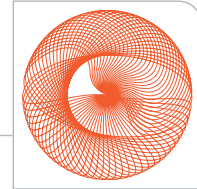


RAVE

risk and value engineering



“enable strategic decisions to be made on a sound, timely and auditable basis”

a window of opportunity

The need for RAVE

RAVE (Risk And Value Engineering) defines an approach to system engineering encompassing life of field (LOF) reservoir-export modelling, financial evaluation and translation of data uncertainties into project risks.

Extract maximum value from your assets



**Rapidly identify and rank
alternative investment options**



Collaborative problem solving across all disciplines



Reduced decision cycle time



Quantitatively improve decision quality



Identify and quantify life of field risks



**Provision of look back on decisions
and audit capability for reserves calculations**



The benefits of RAVE

The RAVE application allows the following:

Stochastic analysis to quantify the key risk/uncertainty/value relationships



Full economic value calculation, including detailed UKCS fiscal modelling



Easy configuration for alternative tax regimes



Flexible definition of drilling/infrastructure development programs and schedules.



Rigorous point-by-point production optimisation, including system constraint handling



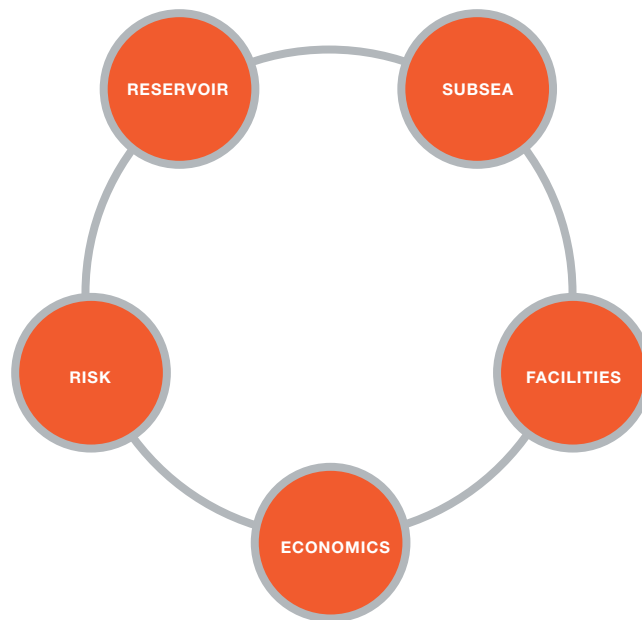
Pressure network solution from injection to export to honour system deliverability

All of this is achieved within a fast model that has been built within a collaborative framework that ensures everyone buys into the end result.



A unique product

RAVE integrates models of all the key components required to execute a field development study. The RAVE program incorporates a full pressure network solution of the system thus fully honouring the constraints on deliverability on the system. A proprietary optimisation algorithm included in the RAVE solver maximises point-by-point production/value, including gas-lift optimisation, within the resource constraints imposed at the facility.



reservoir Reservoir performance modelling
Continuous linking of geological uncertainty to reservoir flow performance
Drilling programmes
History matching
Modelling 'by well'

subsea Wells and flowlines
Production systems
Pressure balance and constraint management to assess development
Optimise gas lift or pumping power and capacity

facilities Topsides facilities
Export & terminals
Ability to optimise production to constraints

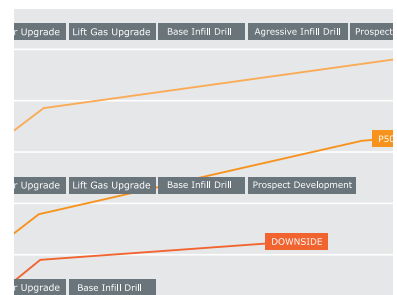
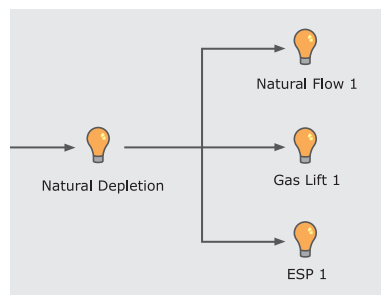
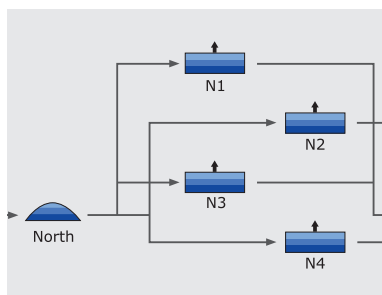
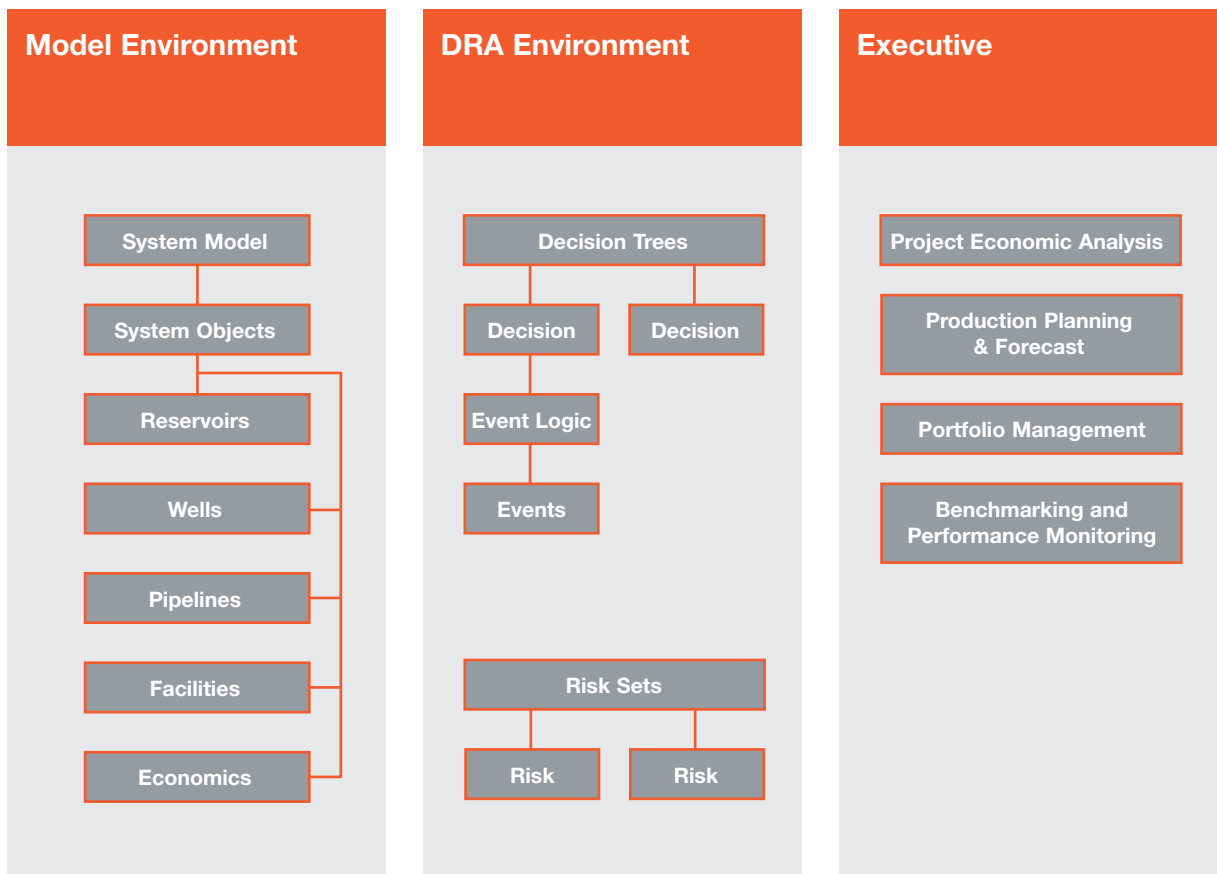
economics Oil price forecasts
Econometric modelling
Tax regimes

risk Decision risk analysis
Business development logic to lock in uncertainty assessment



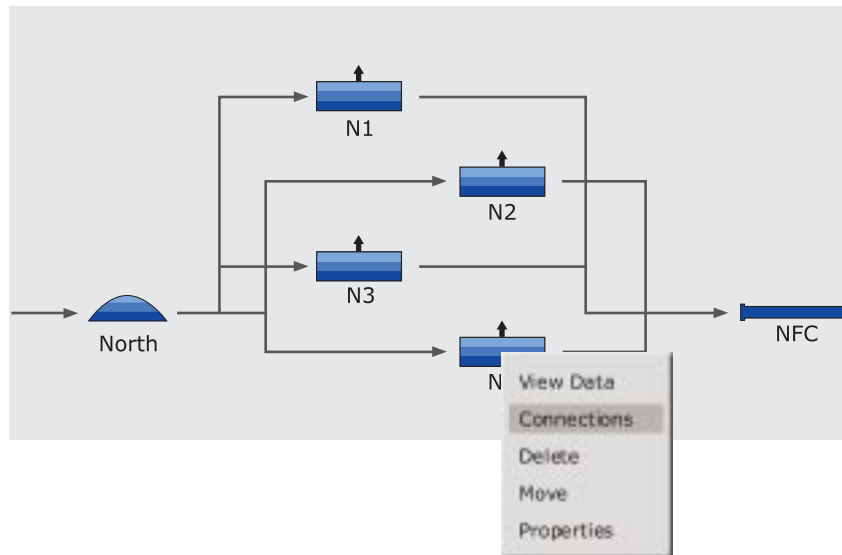
The risk and value tool

The RAVE tool is organised into three modelling environments that lead the user from the definition of the problem using the model environment, through questions and answers with decision and events toward strategy and portfolio development.



RAVE model construction

Drag and drop icons are used to represent the system icons. The addition of an object creates a worksheet encapsulating object data and functions



E1 Properties [X]

Please select the property you want to modify from the following list and change its value by entering an appropriate value in the corresponding box.

Property: ▼

Value: STB/PSI

Core Information

Obj Name:

Eco System: ▼

E1 Connections [X]

Please enter the connection object(s) for this item.

E1

From: ▼

To: ▼



RAVE model construction

The flow/pressure balance is considered at an object and system level. At the system level, a simultaneous network solution algorithm is used. At the object level, performance curves are used for all network objects. These curves may be generated from commercial applications (PIPESIM, PROSPER etc.).

Object	Name	Tab	No	System	From
Well	N1	N1		1	North
Lift Mechanism	1 Nat Flow				
Max Gas Lift	0.00 MMSCFD				
Well Target Rate	13 MBLPD		a	0.200	
Compartment Producers	1		b	1.00	
Compartment PI	12 STB/PSI		QDRY	1.0 nmbis	
Drill Date	31/10/2003		IOC	100%	
Well Start Date	31/10/2003				
Year	Pressure In [psi]	Pressure Out [psi]	Peak Liquid Rate [MBPD]	Peak Oil Rate [MBPD]	Peak Water Rate [MBPD]
28/2/02		-	-	-	-
31/3/02	5,000	230	-	-	-
30/4/02	5,016	230	-	-	-
31/5/02	5,034	230	-	-	-
30/6/02	5,052	230	-	-	-
31/7/02	5,070	230	-	-	-
31/8/02	5,089	230	-	-	-
30/9/02	5,106	230	-	-	-
31/10/02	5,124	230	-	-	-
30/11/02	5,141	230	-	-	-
31/12/02	5,159	230	-	-	-

Network solution and constraint optimisation is carried out for each month of field life

Lift Gas	Flows	100	1.573	3.145	4.717	6.290	7.862	9.435	11.007
Water Cut	0%	5%	10%	20%	40%	60%	80%	95%	
Lift Gas	0.00	1.00	1.50	2.00	2.50	3.00	4.00		
239	2,389	2,474	2,562	2,742	3,130	3,560	4,040		
239	2,390	2,475	2,564	2,745	3,132	3,565	4,044		
241	2,410	2,493	2,579	2,757	3,138	3,569	4,053		
248	2,478	2,556	2,637	2,805	3,173	3,595	4,075		
257	2,569	2,642	2,717	2,876	3,225	3,633	4,107		
268	2,677	2,744	2,814	2,962	3,291	3,683	4,148		
279	2,794	2,856	2,920	3,059	3,367	3,744	4,197		
292	2,915	2,974	3,035	3,163	3,454	3,814	4,253		
177	1,769	1,824	1,882	2,000	2,245	2,507	2,793		
191	1,914	1,977	2,045	2,181	2,467	2,777	3,124		
207	2,070	2,135	2,205	2,346	2,646	2,977	3,355		
223	2,227	2,291	2,358	2,497	2,796	3,133	3,524		
238	2,381	2,442	2,506	2,640	2,931	3,264	3,660		
253	2,532	2,590	2,650	2,778	3,057	3,382	3,778		
268	2,681	2,735	2,792	2,913	3,179	3,497	3,886		
283	2,827	2,879	2,934	3,048	3,301	3,609	3,989		
164	1,642	1,693	1,748	1,858	2,082	2,314	2,563		
179	1,792	1,849	1,910	2,035	2,291	2,565	2,866		
197	1,965	2,025	2,089	2,219	2,489	2,785	3,118		
214	2,143	2,201	2,263	2,391	2,664	2,970	3,318		
231	2,312	2,369	2,429	2,553	2,822	2,126	3,484		
248	2,477	2,531	2,588	2,708	2,968	3,266	3,628		
264	2,637	2,689	2,742	2,857	3,106	3,399	3,758		
279	2,792	2,742	2,894	3,001	3,241	3,527	3,879		
156	1,561	1,710	1,663	1,770	1,985	2,207	2,440		
171	1,713	1,767	1,825	1,940	2,176	2,425	2,696		
189	1,890	1,946	2,005	2,125	2,375	2,644	2,943		
208	2,077	2,111	2,189	2,308	2,561	2,841	3,156		
226	2,257	2,321	2,367	2,483	2,734	3,014	3,340		
243	2,432	2,488	2,537	2,650	2,893	3,170	3,501		
260	2,600	2,642	2,700	2,808	3,043	3,317	3,647		
276	2,762	2,811	2,860	2,962	3,189	3,456	3,783		

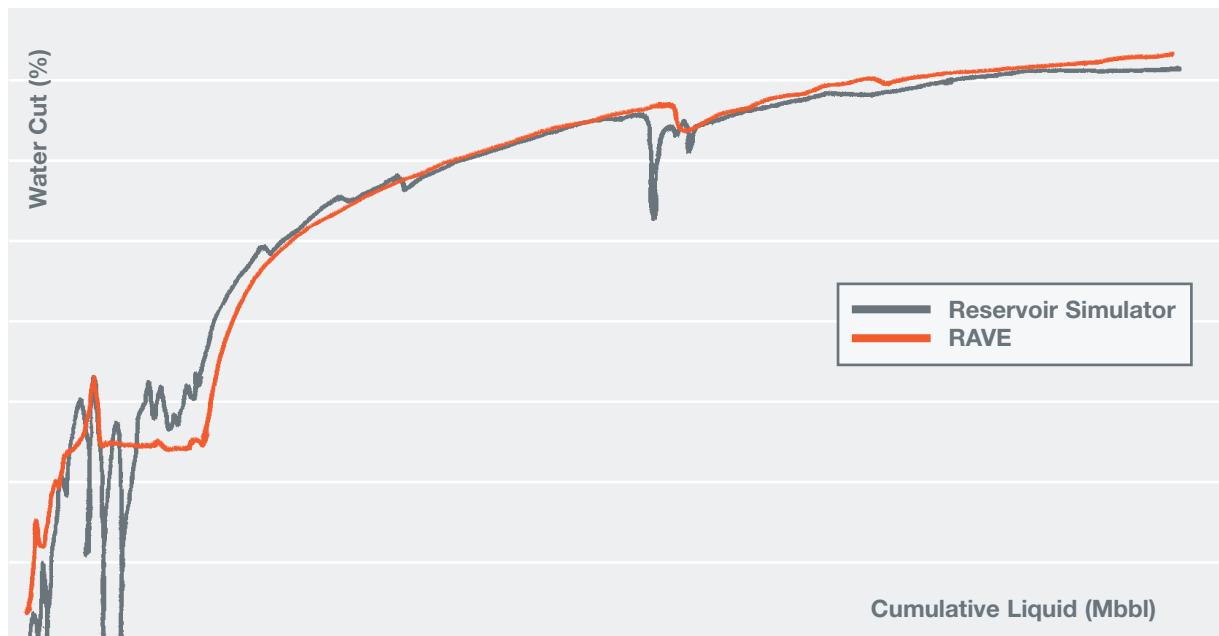
Productivity and performance curves are combined to determine overall pressure/flow relationship for the well



RAVE fitting and matching

Production performance for wells and reservoirs may be input as decline relationships or supplied from reservoir simulations. This approach can combine historical data matching along with predictions from, for example, detailed reservoir simulations.

Ingen has developed in-house mathematical models for advanced decline analysis of water flood (C curve).



The proxy reservoir models replicate effects predicted by reservoir simulations. In this case, the match to historical data reduces the variability in the predicted well performance.



RAVE decisions and events

Evaluation of development strategies is contained within 'Decision Trees'. Multiple decision trees are supported.

The screenshot displays the 'Risk and Value Engineering - Demo Version' interface. The main window shows a 'RAVE Decision Tree - 3rd party - 2 Wells (06/09/2002 by PvdP)'. A 'Gas Lift 1 Properties' dialog box is open, showing a table of objects and variables.

Object	Variable	Value
N1	Lift Mechanism	2
N2	Lift Mechanism	2
N3	Lift Mechanism	2
N4	Lift Mechanism	2
2 Wells	2 Wells	Event

The dialog box also includes 'Decision Details' with fields for Object, Variable, and Value, and buttons for Update, Add, Remove, OK, and Cancel. The name 'Gas Lift 1' is entered in the Name field.

The decision tree diagram shows a 'Natural Depletion' node branching into 'Natural Flow 1', 'Gas Lift 1', and 'ESP 1'. A separate branch leads to 'Natural Flow 2'.

As an example, this decision represents drilling an additional two gas lift supported wells

This screenshot shows the same RAVE software interface, but with numerical values for Field NPV associated with each decision path. Two production plots are overlaid on the left side of the screen.

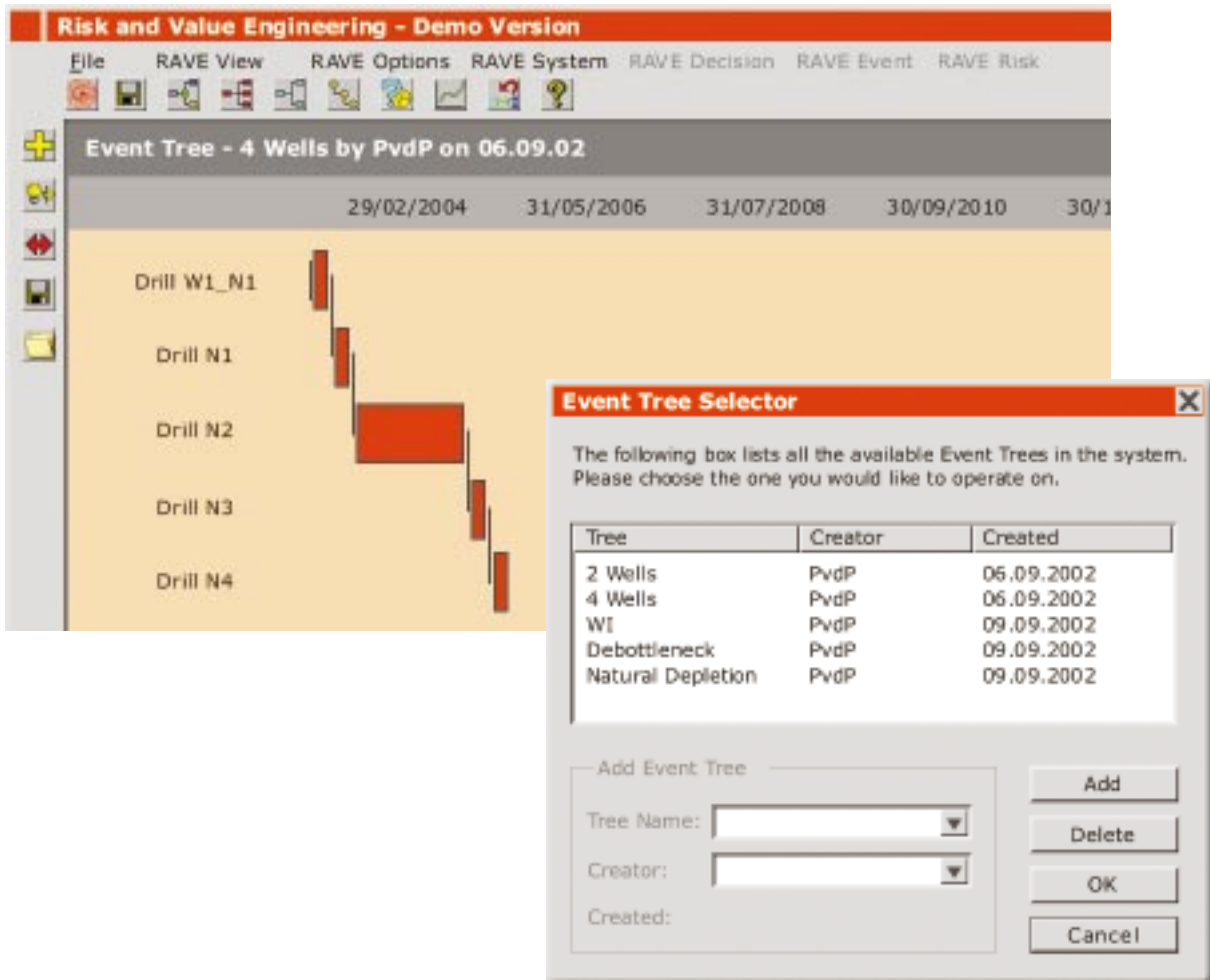
Decision Path	Field NPV (€m)
Natural Flow 1	34.36
Gas Lift 1	36.77
ESP 1	30.51

The production plots show multiple curves representing different variables over time, likely production rate and cumulative production.



RAVE decisions and events

In addition to decisions, RAVE incorporates the concept of 'Event Trees'. Events allow control over variables over time. For example, a drilling sequence or facilities upgrade. Event trees and events are activated by decisions.



RAVE decisions and events

Events permit the user to set the business logic, development schedule and response to uncertainty.

Debottleneck Facility Properties

Event | Date | **Details**

Please note that any change made to the event details will take effect immediately and cannot be rolled back using the cancel button.

Set CPF: Liquid Capacity [KBPD] = 120
Set CPF: Oil Capacity [KBPD] = 40
Set CPF: Water Capacity [KBPD] = 80

OK Cancel

Drill N2 Properties

Event | Date | **Details**

Start

Date [] (inclusive)
 Object [] parameter []
 Event [Drill N1] end

End

One-off event. This event only acts on the start date

Date [] (inclusive)
 Duration [24] months
 Record end date in object [N3] parameter [Drill Date]

OK Cancel



RAVE risks

RAVE incorporates functionality to assign probability distribution functions to any variable to facilitate probabilistic simulations. Risk sets are entered in a tree diagram in a similar manner to decisions.

The screenshot displays the 'Risk and Value Engineering - Demo Version' software interface. The main window shows a 'RAVE Risk Plan - Initial Risk Tree (by)' with a tree diagram where 'Geological' and 'Commercial' are connected by a horizontal line, both marked with question marks. Overlaid on this are two dialog boxes: 'Risk 1 Properties' and 'Risk Simulation'.

Risk 1 Properties dialog box details:

- Text: "The following list shows all the parameters set to be risked in the current risk object. Click 'Add' to insert a new risked parameter or click a list object to delete it from the current object."
- List:
 - OUTPUT:GlobalScratchPad-Field NPV
 - INPUT:GlobalScratchPad-Oil Price has been risked by RiskTriangle(12,18,25)
- Controls: 'Risk Selection' dropdown, 'Risk Object:' dropdown, checkbox 'I want to select a Risk output', 'Param/Result:' dropdown, and buttons 'Add', 'Delete', 'OK', 'Cancel'.

Risk Simulation dialog box details:

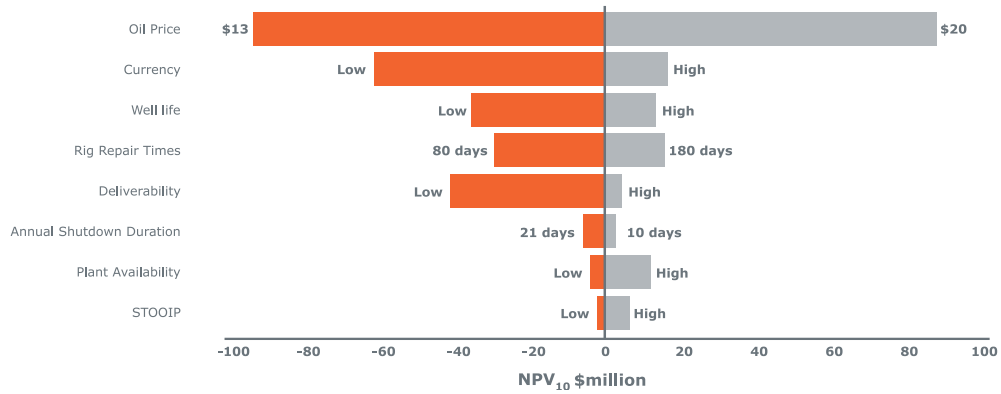
- Text: "Please fill out the following details appropriate for your model. Please note that simulation times will vary according to your machine specification. Click 'Predict Duration' for an estimated simulation time. You may also perform a formula upload to allow use of the model with a copy of @Risk."
- Sampling Type:
 - Latin Hypercube - Return Latin Hypercube Samples
 - Monte Carlo - Return Monte Carlo Samples
 - True EV - Return the expected value of all distributions
 - Expected Value - Return the expected value of all distributions, except for discrete distributions which return the value that is closest to the true EV
- Random Generator Seed:
 - Choose Randomly
 - Fixed: 1
 - Multiple Simulations use different Seed Values
- @Risk Compatibility:
 - Text: "To use this model with @Risk you can upload risk formulae using the controls below. Please note that the model may not run on a machine without @Risk once a formula upload has been done."
 - Buttons: 'Remove @Risk Formula', 'Upload @Risk Formula'
- Simulation Settings:
 - No. of Simulations: 1
 - No. of Iterations: 1
 - Buttons: 'Project Duration', 'View Results', 'Cancel', 'Proceed'

The commercial RAVE package uses the third party @RISK developers module to generate the probability distribution functions.

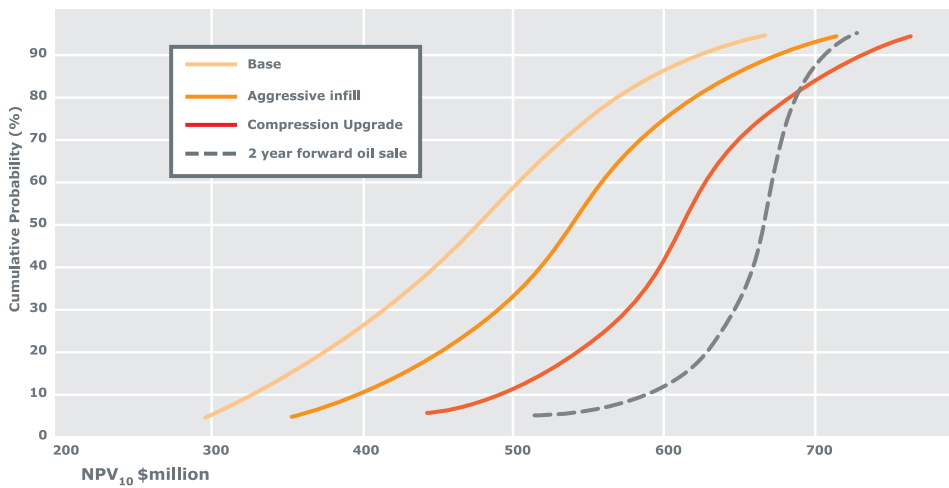


RAVE risks

Tornado analysis is used to identify the most important uncertainties in the project

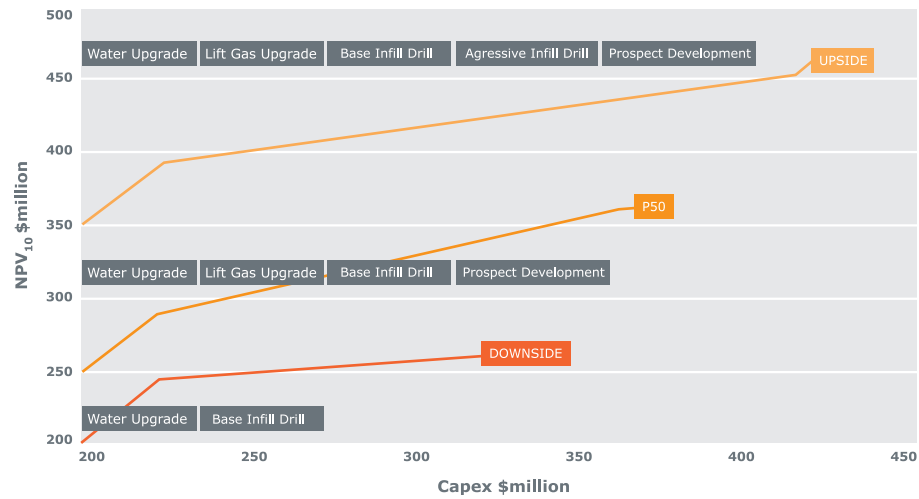


Risk sets can be applied to different development options and the range of outcomes compared.



RAVE executive

RAVE handles multiple decision trees, events and risk profiles. All key results are stored with the decision with which they are associated.



The RAVE Executive provides the capability to post-process results with complete flexibility. This allows:

- **Creation of project incremental economics and production profiling**
- **Creation of AFE packs**
- **Creation of opportunity screening (frontier analysis)**
- **Asset project planning**
- **Reserves auditing**

The XML file format is used with an eye to future web-based development of the application.

