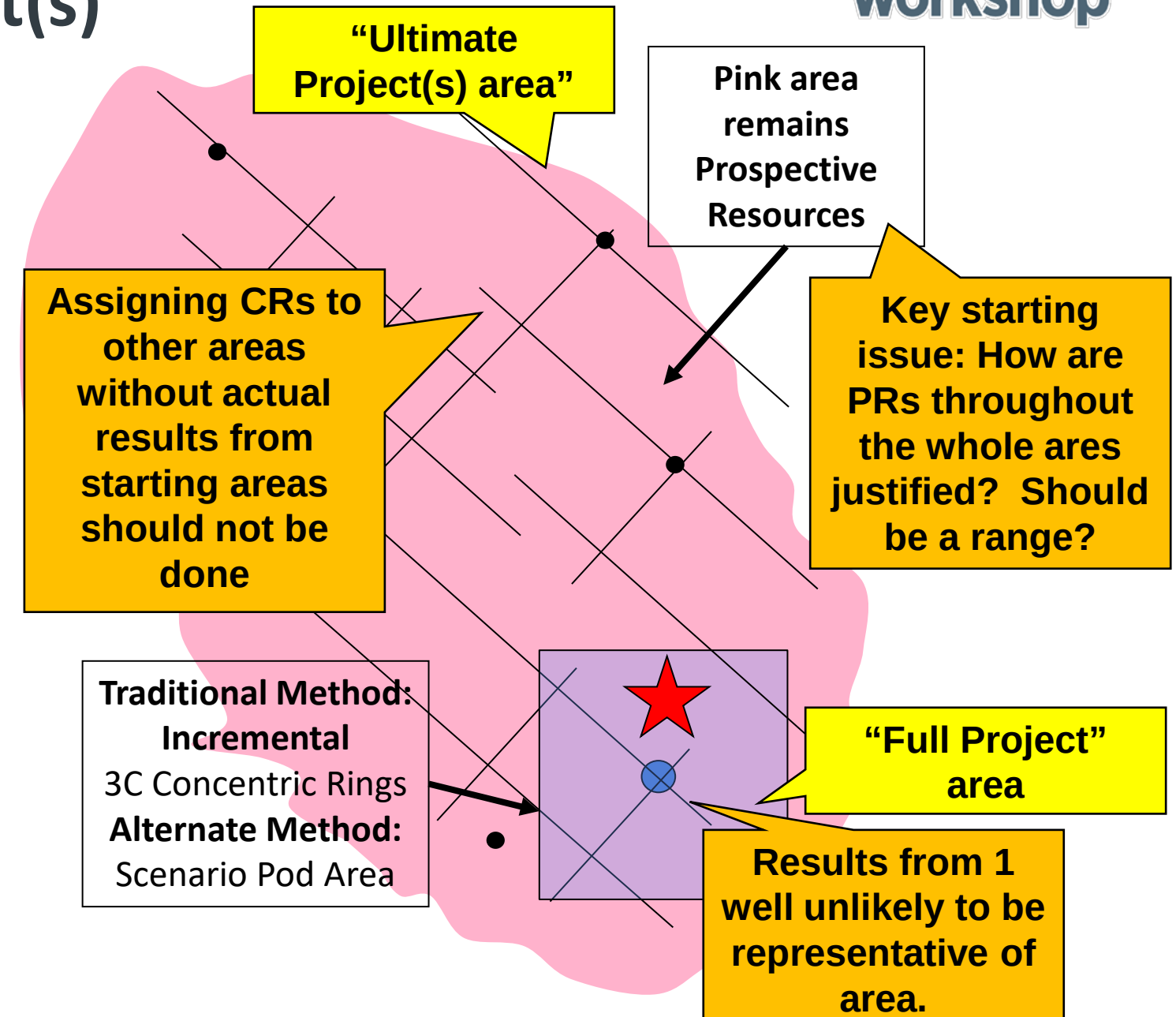
A relatively small "Full Project Area" (ie POD) is assigned given that the 2D seismic and well data surrounding the discovery well (●) are of poor quality

A planned and budgeted pilot project (★) is located within the assigned CRs area:

Traditional Method: Incremental Method: 3C CR area defined number of wells based on the applied recovery technology, concentric rings representing 1C, 2C, and 3C estimates of CRs.

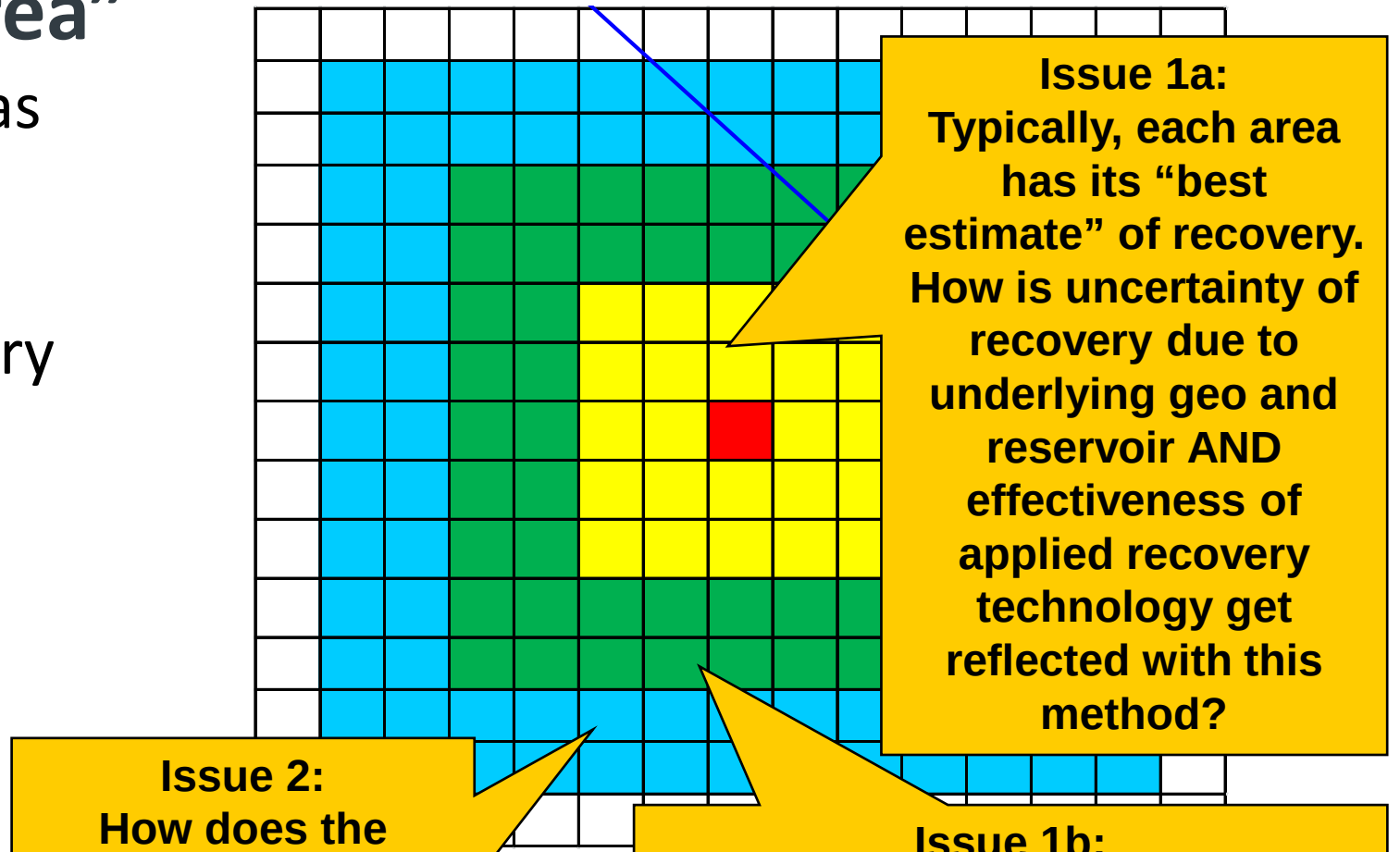
OR

Alternate Method: Scenario Method: Pod Area based on the same number of wells for 1C, 2C, 3C with a range reflecting the underlying geo and reservoir uncertainty AND uncertainty in the effectiveness of the applied recovery technology.



Traditional Method -> Incremental Method – "Full project area"

- The technique is referred to as a deterministic (incremental) method
- The red square is the discovery well
- The 1C area (red + yellow) contains 25 wells
- The 2C area (red + yellow + green) contains 81 wells
- The 3C area (red + yellow + green + blue) contains 169 wells



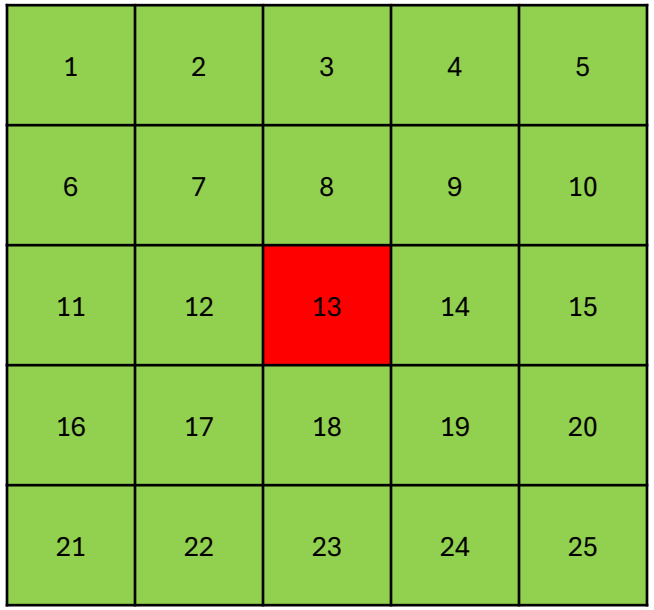
Issue 1a:
Typically, each area has its "best estimate" of recovery. How is uncertainty of recovery due to underlying geo and reservoir AND effectiveness of applied recovery technology get reflected with this method?

Issue 2:
How does the PRMS requirement of 1C->1P, 2C->2P, 3C->3P get followed by this method?

Issue 1b:
How does the PRMS requirement of CRs representing the "full distribution" of CRs get reflected in this method since it typically is a "success case"?

Alternate Method -> Scenario Pod Method – "Full project area" – *addresses all prior issues*!

- Match size of Pod to 2P Reserves using Incremental Method. Ie 5x5 well spacing
- Keep this constant for 1C, 2C and 3C.
- Probabilistically calculate Low, Best and High recovery (ie "full distribution"):
  - Geo and reservoir parameters
  - Recovery Factors assuming no issues with recovery technology AND
  - Effectiveness of recovery technology
- Determine the success portion, and hence Pd(Trun)
- Calculate Pd(Full) by equating risked means
- Adjust Pd(Full) for other commerciality risk factors



Other configurations are possible, such as one ring each of 1C, 2C, and 3C Contingent Resources, depending on the evaluator's confidence in how reservoir parameters change away from the discovery well

Alternate Method -> Scenario Pod Method – "Full project area" – eg:

RF range with "no" recovery tech issues eg from simulation

Recovery tech "effectiveness"

Case	VF_Unconv Pod A PRs potential ED1 -> ~1 pods = 25 wells				Frac Efffectiveness = 0.7-1, TPS 50					
Wells	25	25	25	25						
Area sq km	25	25	25	25	**P90**	**P50**	**P10**	**Mean**	**P1**	
Recovery Factor with "no" issues with applied recovery technology					0.10	0.14	0.20	0.15	**0.27**	**ie maximum recovery with no issues is 27%**
Effectiveness of Recovery Technology					0.70	0.84	1.00	0.84	**1.16**	**ie assumed there is a chance that best achievable across all Pod wells is > 100%**
Average overall recovery factor								**0.12**		

	Full Distribution (Bcf Sales)							Truncated Portion of Full Distribution (ie Success) (Bcf Sales)							
Pg	**P90**	**P50**	**P10**	**Mean**	**Pd $_{full}$*** Mean(Trun) X PTPs/Mean(Full)	**Expected Outcome Pg = 1**	**Expected Outcome for given Pg**	**TPS**	**P90**	**P50**	**P10**	**Mean**	**Pd $_{TPS}$***	**Expected Outcome Pg = 1**	**Expected Outcome for given Pg**
75.0%	29.1	48.6	81.2	52.4	62.8%	32.9	24.7	50	52.5	65.0	93.8	69.5	47.3%	32.9	24.7
Per Well	1.16	1.94	3.25	2.09				Per Well	2.10	2.60	3.75	2.78			

* **Pd only includes consideration of being "economic and meeting defined investment and operating criteria"**
Consideration of other commerciality criteria and commitment will likely reduce these

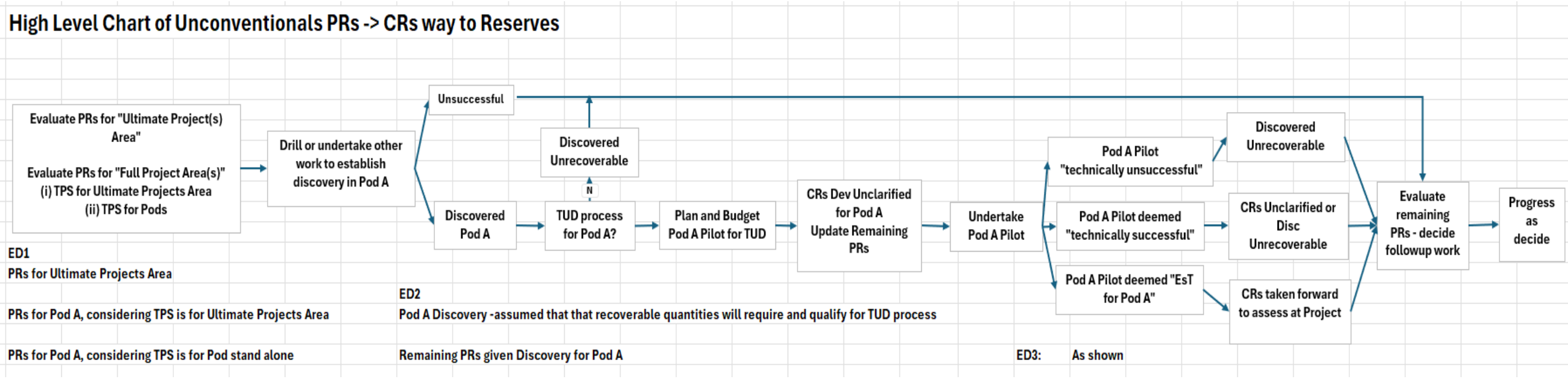
Reporting per PRMS = Full Distribution, accompanying Pg and Pd

Comment: This is reflects range from discovering 1 Pod, recovery effectiveness uncertainty, TPS for incremental pod stand alone
Assumes:
Range of 25 sq kms will be discovered
Uncertainty in recovery technology
TPS of 50 bcf
Ok for reporting per PRMS?

Overview of Process

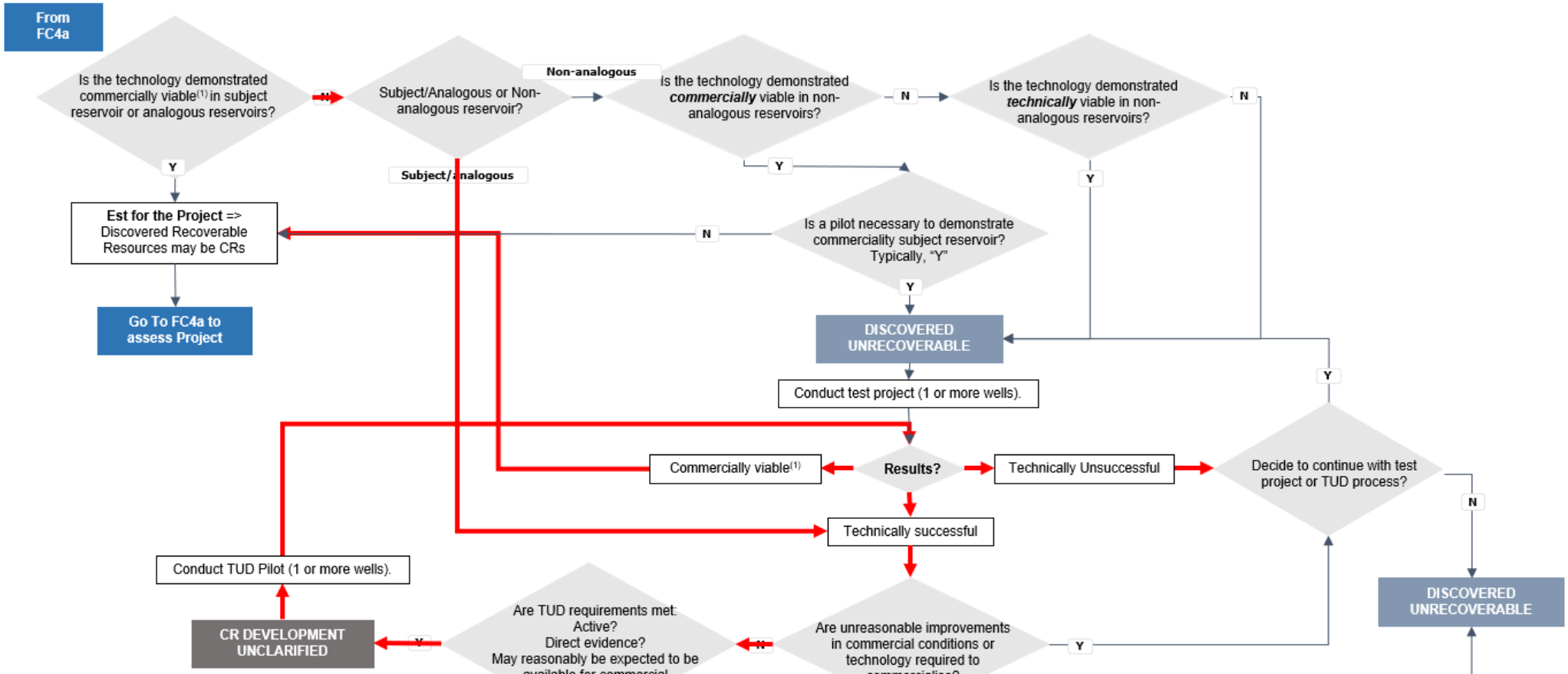
Overview of Process (1/2)

Examining 3 Effective Dates (EDs):



Overview of Process (2/2)

Path through FC4b TUD for the Project:



Note (1): "commercially viable" refers to the recovery process being technically mature enough as part of meeting the "technically mature, feasible development plan" requirement of the Commerciality Criteria (2.1.2.1 A).

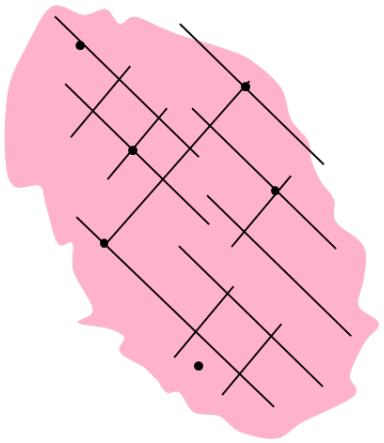
ED 1: PRs, Pg, Pd

ED 1: PRs, Pg, Pd (1/7)

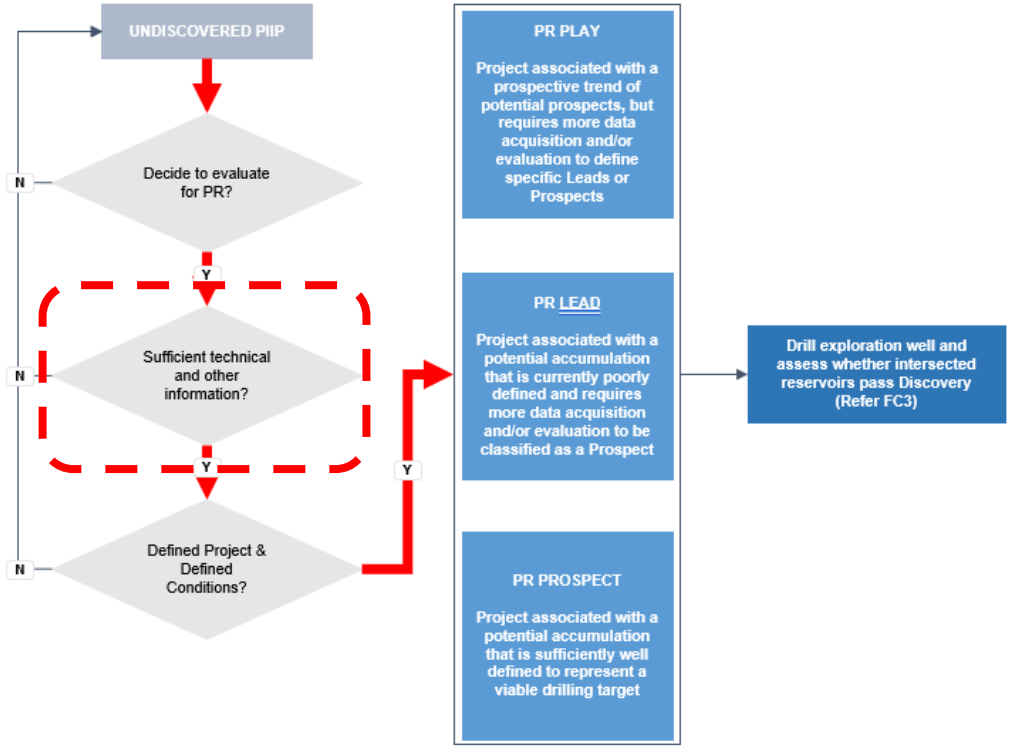
PRs need to be based on sufficient technical and other information to be credible -> if not justified -> PRs should not be recognized until such information is obtained!

- Such information may be available directly from the subject area (eg existing wells and seismic)
- Adjacent areas
- Beware building too much from “nothing”!

Existing (typically) conventional wells and seismic



FC2: Undiscovered PIIP ⇨ Prospective Resources (PRs), Play, Lead, Prospect



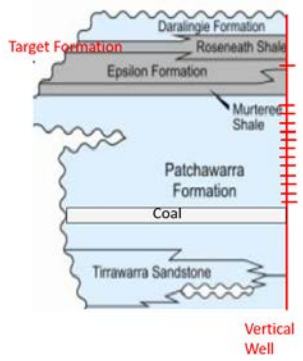
ED 1: PRs, Pg, Pd (2/7)

(1) Pick a **target formation**

(2) Determine "Ultimate Project(s)" area

- Remove non-permit area(s)
- Remove areas Absent, or No productivity

-> Ultimate Project(s) area



(3) Decide **recovery process options**

(4) Pick size and location of ***initial*** "Full Project" areas

-> **Each "full project" area = <PRMS> Project**

(5) **Play Risk** elements - PRMS does not address "play risk", should it?

(6) **Prospect Risk** elements for Unconventional (eg):

Pg = Prs x Pch x Psl x Pd

•Reservoir (Prs)= Presence & Quality

•Charge (Pch) = Maturity and not migration

•Seal (Psl) = Top & bottom seals.

•Deliverability (Pdl) = a combination of frackability (brittleness, elasticity, stress magnitude/principle) and ability to deliver to a surface infrastructure (pore pressure).

(7) Derive **PRs for the Ultimate Projects** area target zone – "full distribution", Pg

(8) Estimate **potentially recoverable quantities from "full project"** areas upon discovery – full distribution, Pg

(9) Determine **Threshold Project Sizes (TPS)**

– Ultimate Projects Area, Full Projects areas (covering "ultimate projects" and "stand alone")

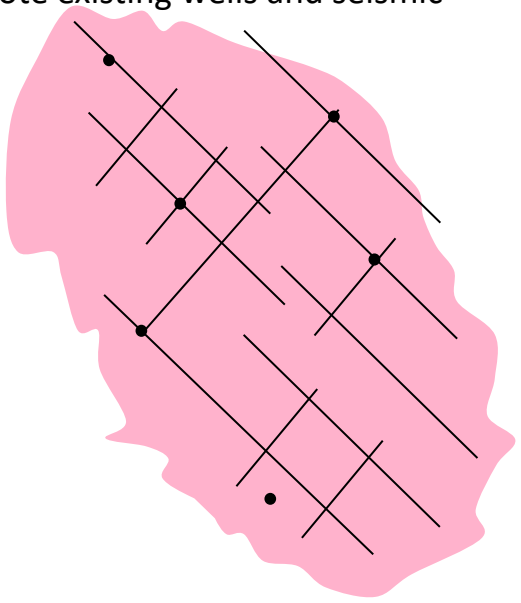
(10) Determined **Pd's for "full distributions"** from Truncated Distributions Pd's (only considering economics in this eg)

(11) **Select recovery technology optio**n to represent PRs and way forward

(12) Pick **location to attempt discovery** – iteration and decision tree analysis likely required

Ultimate Projects Area

- Note existing wells and seismic



Recovery Process options?

Vertical Frac (VF) wells, or
Horizontal Multiple Frac

Pg = 0.75 in this eg

ED 1: PRs, Pg, Pd (3/7)

For HMF Recovery Process “full project areas”, use ”Early Phase Scenario 2” per AG22 Fig 10.19:

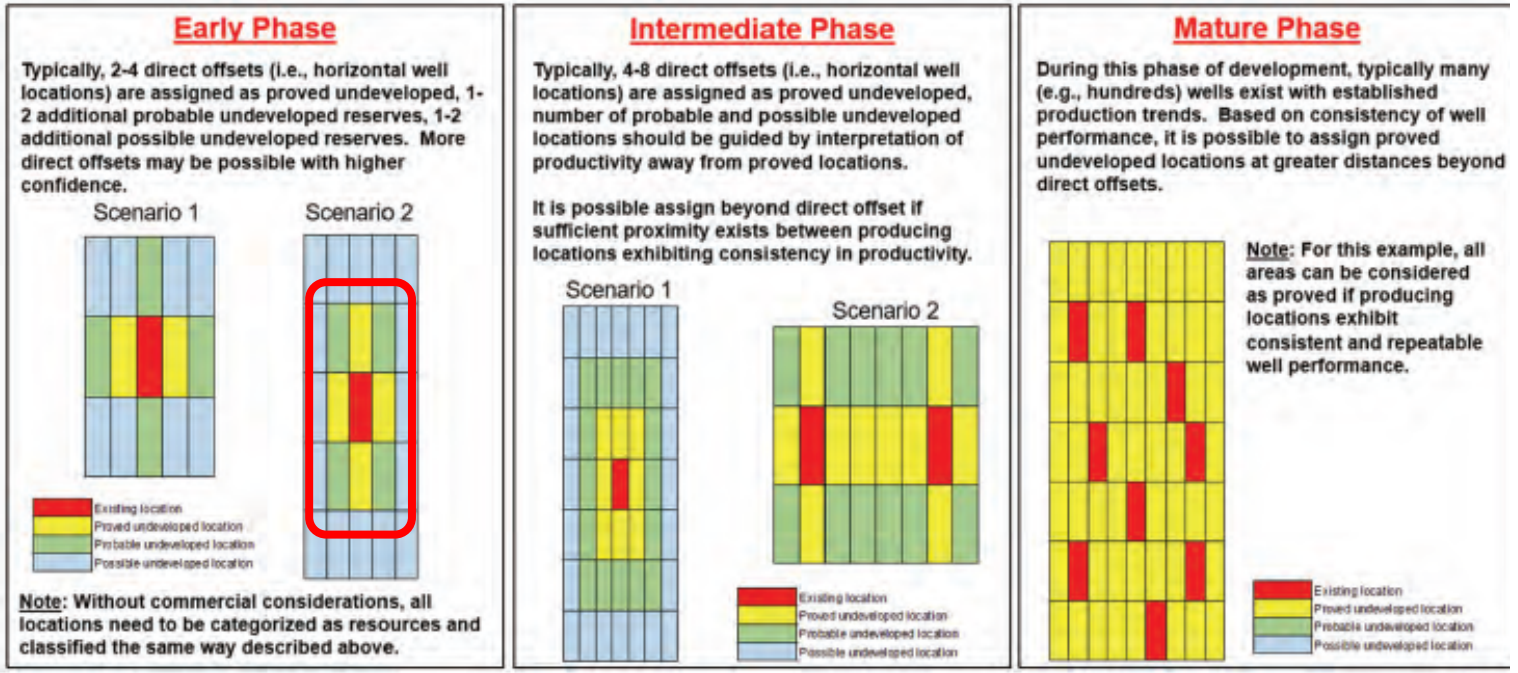
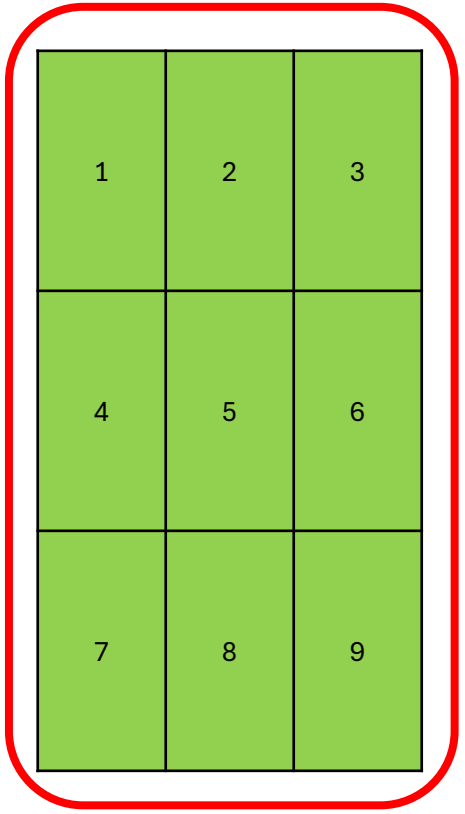


Fig. 10.19—An example illustration of assigning resources to undeveloped locations in the deterministic incremental approach.



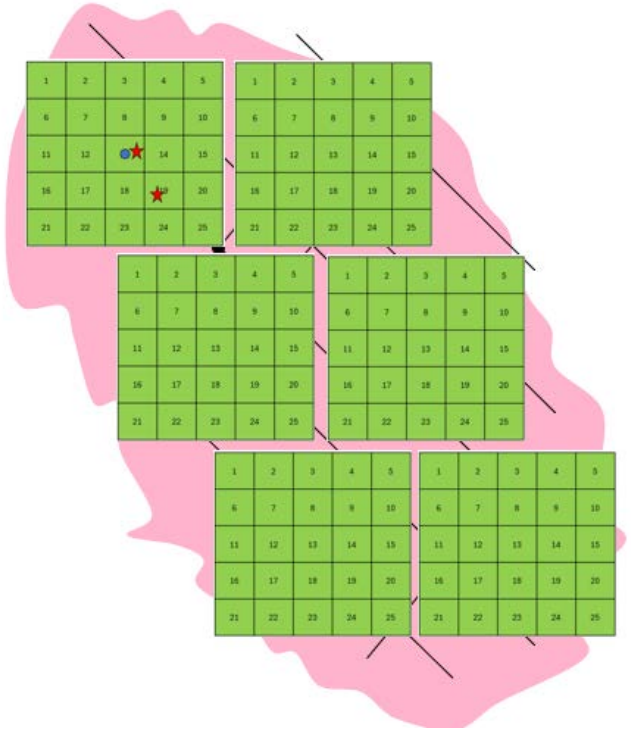
ED 1: PRs, Pg, Pd (4/7)

Recovery Process: Vertical Frac (VF) wells

Ultimate Projects Area:
- 6 x VF “Full Project” are
- 150 well locations
- 150 sq kms
- TPS – 100 Bcf Sales Gas
- Pg = 0.75

RF Range – no issues
P90 – P10: 10% - 20%

Effectiveness of recovery pr
P90 – P10: 0.7 - 1.0



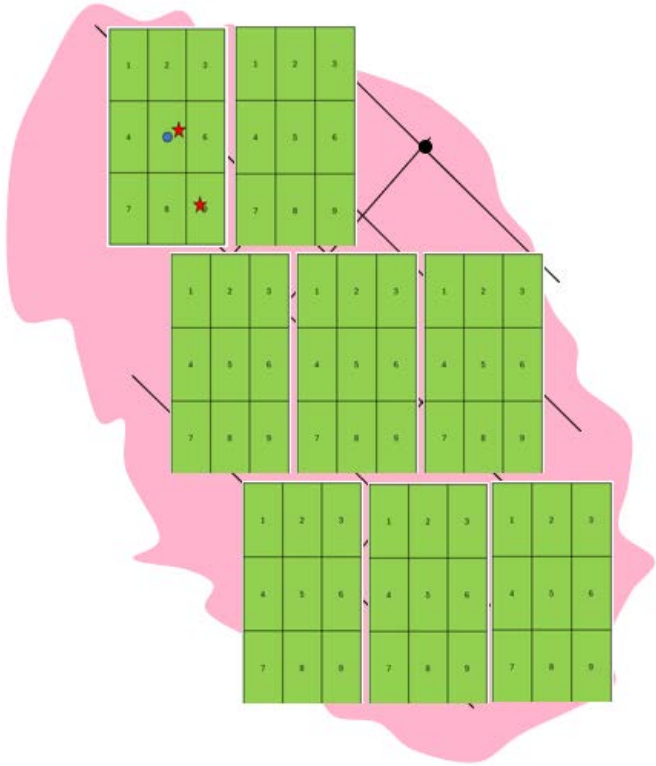
VF “Full Project” areas:
- Based on traditional “2P” area
- 25 vertical frac wells
- 1 km spacing
- Area 25 sq kms
- Will have Low, Best and High estimates
- Stand alone TPS – 50 Bcf Sales Gas

Recovery Process: Horizontal Multiple Frac (HMF) wells

Ultimate Projects Area:
- 8 x HMF “Full Project” areas
- 72 well locations
- 144 sq kms
- TPS – 100 Bcf Sales Gas
- Pg = 0.75

RF Range – no issues
P90 – P10: 30% - 50%

Effectiveness of recovery proce
P90 – P10: 0.3 - 1.0

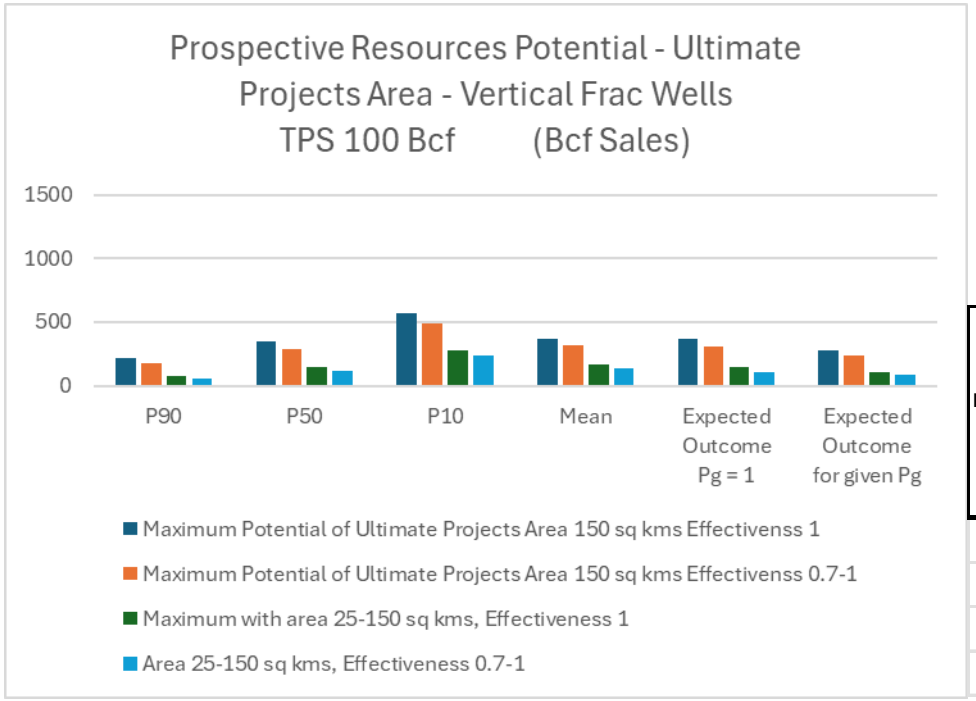


HMF “Full Project” areas:
- Based on “2P” area per AG22 Fig10.19
- 9 horizontal wells with multiple fracs
- 2 km x 1 km = 2 sq kms spacing
- Area 18 sq kms
- Will have Low, Best and High estimates
- Stand alone TPS – 50 Bcf Sales Gas

For Initial “full project area” Pod A
Proposed location for Discovery well
Test Project (not required in this eg)
TUD Pilot (2 wells anticipated)

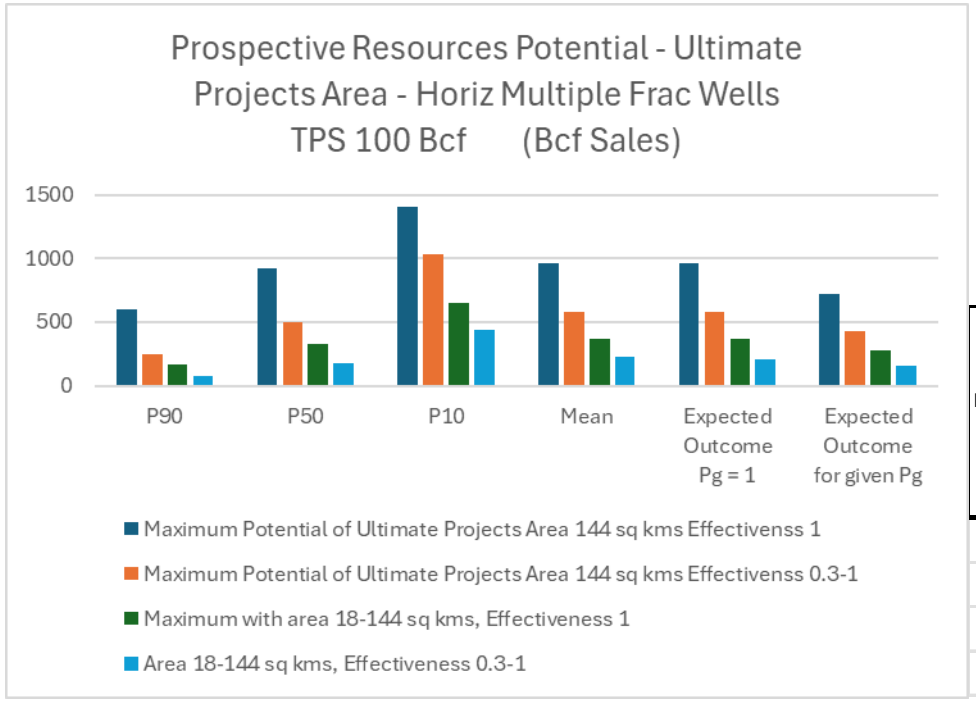
ED 1: PRs, Pg, Pd (5/7) – Ultimate Projects Area

Recovery Process: Vertical Frac (VF) wells



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.99
0.99
0.87
0.80

Recovery Process: Horizontal Multiple Frac (HMF) wells



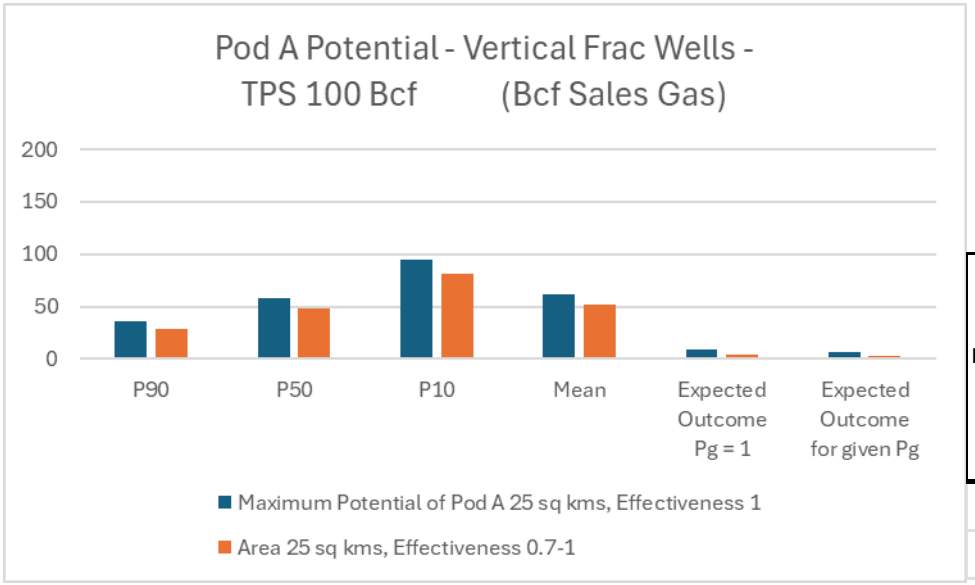
Pd full* Mean(Trun) X PTPS/Mean(Full)
0.99
0.99
0.99
0.93

- Both look good on the face of “Ultimate Projects Area” recoveries alone
- HMF looks better
  - Should do some cashflow analysis and decision evaluation

- **What would be the PRs per PRMS, if any of these?**

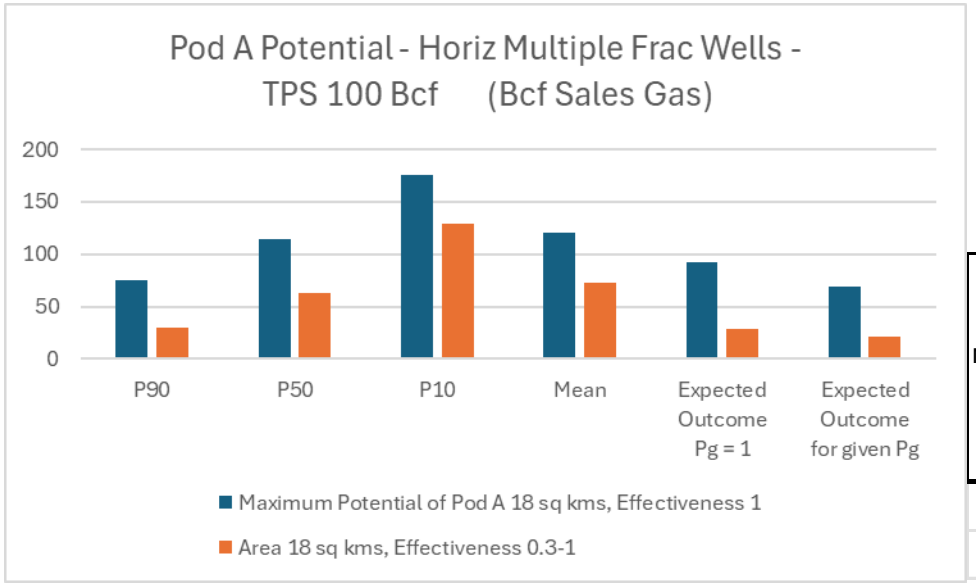
ED 1: PRs, Pg, Pd (6/7) – Pod A TPS 100 Bcf Sales Gas

Recovery Process: Vertical Frac (VF) wells



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.15
0.09

Recovery Process: Horizontal Multiple Frac (HMF) wells



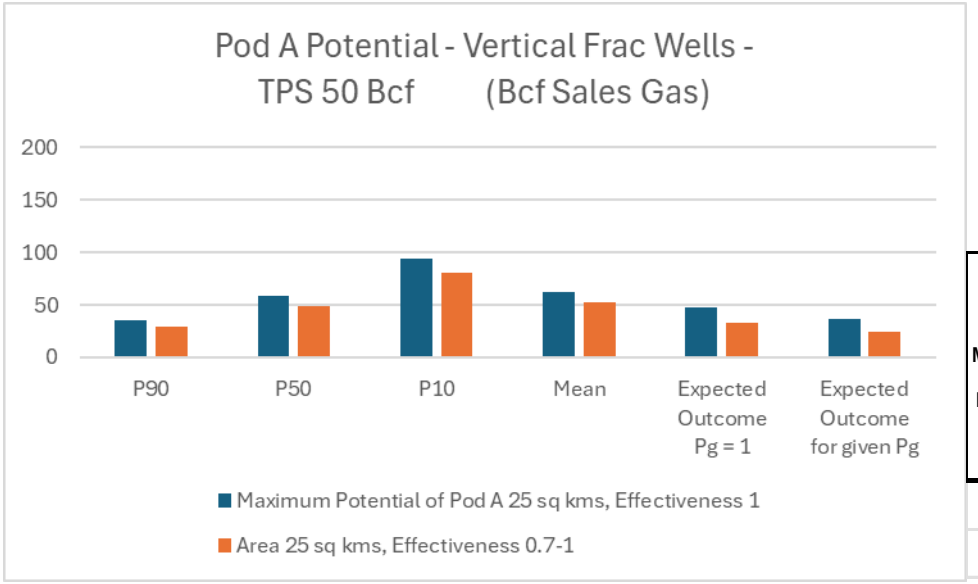
Pd full* Mean(Trun) X PTPS/Mean(Full)
0.76
0.40

- Limited chance of a single pod covering the TPS (100 Bcf) for the Ultimate Projects area
- HMF is better
  - Should do some cashflow analysis and decision evaluation

- **If PRs for Pod A were being reported, which would they be, if any of these?**

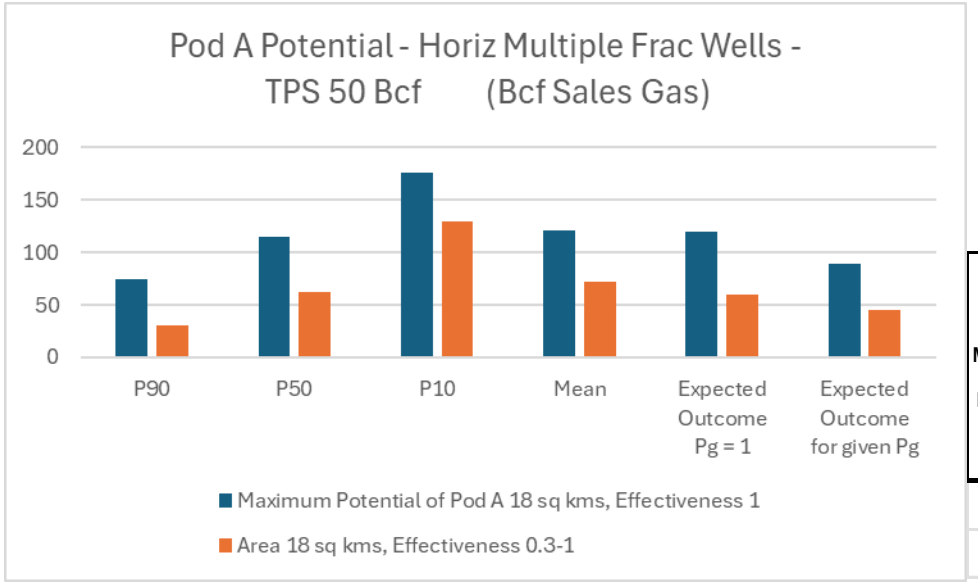
ED 1: PRs, Pg, Pd (7/7) – Pod A TPS 50 Bcf Sales Gas

Recovery Process: Vertical Frac (VF) wells



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.77
0.63

Recovery Process: Horizontal Multiple Frac (HMF) wells



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.99
0.83

- Much better chance of a single pod covering the TPS (50 Bcf) for stand alone
- HMF is better – selected as go forward recovery process basis for estimates
  - Should do some cashflow analysis and decision evaluation

- **If PRs for Pod A were being reported, which would they be, if any of these?**

ED 2: Result of Discovery Test in Pod A

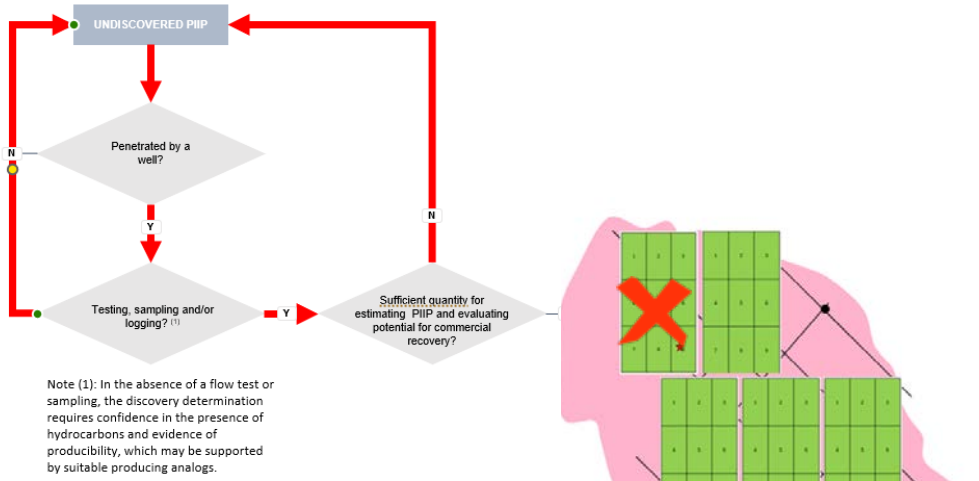
(1) Discovery Test Unsuccessful

(2) Discovery Test Successful BUT reservoir “non-analogous”

(3) Discovery Test Successful and confirms pre-drill technical viability

ED 2: Result of Discovery Test in Pod A (1/4)

FC3: DISCOVERY TEST: Prospect (or Undiscovered PIIP) ⇨ Di

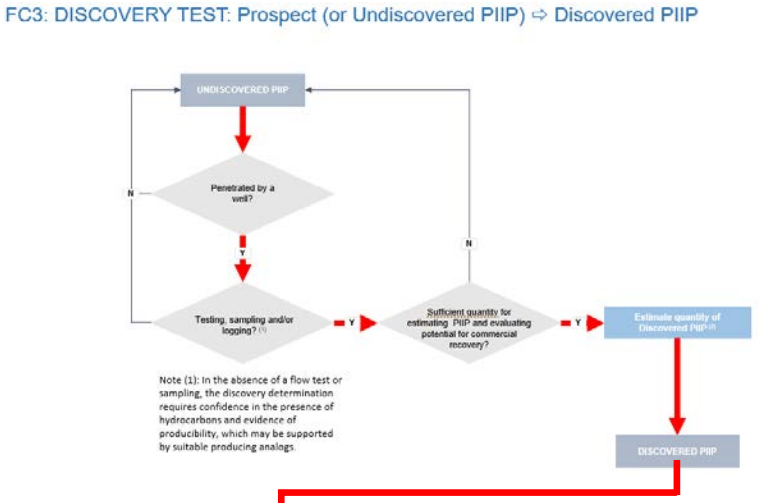


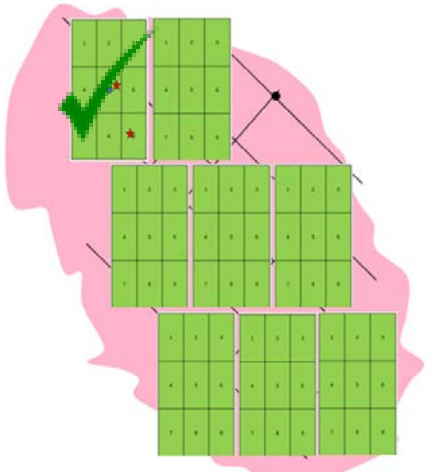
(1) Discovery Test Unsuccessful

- Exclude Pod A from Ultimate Projects area
  - Must be justified if NOT excluded
- Reassess parameters and risking
- Possibly change “full project areas”
- Evaluate remaining PRs, “full project area” potential, Pg, Pd
- Decide go forward plan

ED 2: Result of Discovery Test in Pod A (2/4)

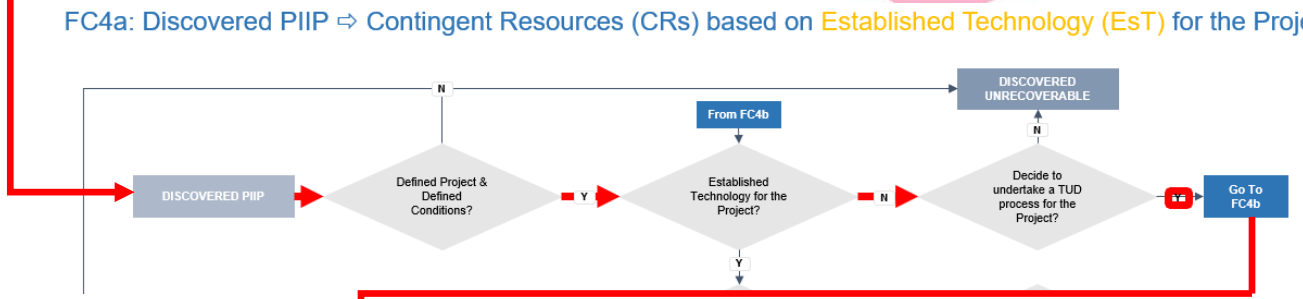
(2) Discovery Test Successful BUT reservoir "non-analogous":

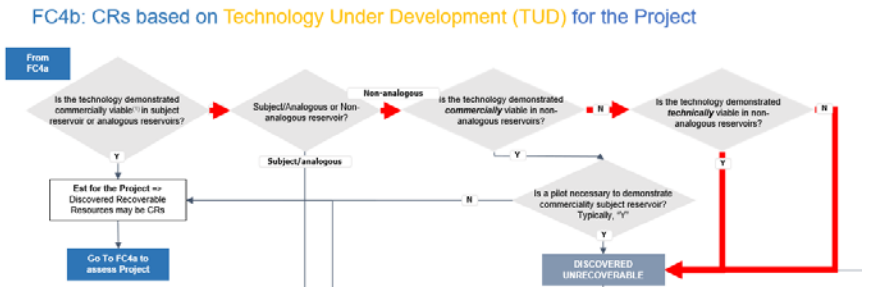




If discovery does not confirm pre-drill technical viability expectations ie "non-analogous" -> need to implement test for "direct evidence"

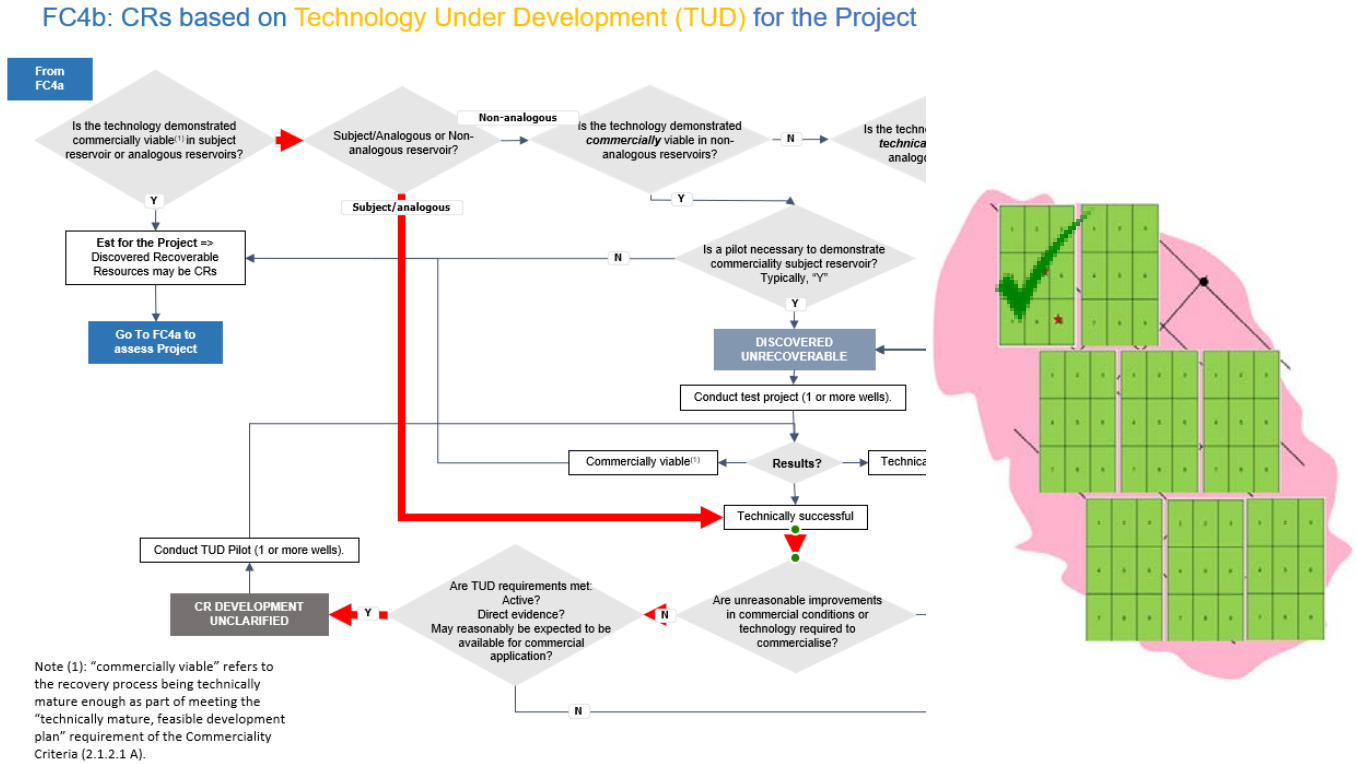
- Pod A remains Discovered Unrecoverable Resources until pass requirements of TUD
- Evaluate remaining PRs, "full project area" potential, Pg, Pd





ED 2: Result of Discovery Test in Pod A (3/4)

(3) Discovery Test Successful and confirms pre-drill technical viability (1/2):



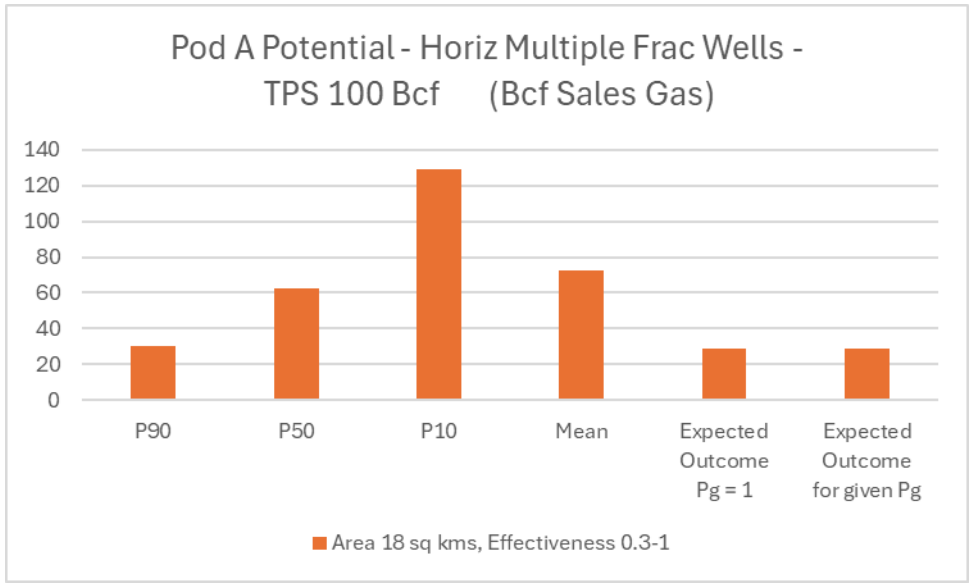
If discovery confirms pre-drill technical viability expectations for recovery process

- Check TUD requirements met? -> Yes ->TUD process
- Promote Pod A to CRs Dev Unclarified?
  - No, better to wait for results of TUD process
  - Especially if pod is FIRST TUD process
- Reassess parameters and risking
- Evaluate remaining PRs (7 pods), "full project area" potential, Pg, Pd
- Ready to implement TUD process

ED 2: Result of Discovery Test in Pod A (4/4)

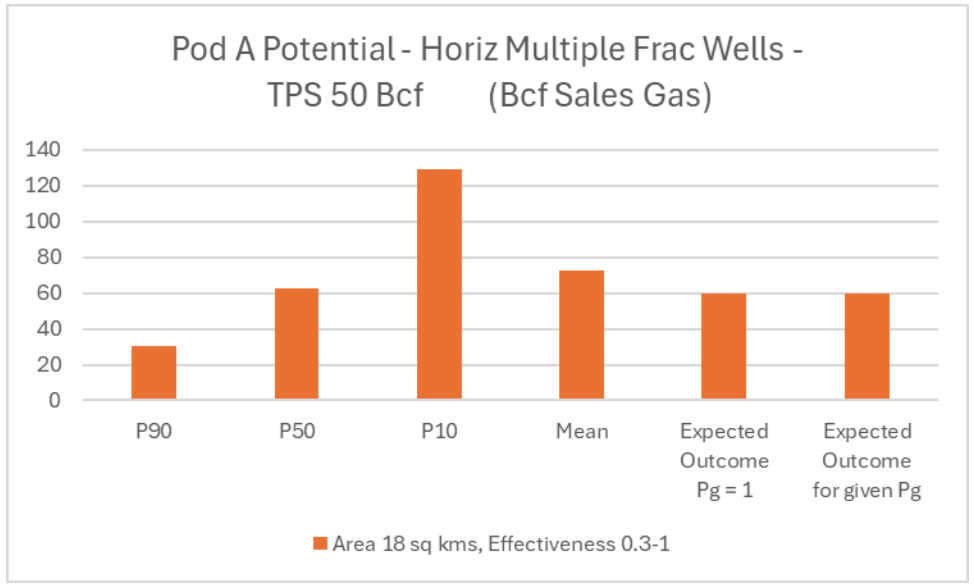
(3) Discovery Test Successful and confirms pre-drill technical viability (2/2):

TPS 100 Bcf Sales Gas



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.40

TPS 50 Bcf Sales Gas



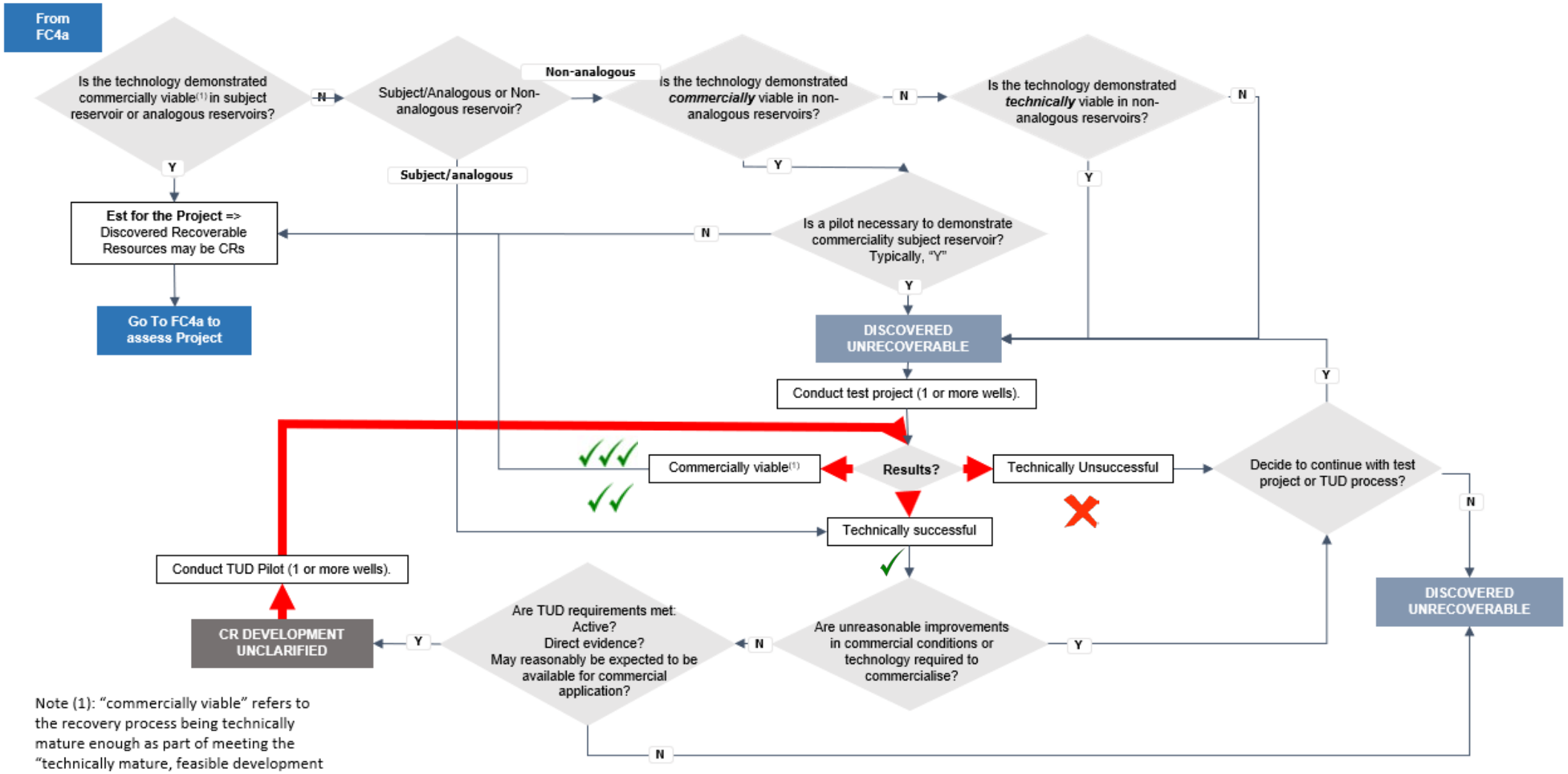
Pd full* Mean(Trun) X PTPS/Mean(Full)
0.83

- May report CRs for “full project area” Pod A, though prudent to wait until TUD process results
- Compliant TUD process
- Distribution the same for each TPS, but Pd lower, 0.4, for TPS 100 Bcf vs 0.83 for TPS 50 Bcf
- Assumes same parameters and recovery process effectiveness as pre-drill estimates
- Redo remaining PRs per ED1 (parameters and risking updated as appropriate)

ED 3: Results of TUD Process

ED 3: Results of TUD Process – Pod A (1/3)

FC4b: CRs based on Technology Under Development (TUD) for the Project



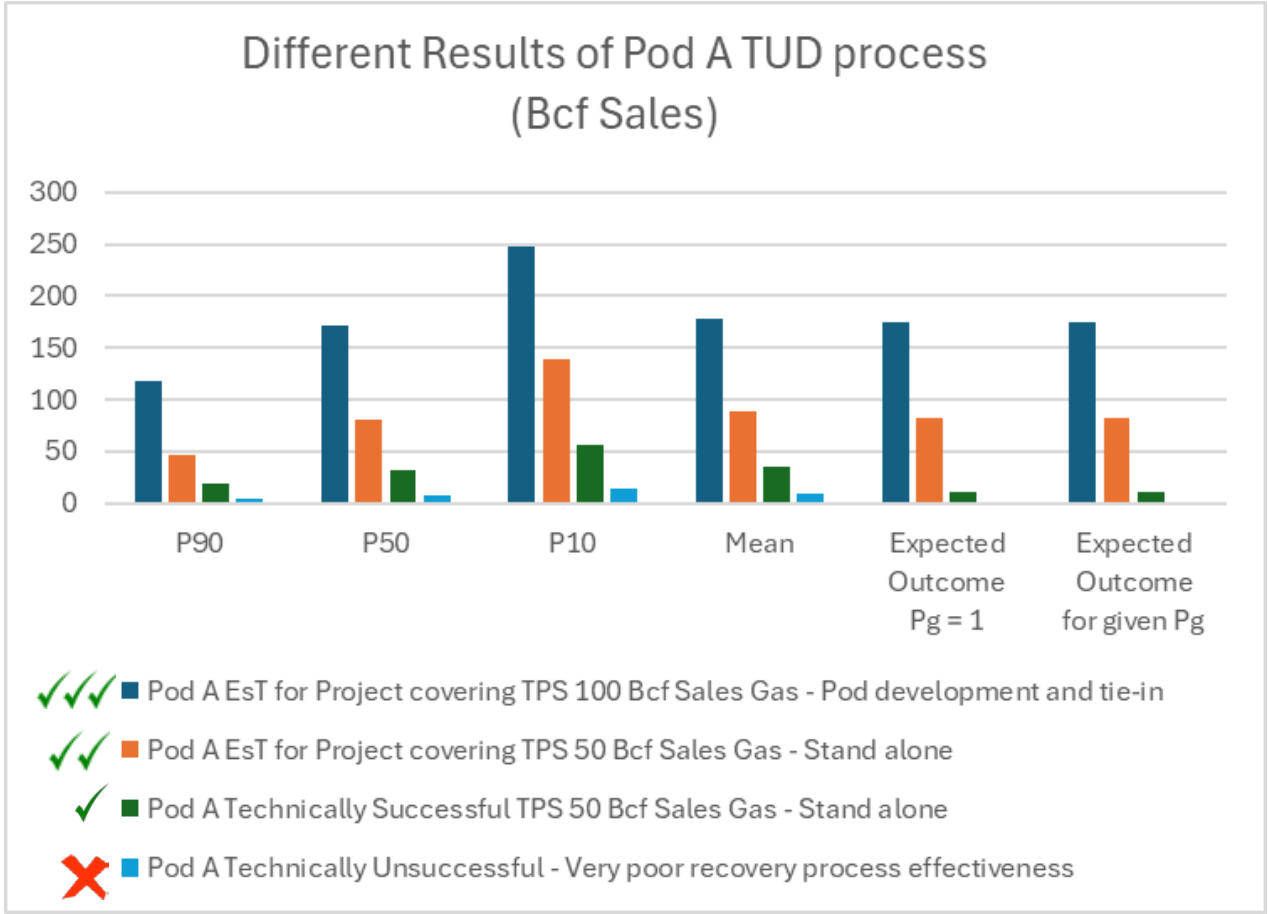
Note (1): "commercially viable" refers to the recovery process being technically mature enough as part of meeting the "technically mature, feasible development plan" requirement of the Commerciality Criteria (2.1.2.1 A).

ED 3: Results of TUD Process – Pod A (2/3)

- 4 broad outcomes may occur for the “Pod”
- Each have implications for placement in PRMS
- And next steps …

Pod A Result	Result > Ult Projects TPS	Result > Pod TPS	Technically Successful	Technically Unsuccessful
(i) Commercially Viable for Ultimate Projects area	✓	✓	✓	
(ii) Commercially Viable for Pod		✓	✓	
(iii) Technically Successful			✓	
(iv) Technically Unsuccessful				✗

Recovery Process: Horizontal Multiple Frac (HMF) wells



Pd full* Mean(Trun) X PTPS/Mean(Full)
0.98
0.93
0.28
0.00

ED 3: Results of TUD Process – Pod A (2/3)

(i) & (ii) “Commercially viable”

(iii) Technically Successful

(iv) Technically Unsuccessful

- Rework all estimates and risking –> follow-up discovery test and pilots
- Technically Unsuccessful “full project area” should remain “discovered unrecoverable” or be relegated to “discovered unrecoverable”, especially if tried “twice”

  - If not relegated, must be justified;

  - If TUD no longer active, or, not supported by direct evidence or, requires unreasonable improvements in commercial conditions or technology to commercialise -> must be relegated to “discovered unrecoverable”

Questions!