Rockflow Resources

Advisors to the Energy Industry

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Resource Aggregation:
When two fields are better than one, but by how much?

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- The techniques outlined here are meant to give an indication of possible methods to assist reserves and resource estimation. The methods are not definitive, nor unique. The audience is advised to seek independent advice on any matter relating to the estimations of reserves and resources.
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Outline

- Aggregation: What does PRMS have to say?
- Example Cases: which consider aggregation:
  - by arithmetic addition;
  - by probabilistic summation;
  - by combining scenarios;
  - by considering the CoP of a host facility;
  - of new and old projects; and
  - for the operating company and for the non-operating partner.
- Summary

PRMS on Aggregation

- PRMS definition of Aggregation:

  "*The process of summing well, reservoir, or project-level estimates of resources quantities to higher levels or combinations, such as field, country or company totals. Arithmetic summation of incremental categories may yield different results from probabilistic aggregation of distributions.*"

- Please refer to Section 4.2.5 on Aggregation Methods.

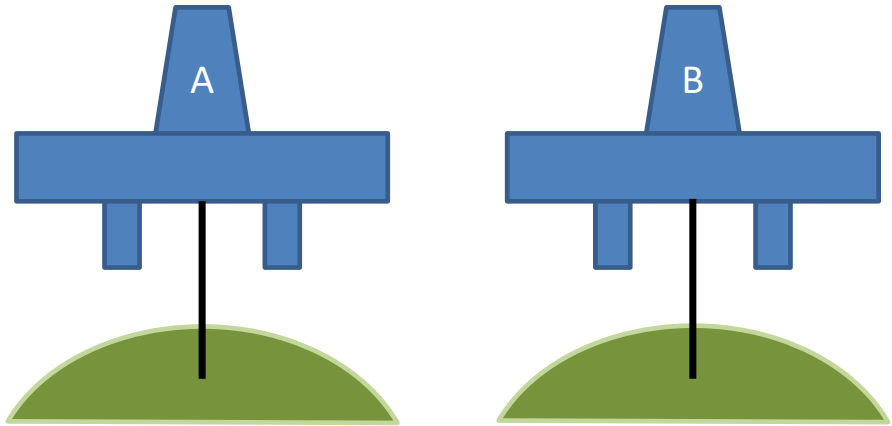
  "*Two general methods of aggregation may be applied:* ***arithmetic*** *summation of estimates by category and* ***statistical*** *aggregation of probability distributions.* "

  "*It is recommended that for reporting purposes,* ***assessment results should not incorporate statistical aggregation beyond the field, property, or project level****. Results reported beyond this level should use arithmetic* ***summation by category****…*"

Example 1:

- Two separate fields/platforms, (both on production).
- No joint commercial ownership

- Reserves should be added arithmetically:
  - 1P with 1P;
  - 2P with 2P, etc.
- Reserves should *not* be added statistically.

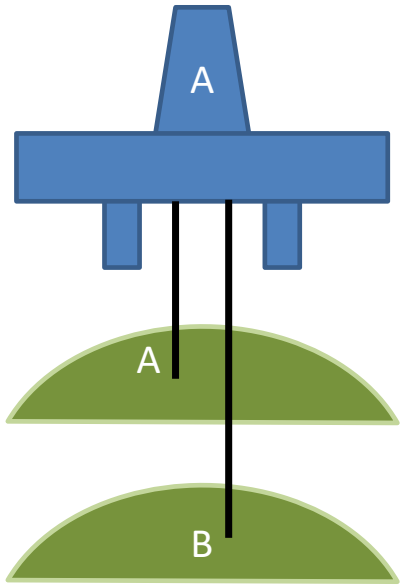


Ownership	Field A	Field B
Company A	100%	100%

Example 2:

- Two separate reservoirs, same field/platform, (both on production).
- Common commercial ownership

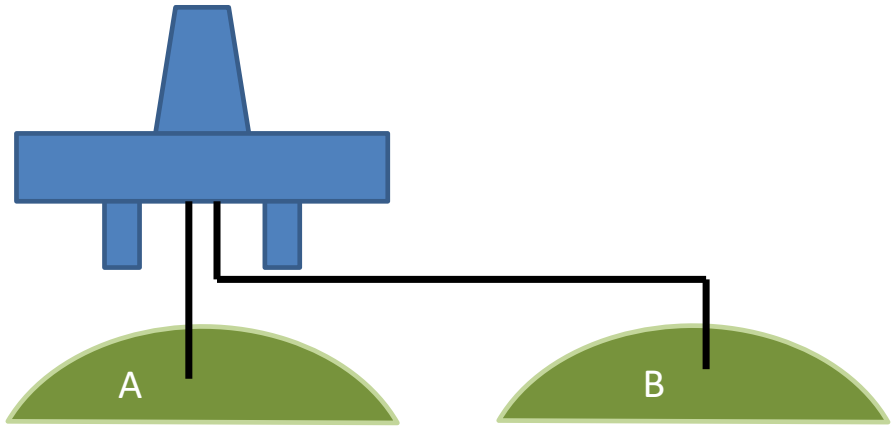
- Reserves can be added arithmetically:
  - 1P with 1P;
  - 2P with 2P, etc.
- Reserves can be added statistically:
  - "*aggregation should incorporate the degree of dependency*" (e.g. common structural issues)



Ownership	Reservoir A	Reservoir B
Company A	100%	100%

Example 3(i) the operator's view:

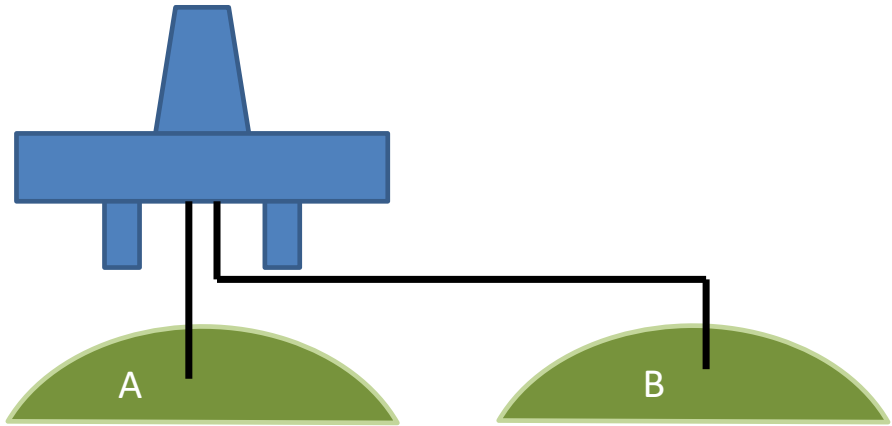
- Company A is the operator of a platform, originally build to develop Field A. Field B is owned by Company B, and is tied back to the platform. Both fields are on production.
- Company A, as operator, may have full information for both fields and so can:
  - Evaluate a range of recoverable volumes (TRR) for each field;
  - Perform an economic limit test (ELT) on Field A to get its CoP date; and
  - Perform an ELT on the platform, considering both Fields to get the CoP date of the facility;



Ownership	Field A	Field B
Company A	100%	0%
Company B	0%	100%

Example 3(ii) Company B's view:

- Same fields and ownership as Ex 3(i)
- Company B may *not* have full information for both fields and so can:
  - Evaluate a range of recoverable volumes (TRR) for Field B;
  - Rely upon Field A TRR/profile and costs from the Operator as third party information (single estimate?);
  - Perform an economic limit test (ELT) on Field B to get its CoP date; and
  - Perform an ELT on the platform, considering both Fields to get the CoP date of the facility, or rely upon the Operator's view;
  - Confirm that the platform is economic at least as long as Field B is economic.



Ownership	Field A	Field B
Company A	100%	0%
Company B	0%	100%

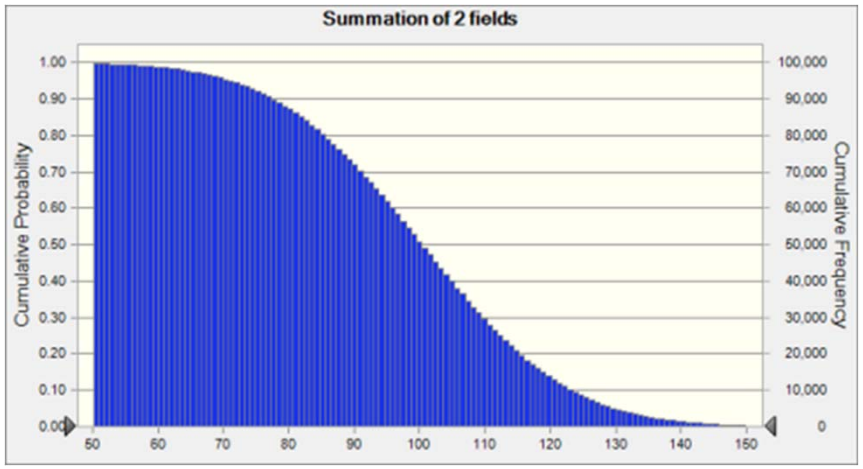
How to Work out the CoP date from multiple fields

- For the host facility, how do you work out the CoP date, given 2 or more fields, each with a range in profiles?
- There are two fields, each with L, M & H profiles for each field. There are 9 possible combinations (see table). Which one should be used for the Low Case?
- For the Mid Case, the A:Mid with B:Mid seems reasonable (⑤).
- But for the facility Low Case, should you use A:low with B:Low (①) or Low/Mid combination (② or ④)?

		Field A		
		Low	Mid	High
Field B	Low	1	2	3
	Mid	4	5	6
	High	7	8	9

Monte Carlo for 2 fields

- Let's assume that the TRR ranges (P90-P50-P10) are: Field A:49-70-91 and Field B:21-30-39.
- A Crystal Ball Monte Carlo model gives a summed range: 76-100-122 (left)
- Compare to the discrete combination of the L/M/H cases for 2 fields (right).
- The L-L combination does seem too low, but both of the L-M combinations are too high.
- [Perhaps counter-intuitively, the Monte Carlo gave 70 as the P95, not the P99]



		Field A		
		Low	Mid	High
Field B	Low	70	91	113
	Mid	79	100	121
	High	88	109	130

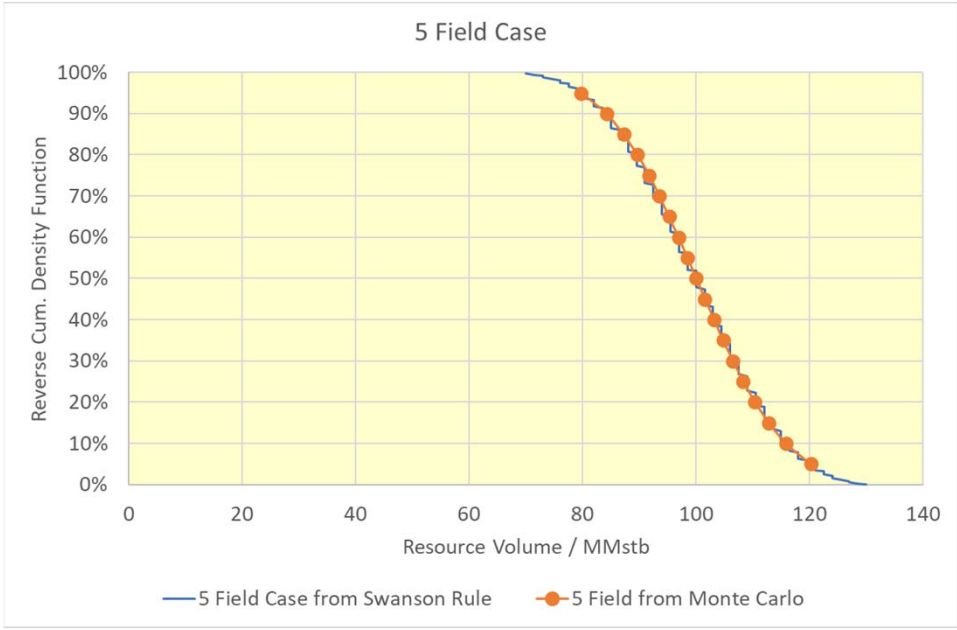
Adaptation of Swanson's Rule for 2 fields

- Consider a technique which adapts Swanson's Rule.
- Originally used to estimate a mean from P90, P50 & P10 values using a 30%-40%-30% weighting.
- Using this weighting, we can estimate the likelihood of occurrence of any combination of two (or more) fields. E.g. 30% weighting of the Low case for field A, at the same time as a 30% weighting of the Low Case for field B, gives (30% x 30%) 9%.
- If the outcomes are ranked in ascending order, then the P90 is somewhere between the L-L and L-M combinations.

		Field A		
		Low	Mid	High
Field B	Low	9%	12%	9%
	Mid	12%	16%	12%
	High	9%	12%	9%
	Total	100%		

Swanson's Rule applied to 5 fields

- Assume you have profiles and TRR for the P90, P50 & P10 cases of each field.
- Low, Mid & High for 5 fields gives (3^5) 243 combinations.
- Each combination has a chance of occurrence based on the 30-40-30 weighting. The total TRR from the 5 fields is summed in each combination.
- All TRRs are sorted from low to high, and the combination that gives the P90, P50 & P10 volumes can be retrieved.
- Tested: plot shows a comparison (from a made-up example) of a Cum density function using Swanson, where the P90, P50, P10 are given, and a Monte Carlo with 100,000 iterations, with the same Normal distributions. Answers agree within ±1%.

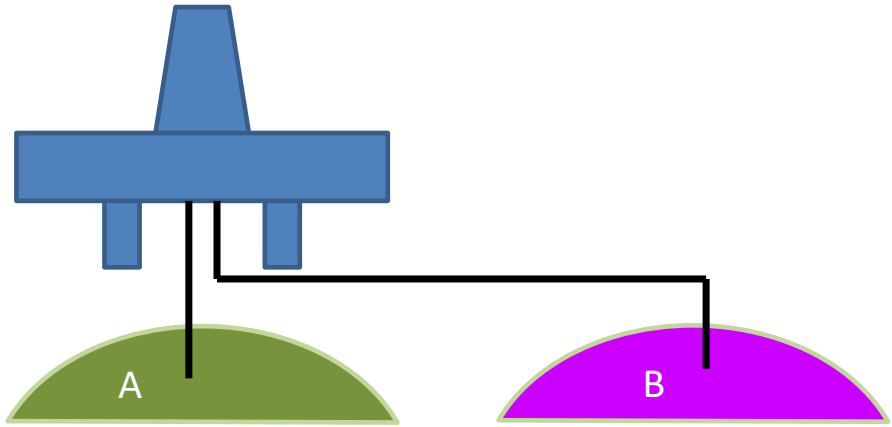


Notes on Swanson

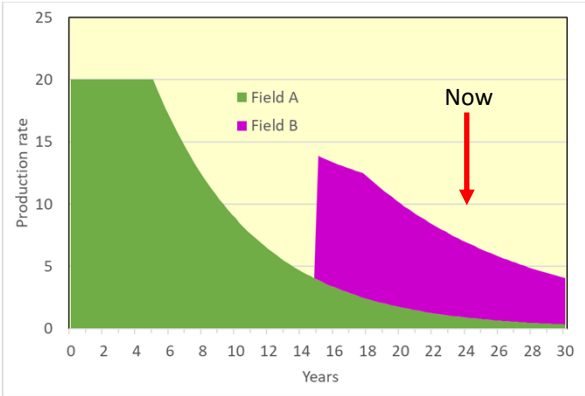
- For more information see “An Introduction to Risk Analysis”, R.E. Megill, 1977
- One advantage of this method is that instead of just giving ranges in TRR volumes, it also shows which combination of outcomes give that desired result. If each field has its L-M-H profile, then it offers the combination of profiles that could be used for an Economic Limit Test.
- This is a suggestion for a technique, it is not the only technique.
- There are a number of papers on the topic, not all agree.
- There are other methods, e.g. Monte Carlo, but may require specialist software.

Example 4 (i) the operator's view:

- Field B was brought on stream much later than Field A, and now produces much more than Field A.
- Field B pays a tariff of 5 $/bbl to the platform, but oil prices are currently >50 $/bbl.
- Total revenue from both fields exceeds total costs for the platform.
- Company A treats this in a similar fashion to Example 3(i) as the project is economic



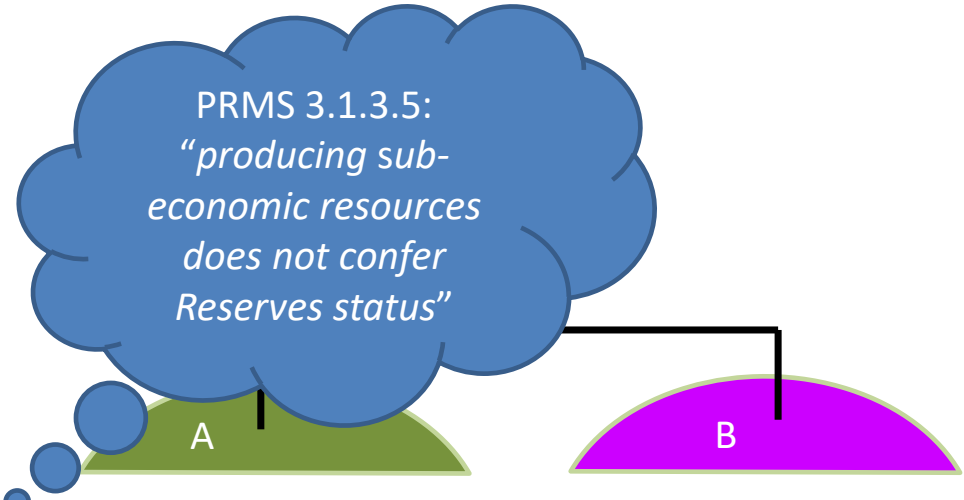
Ownership	Field A	Field B
Company A	90%	100%
Company B	10%	-



Example 4 (i) Company B's view:

☹

- Company B is entitled to 10% of the tariff from Field B, to help offset the costs of running the platform. It's not enough.
- Field A, without Field B is uneconomic. Company B has no economic reserves.
- Options:
  - Read the JOA
  - Request a switch to cost sharing
  - Unitisation/Common Working Interest?
  - Sell?
  - Give Up?



Ownership	Field A	Field B
Company A	90%	100%
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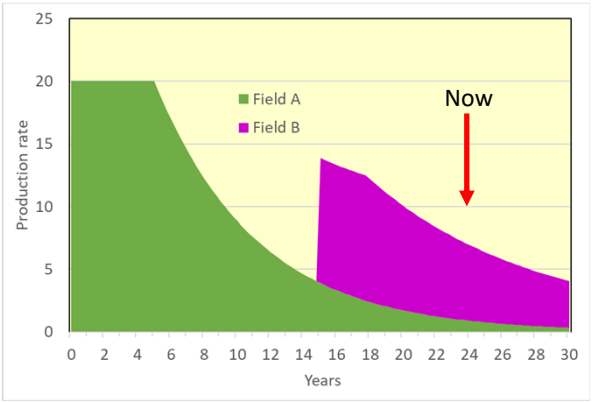
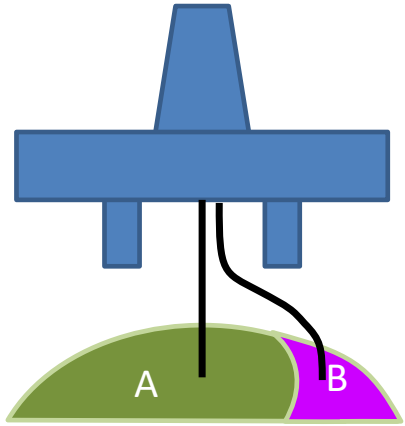
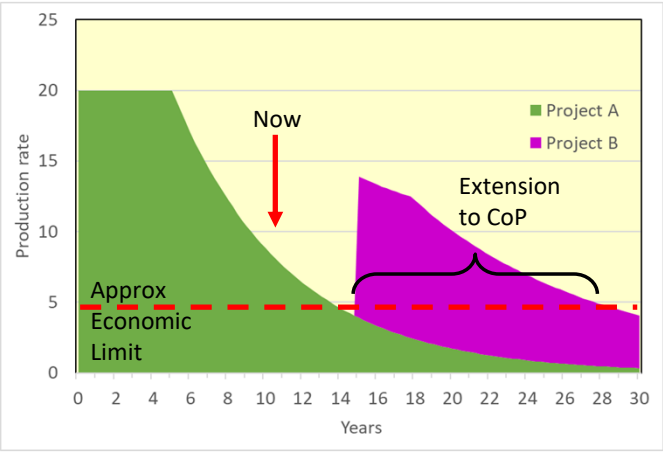


Example 5:

- Project A has been producing for several years. Project B is not yet on production.
- Project B could be new infill wells into the same field, or a step out well into a discovered separate accumulation.
- May be similar to Ex 2, if Project B also has Reserves status.
- If Project B is Contingent, then the Reserves are limited to Project A, which should be cut off at the early CoP.



Ownership	Project A	Project B
Company A	100%	100%



Summary

- Aggregation isn't as simple as the summation of two volumes: two fields, two companies/owners or two projects can complicate the issue.
- When non-operating partners have incomplete information on neighbouring fields, they may estimate different gross (100% working interest) resource volumes to the operator of the same field.
- The Swanson weighting is offered as a suggested technique. Other techniques exist, including Monte Carlo, which may be appropriate for some fields.
- The ownership of licences in mature areas like the UKCS has evolved over many years. It is not always the case that all partners in a licence are aligned to the same gross estimate of reserves, and hence potential investment opportunities.
- PRMS actively discourages the summation of reserves and contingent resources (4.2.6.1). Nor should contingent resources from one field be used to extent the CoP, and reserves, of another.

Many thanks for your attention.

Any Questions?

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