Beyond Creaming Curves

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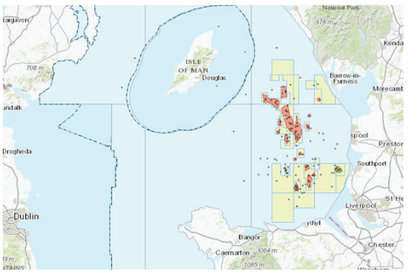
A simple and practical method to estimate undiscovered hydrocarbons for a specific timeframe

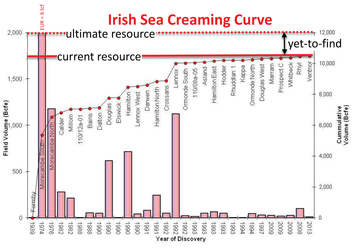
RISC Advisory has developed a simple approach to estimate the undiscovered resources for basins with a material exploration history for such a timeframe.

The approach uses raw data on exploration wells including the number of wells, the number of discoveries and field sizes.

In basins with some exploration success, experience informs us that additional discoveries will be made; these currently undiscovered resources are the 'yet-to-find'.

There is no probability of success attached to them but there is an implied certainty of discovery. However, there is considerable uncertainty in the total volume to be found; thus estimates of undiscovered volumes must be quoted as a range, for example Low - Mid - High.





Exploration tends to discover the largest fields first, followed by incrementally smaller fields. Cumulative discovered resources thus show progressively smaller increases through time, asymptotically approaching the ultimate resource for the basin.

The difference between the ultimate resource and the current cumulative (original) resource is the yet-to-find.

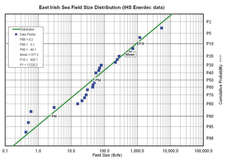
A wide range of techniques can be used to estimate undiscovered resources. At one end of the spectrum are the approaches that require a full geological understanding:

- Very detailed and data-intensive ground-up petroleum systems and play fairway analyses
- Charge modelling and migration pathways, depositional environments and reservoir distribution, trap sizes

At the other are approaches that use extrapolation of discovery rates.

- Also known as discovery-process modelling
- Requires minimal geological input

These methods may be combined.



Discovery-process modelling of undiscovered resources

Conventional approaches use the observation that field sizes follow a 'parabolic fractal' trend and require the right choice of 'decay' from the largest discovered field to define ***ultimate*** resource trend. With conventional approaches, a historic 'look-back' is possible but forecasts for specific time periods are difficult.

An alternative approach

RISC Advisory have developed a method that:

- Uses basic exploration and field data
- Requires minimal understanding of mathematics
- Has inputs and outputs that are readily assessable for reasonableness
- Is related to a forecast period to address specific company requirements
- Produces a range of estimates to capture the uncertainty in the forecast
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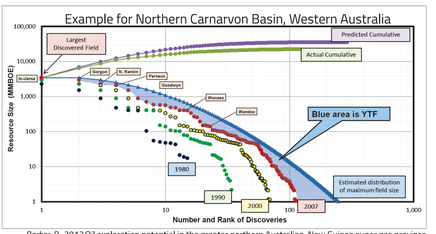
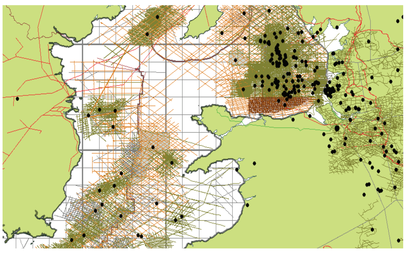
Our approach may be considered as a simple variant of discovery-process modelling.



Barber, P. 2013 Oil exploration potential in the greater northern Australian–New Guinea super gas province, West Australian Basins Symposium, Perth



How it's done: collect the following data

- Well name
- Spud date
- Well result
- For the discoveries, the mid case ultimate resource (ultimate recoverable [UR] volume) and hydrocarbon phase
  - UR estimates derive from government or company websites or use educated guess for nominal volume
  - by convention, all field resources (including field upgrades and extensions) are attributed to the discovery well
- Order by date and give a well count number (1 = first well)
- Identify discoveries (oil/condensate/gas as appropriate) with a flag
- Calculate cumulative resources
- Plot cumulative resources against year (spud date), exploration well count, discovery count.

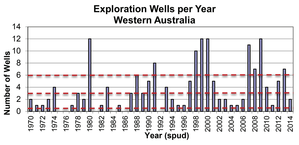
Calculating the undiscovered resource

A simple equation is used (right).

number of years	x	number of wells to be drilled per year	x	average chance of success	x	average size of discovery	=	total undiscovered resource

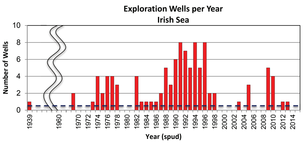
Input 1: Number of years for the forecast period

- Define the number of years that the analysis should cover
- In RISC's experience, a short to medium term forecast of 15 years is often appropriate for company requirements
- This is the only input with a single figure; all other inputs cover a range of outcomes.



Input 2: Number of wells to be drilled per year

- Choose minimum, most likely and maximum ***average*** numbers of ***exploration*** wells to be drilled per year for the forecast **15** year period.



Likelihood	Irish Sea		Western Australia	
Minimum	1 well	0.07 wells/yr	7 wells	0.5 wells/yr
Most Likely	3 wells	0.2 wells/yr	45 wells	3 wells/yr
Maximum	5 wells	0.33 wells/yr	90 wells	6 wells/yr

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Input 3: Chance of discovery

- Choose minimum, most likely and maximum average chance of discovery for the forecast period (no implication for commercial volume)
- Refer to historical success rates since (1) start of exploration and (2) a more recent period to define realistic range
- The chance may not have decreased as the basin becomes progressively better understood.

Parameter	Irish Sea (UK)		Browse Basin (Aus)	
	Since start of exploration	Since 2000	Since start of exploration	Since 2000
Total wells	105	15	170	75
Total discoveries	30	5	21	13
Probability of gas or oil discovery	29%	33%		
Total gas discoveries	23	4	19	13
Probability of gas discovery	22%	27%	11%	17%

Input 4: Average size of discovery

- Choose minimum, most likely and maximum average size of discovery for the forecast period
- Refer to existing field sizes since start of exploration and for a more recent period to define realistic range
- Average size is likely to be materially smaller than historical averages.

Parameter	Irish Sea (UK)		Browse Basin (Aus)	
	Since start of exploration	Since 2000	Since start of exploration	Since 2000
Total discoveries	30	5	21	13
Total gas discoveries	23	4	19	13
Cum oil/gas discovered, Tcfe	10.5	0.159		
Average oil/gas discovery size, Tcfe	0.349	0.032		
Cum gas discovered, Tcf	8.876	0.141	45.2	19.7
Average gas discovery size, Tcf	0.386	0.035	2.4	1.5

Chance of discovery

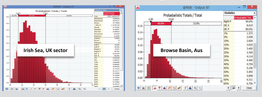
Forecast Likelihood	Irish Sea (UK)	Browse Basin (Aus)
Minimum	10%	5%
Most Likely	20%	11%
Maximum	30%	23%

Average size of discovery

Forecast Likelihood	Irish Sea (UK)	Browse Basin (Aus)
Minimum	0.010 Tcfe	0.2 Tcf
Most Likely	0.035 Tcfe	0.8 Tcf
Maximum	0.500 Tcfe	2 Tcf

Results - example

- **Inputs:** The various inputs are defined as a simple triangular distribution
- **Results:** The various inputs are multiplied probabilistically
- **Results:** Arithmetic multiplication would give low and high extremes.



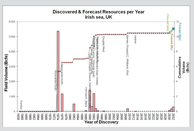
Case	Irish Sea (UK)		Browse Basin (Aus)	
	Total new wells to 2050	Forecast additional gas, Tcf	Total new wells to 2050	Forecast additional gas, Tcf
Low Case (P90)	1	0.070	25	2.1
Mid Case (P50)	3	0.166	46	5.3
High Case (P10)	5	0.301	71	11.3

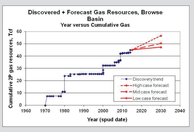
Plot the forecast - (1) Cumulative resources vs. year

- Forecast lines have same length, all corresponding to the forecast period
- Check the forecast resources range – is it realistic?
- Plot shows the actual progress of exploration and discovery year by year. The forecast lines are linear; resource only calculated for the end of the period.

Plot the forecast - (2) Cumulative resources vs. discoveries

- Plots show the increase of total resource measured against discovery well count
- This is the true 'creaming curve'
- Forecasts are different lengths due to different forecast well numbers.

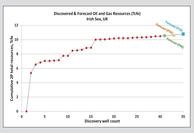


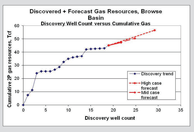


Field size distribution

As field size is fundamental to commercial viability, companies interested in total undiscovered resources will also be interested in future field sizes. The basic input data contains the necessary information to assess the pool size distribution. Field size distributions plotted as part of conventional resource estimates tend to use field rank plots. However RISC has used a simpler approach. The discovered field size data is organised in groups of an approximately logarithmic nature, and plotted against the number of fields. The expected increasing number of smaller fields in mature basins is offset in practice as:

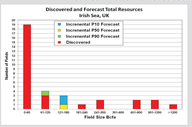
1. Companies drill the largest prospects first, and
2. Smaller uneconomic prospects may never be drilled; this gives a skew towards larger field sizes.

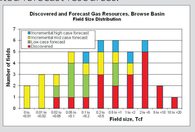




Forecast field size distribution

- The estimated total undiscovered resource is comprised of pools of various sizes
- Additional pools of varying sizes are added to even out the distribution
- With iteration the totals for each of the Low, Mid and High cases match the calculated forecast resources.





Limitations to this technique

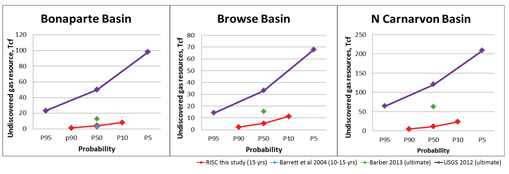
- Needs a material level of exploration within the basin to provide sufficient data for analysis (e.g. assessment of Roebuck Basin/Bedout Sub-basin [Phoenix Field] YTF would not be possible)
- Unexpected success from a new play may not be captured, unless the previously defined high case forecast was particularly optimistic
- These limitations nevertheless also apply to YTF approaches derived from other discovery-process methods
- The analysis refers to whole basins; nominally the area that has been drilled. Consideration of relative prospectivity within basins requires geological analysis.

Comparison with previous estimates

Current study is roughly consistent with Barrett et al, but ultimate resource YTF for Barber, and especially USGS are much higher, and illustrate difficulties in using such work for a short to medium term outlook.

RISC Low, Mid & High estimates for Bonaparte & Carnarvon basins here are arithmetic sums.

Reference	Methodology	Forecast period
Barber, P. 2013	parabolic fractal	ultimate resource
Barrett, AG et al / Geoscience Australia 2004	discovery-process + petroleum systems	10-15 yr ahead
USGS / Pollastro, RM et al 2012	full geological systems analysis	ultimate resource



Future potential

- Exploration discoveries for the Irish Sea (inc Peel basin, Solway basin, Lagman Terrace Northern , East Irish Sea basin and Liverpool Bay Channel and Caernarvon Bay basin) have all been in Triassic sandstones.
- Future exploration discoveries may include Lower Permian Collyhurst Sandstone, Carboniferous sandstones or Basal Namurian gas and oil-prone shales such as Hollywell & Bowland Shales.

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