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Robust Appraisal Planning – Link Between Discovered Resource and Field Development

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NAPE TECHNICAL MEETING

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Outline

- Introduction
- Business case for an appraisal program
- Scope of an appraisal program (Methodology)
- Case study of Kappa Resource
- Common pitfalls in developing a robust appraisal program
- Lessons learned and best practices
- Acknowledgements

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Field Appraisal Program

- What field appraisal is NOT
  - Drilling an additional well to meet up with regulatory requirements
  - Seeking to know the down-dip limit of the hydrocarbon discovery
  - Drilling to get additional data point
  - Appraisal well is NOT drilled to add resources to an already discovered volumes

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What Field Appraisal is

- What field appraisal is
  - Understanding the resource and how viable it is for development is the goal of the appraisal program.
  - It is mostly a data gathering drive to help manage the uncertainties associated with a new discovery.
  - The end goal here is to support the field development decisions.
  - Appraising the field to know whether or not to proceed with development.
  - If we then decide to proceed, how do we develop?

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What Field Appraisal is

- What is an Appraisal Program?
  - *Appraisal program are activities that are carried out after the discovery of oil and gas to assess the:*
    - ***Field extent***
    - ***Reserves,***
    - ***Producibility,***
    - ***Production rate***
    - ***Properties of the oil and gas***

  in order to support the field development decisions.

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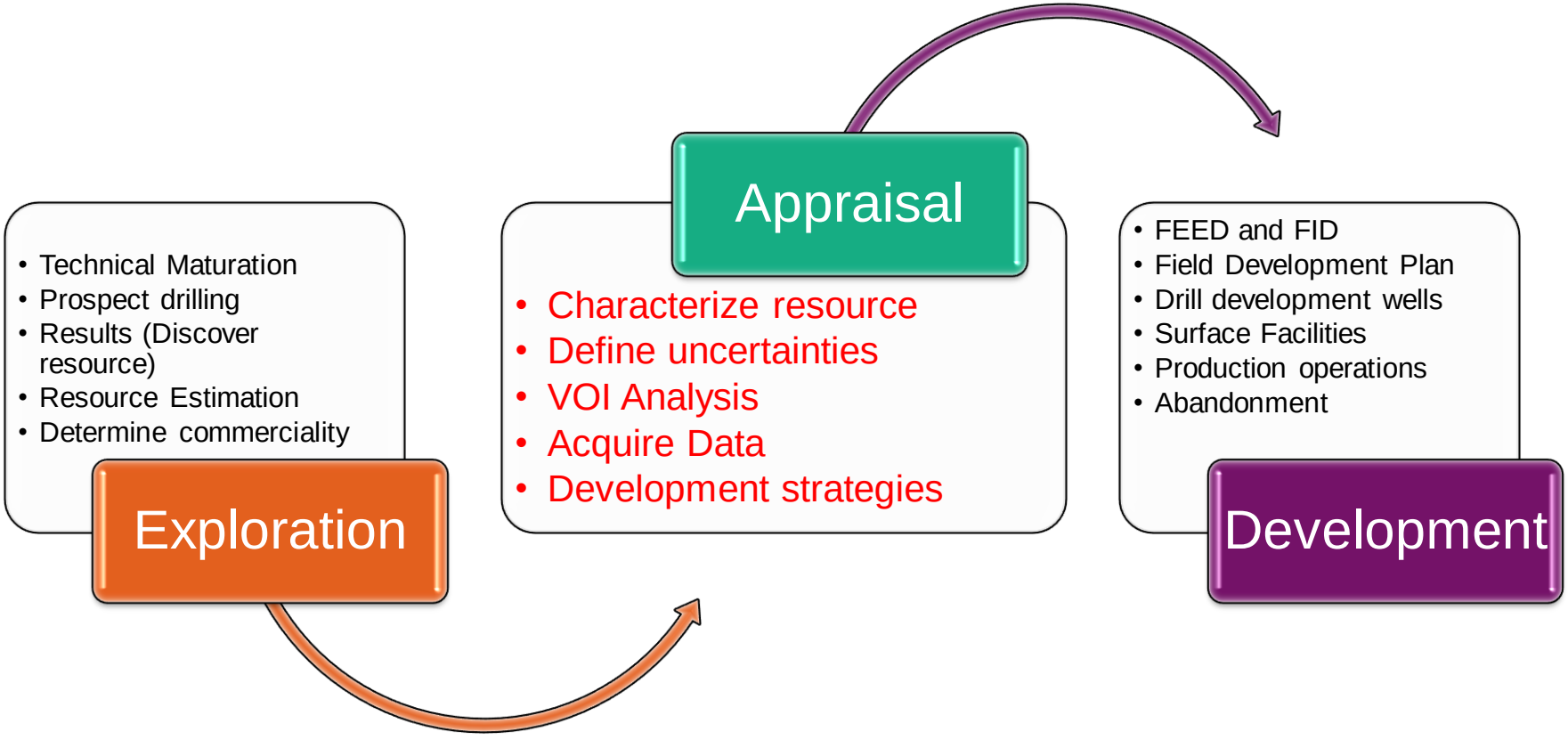
Appraisal Phase – is the link between Exploration and Development



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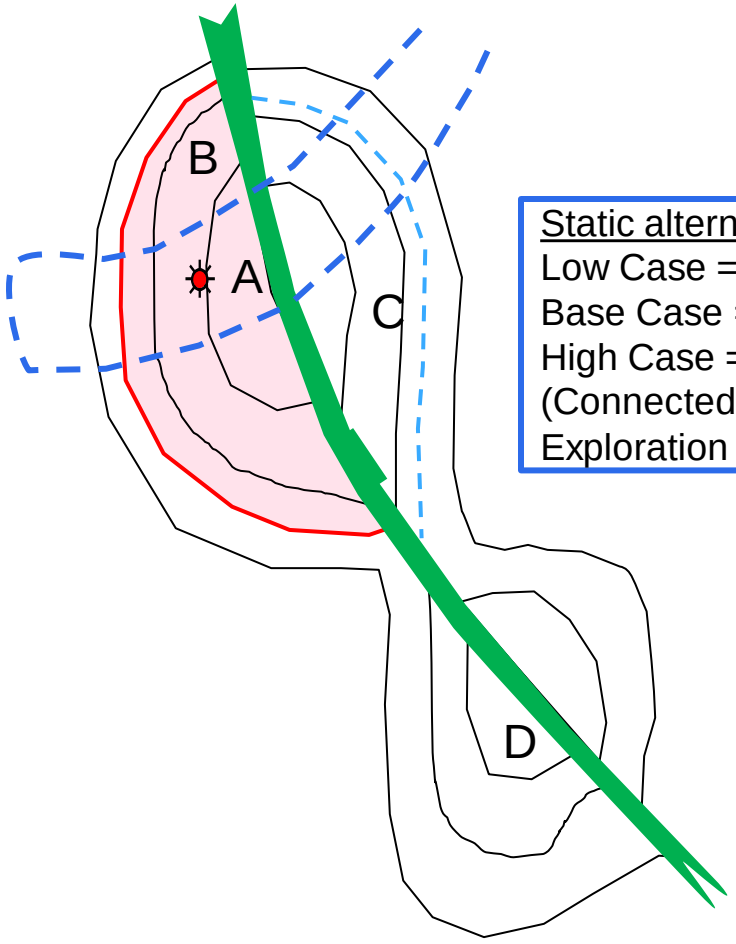
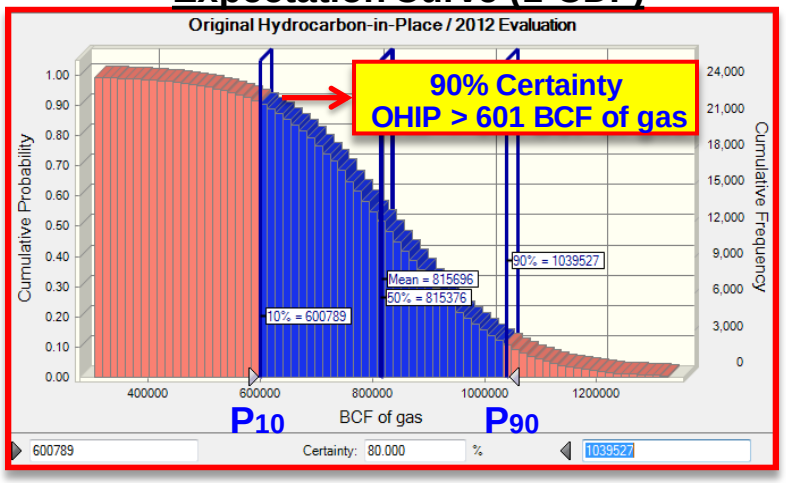
Approach to Appraisal



Static alternatives
Low Case = A
Base Case = B
High Case = B + C
(Connected scenario)
Exploration Opportunity = D

Expectation Curve (1-CDF)



- When to appraise a resource
  - Soon after a discovery of Oil and Gas has been made, helping to understand commerciality
  - The main driver of appraisal is so we have enough confidence to make the next investment decision.
- Resource deterministic case
  - Identify the baseline – if this baseline is all we have, can we still go ahead to develop?
  - Generate alternatives (geologic models) to drive the appraisal program.
  - Have a L-M-H cases for the alternatives
  - Appraisal increase the low case volumes and to narrow the range of uncertainties

Low — Pre appraisal uncertainty — High

Post appraisal uncertainty

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Key Aspects of an Appraisal Program

The Resource Estimation

- Reasonable base case estimate
- Identify what project opportunity exists
- Define static and dynamic scenarios
- Obtain L-M-H estimates

Data Acquisition

- Data inventory
- Data needs
- Data acquisition plan
- Analogs and studies

Uncertainty Management Plan

- Uncertainties from the Discovery well
- Impact and Resolvability of the uncertainty
- Categorize the uncertainties

Value of Information

- Do nothing scenario
- Imperfect information scenario
- Perfect Information scenario
- Current and Future decision and data needs

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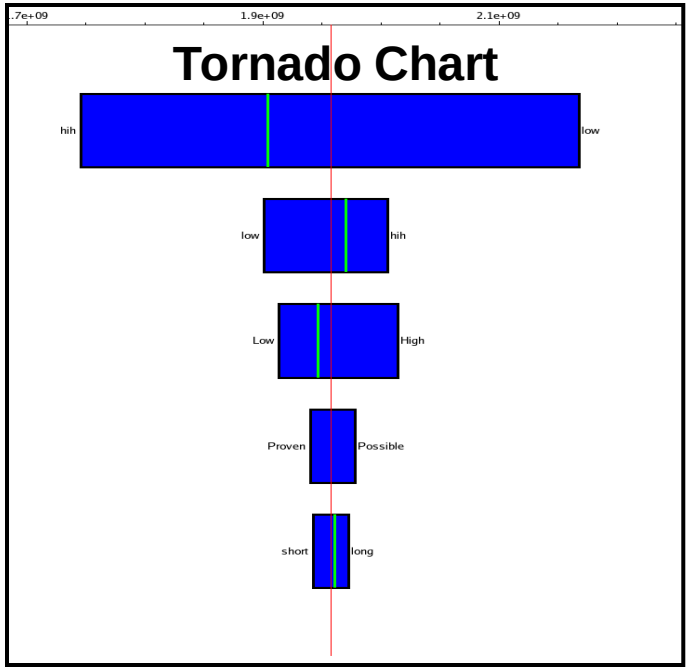
Uncertainty Management Plan

- An Issue-raising session involving a multifunctional team to:
  - List the uncertainties
  - Categorize the uncertainties – Static, Dynamic, facilities and drilling
  - Determine their impact on the current and future decisions
  - Design resolution strategies
  - Plan for upside realization and downside mitigation
- Identify and rank uncertainties with the most impact based on their potential impact
- Apart from being a communication tool, a UMP is a great planning tool
- The UMP should drive the data acquisition program



UMP spreadsheet

	Re-order / Alternative #	3	4	5
Sort ID #	Sort by Score / Sort by Impact / Sort by Deg of Unc	Basic well + sidewall core	Basic well + advanced logging	Basic well + whole core
108	Net-to-gross	L	L	M
112	Compartmentalization - stratigraphic	L	L	M
132	Fluid contacts (GOC, OWC)	M	M	M
133	Effective reservoir area	M	M	M

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Data Acquisition Program

Seismic

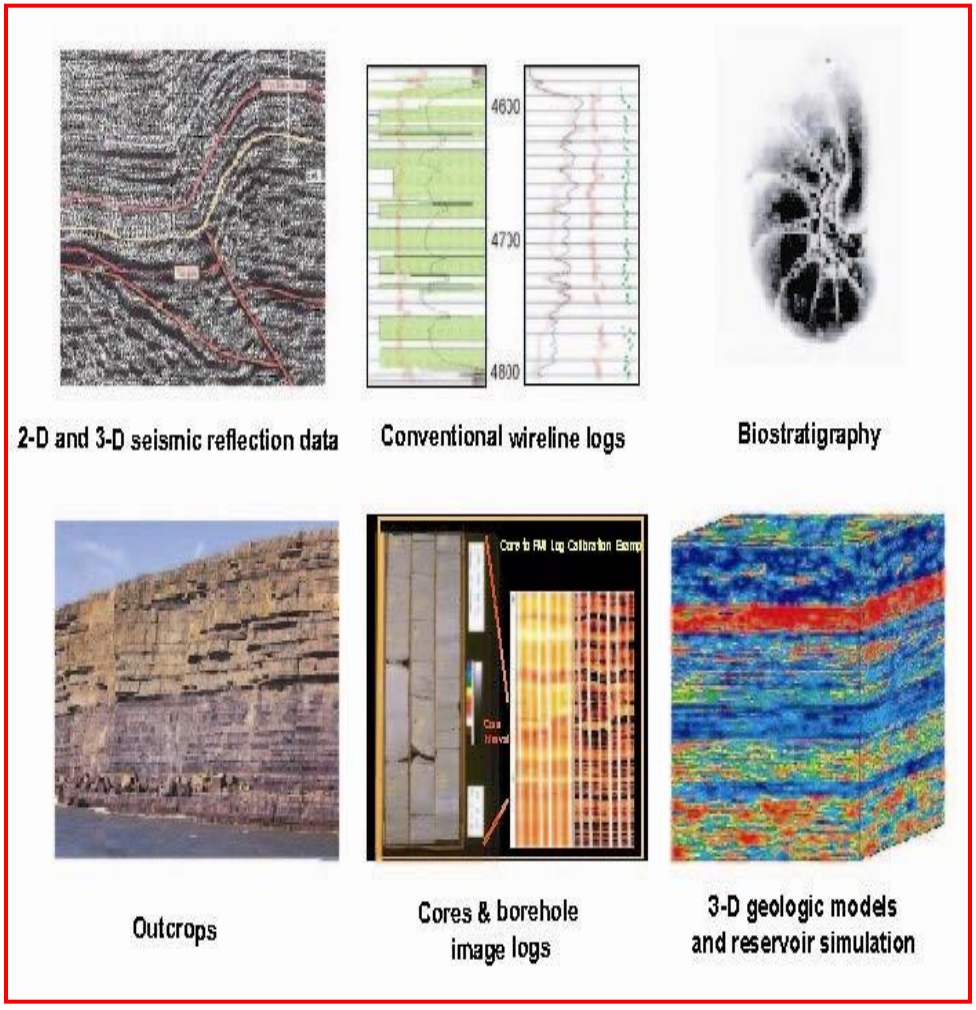
- Seismic analysis / re-interpretation
- New acquisition
- Re-processing

Well

- Well logs
- Coring and Core analysis
- Biostratigraphy

Engineering Information

- PVT data
- Permeability
- Pressure Data
- Well Tests
- Recovery information



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Drilling Appraisal well(s)

- Number and sequence of appraisal wells
  - Assess for when drilling more than one appraisal well will erode value
- The location of the appraisal well(s)
  - Move up resource from low uncertainty to highly certain
  - To test down-dip hydrocarbon limit, Different stratigraphy
  - Compartmentalization
- Data acquisition strategy:
  - Allow each function to identify key uncertainties to be resolved. involve engineering, petrophysics, geophysics, reservoir modelers etc.
  - This needs must agree with the UMP list
  - Conduct a VOI assessment on the data list
  - A data type needed by more than one function or can resolve more than one key uncertainty takes priority.
- Consider planning the well as a keeper/expendable
- Appraisal well results - plan for upside realization and downside mitigation

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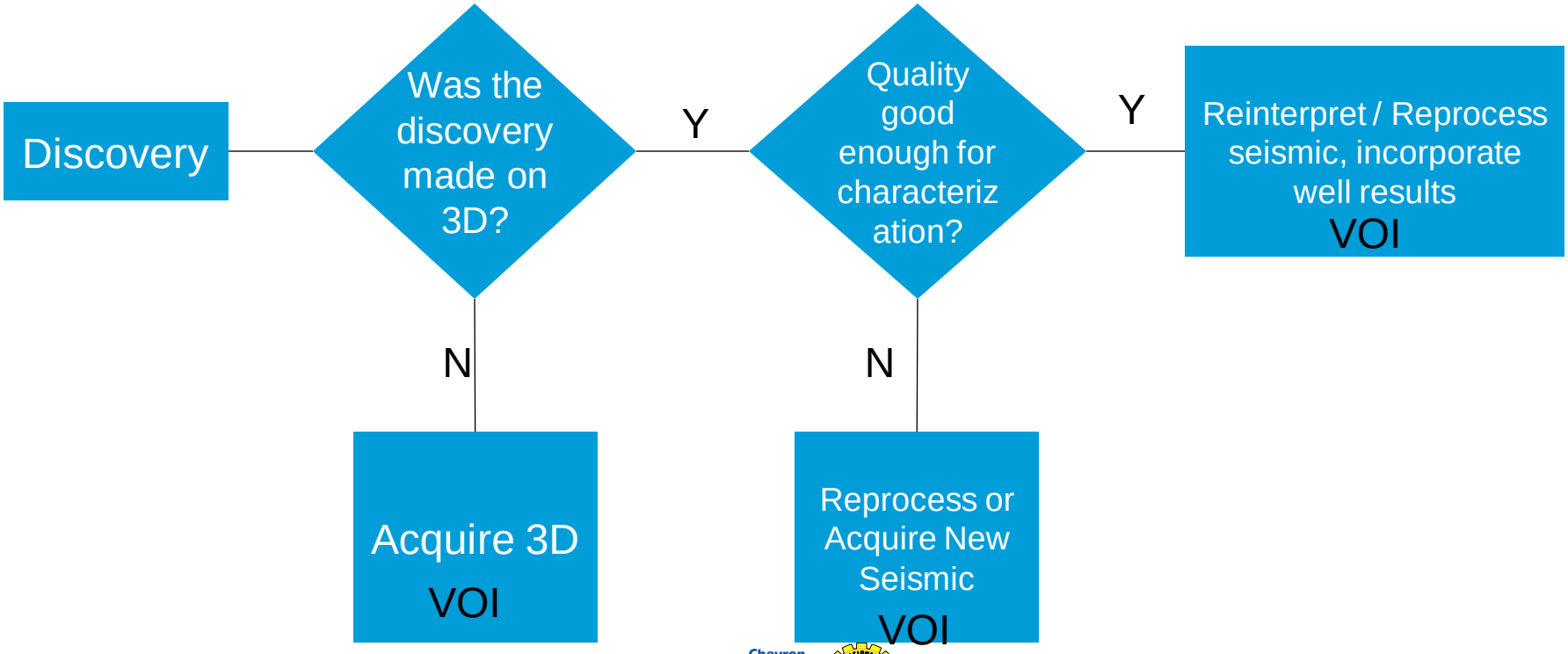
Seismic Data in an Appraisal program

- Reinterpret the seismic data incorporating the well result
- Conduct a seismic analysis and possibly reprocess
- If the discoveries were made on 2D seismic, such will require a 3D Seismic acquisition for appropriate characterization before development
- If a 3D seismic volume exist already, is it of good quality sufficient to define structure and stratigraphy, image the key discontinuities, delineate boundaries and preserve amplitudes?
- Timing is critical. Seismic should be seen as a long lead item



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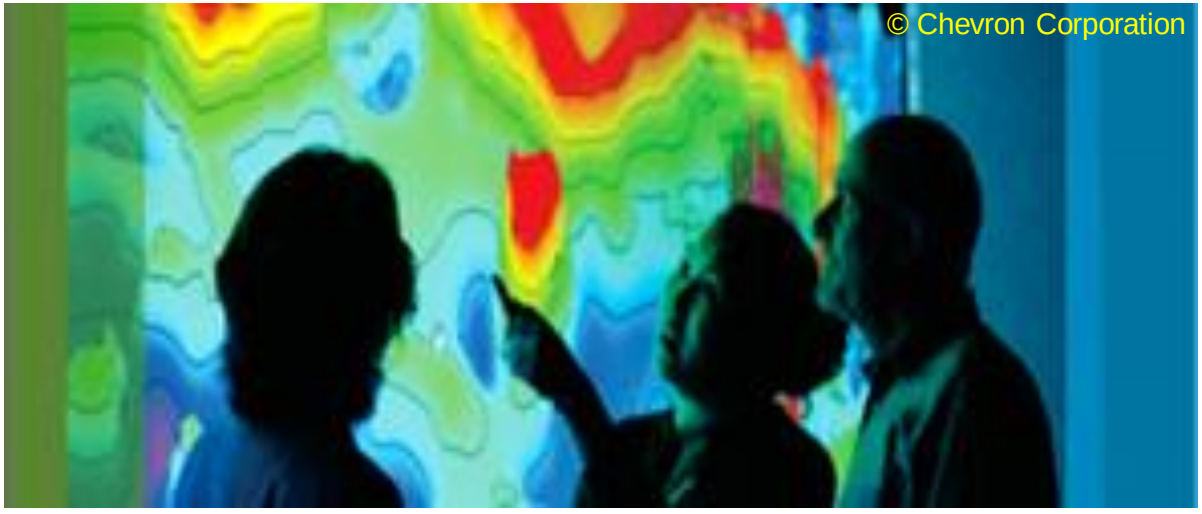
Engineering Data and Uncertainties

Rock (Whole/SWC)	Fluid	Pressure	Rates

• Rock Mechanics
• Special Core Analysis (SCAL)
• PKS
• Compressibility
	• Water Samples
	• Oil Samples
	• PVT
		• PVT
		• RFT/ MDT
			• Well Tests
			  • DST
			  • MDT



Dynamic Uncertainties
PVT
Relative Permeability
kv/kh
Pore Volume Compressibility
Aquifer Size
Aquifer PI
Trapped Gas Saturation
Mechanical Skin
Condensate Banking
GOR / Yield
Viscosity
Formation Volume Factor
Fault Transmissibility
boundary identification
Bubble point
Drive Mechanism
Secondary recovery technique

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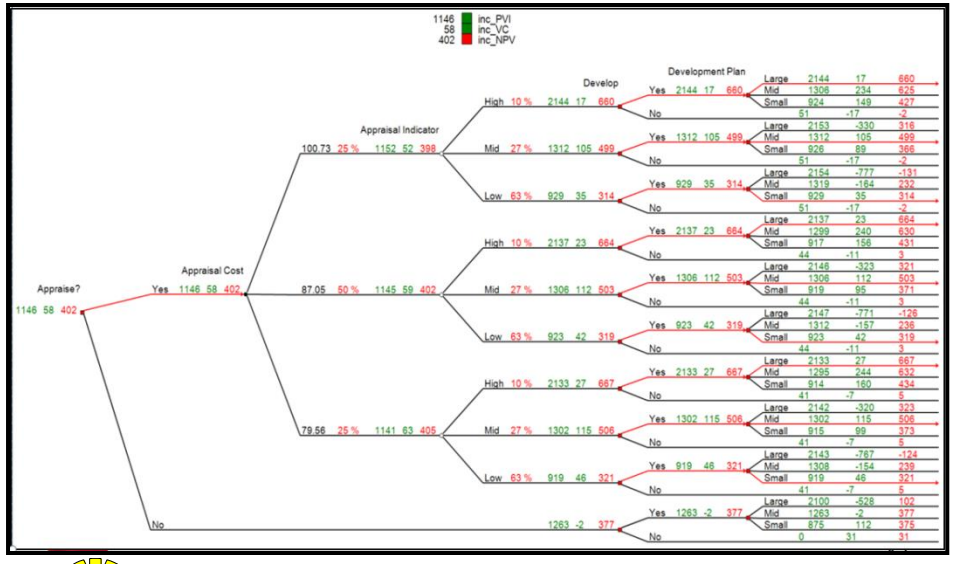
Value of Information (VOI)

Value of Imperfect Information (VoI) = (Asset Value $_{with\ Information}$) – (Asset value $_{without\ Information}$)

- We estimate what would be the project value if we develop the reference case based on the available information.
- What is the uplift to the project if we acquire this data? - VOI
- When to stop appraisal (Up to a point where it begins to erode value rather than create. Where the cost of the data acquisition is greater than the value to be derived)
- ‘Do-nothing’ scenario reference case



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Case Study of Kappa Field

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Kappa-01 Resource Appraisal Program

- Structure is a 3-way NE-SW trending closure against a normal fault
- Resource is ~200MMBOE spread among 5 Main hydrocarbon intervals
- Appraisal well will seek to move/prove up current Pmean volumes estimates to P10
- Appraisal program has been designed to address key uncertainties – Reservoi quality and connectivity, EOD, Fluid contact and well deliverability
- Well to also provide additional calibration point for seismic amplitude
- Acquire conventional core
- Economics supported drilling an appraisal well

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Kappa Appraisal – Strategy Table

Focus Decisions ----->>>					
Well type	Wireline program types	Perform coring operations	Well Utility	Need for well test (DST)	Number of Appraisal Wells
Deviated	Basic Logging	Yes	Keeper	Yes	1
Vertical	Advanced Logging	No	Disposable	No	2
Multilaterals					> 2

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Kappa Appraisal – Strategy Table

Focus Decisions ----->>>					
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Kappa Appraisal - List of Uncertainties

- Pore pressure/Wellbore Stability
- Velocity model - hitting objective section within prognosis
- Accelerated Drill Schedule and scheduling issues
- Logistics and Long lead items
- Rig Availability
- Telecommunication breakdown
- NPT (Non Productive Time)
- Political Unrest
- Organizational Strike
- Filled Area / Reservoir compartmentalization
- Recovery Factor
- EUR/Well
- NTG

- Reservoir compartmentalization - Fault
- Reservoir compartmentalization - Stratigraphy
- Depositional model
- FVF
- Reservoir continuity
- Reservoir pressure
- Reservoir thickness
- reservoir top and base
- Asphaltenes, emulsions and other flow assurance issues
- Drilling and completion timing and cost
- Fault location, compartmentalization
- Fracture characterization
- How do we use perm multipliers for fracture characterization- are physics honored by model?

- Avg. Permeability
- Fluid Contacts
- Velocity Model
- Reservoir Drive
- Porosity
- Aquifer Activity
- KPA resource is sufficient to aid the start-up of Kappa project
- Fault seal
- Productivity Index
- Recovery Factor, Primary
- Relative permeability
- Vertical perm heterogeneity
- Water compatibility
- Water Saturation
- Well to seismic tie quality
- Wireline log quality
- Flow unit determination sensitivities

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Key Subsurface Uncertainties

- Reservoir
  - Geometry and size (seismic amplitude ambiguity could be lithology, thickness or fluid induced)
  - Quality (wide range of porosity:16 – 34% and permeability: 61 – 5,874 mD)
  - Connectivity: lateral extent multi-lobate reservoirs, shale separation ranges <5ft to >70ft
  - Environment of Deposition, No conventional core
- Hydrocarbon
  - Fluid contact (Most of the discoveries have LKO and HKO, only one fluid contact)
  - Flow assurance (some intervals are heterolytic)
- Compartmentalization
  - Well count – Crestal faults and stratigraphic (channel system) compartments
- Recovery
  - Preliminary estimates ranges obtained from MDT

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Kappa Appraisal UMP table
Key Subsurface Risks and Uncertainties

Risk or Issue	Probability of Occurrence (H,M,L)	Impact (H,M,L)	Mitigation Strategy
Lateral reservoir continuity/compartmentalization	H	H	Offset wells to discoveries, Stratigraphic modeling using analogs, acquire core to determine environment of deposition
Hydrocarbon contact and type	H	H	Advanced logging, Fluid identification logging tools e.g. MR scanner, acquire MDT data,
Permeability cut-offs for commercial flow rates	M	M	Flow test wells and zones of varying permeability, SCAL analysis for relative permeability
Effective Reservoir Area and geometry	H	H	Seismic stratigraphic analysis, isopaching, integrate with core data
Effective Porosity	M	H	Collect whole core over reservoir intervals, compare analysis to logs
Column lengths	M	M	Column calculation work , offset discoveries, Well test information
Recovery Factor	H	M	Leverage DST information obtained from Kappa main, Acquire DST, obtain analogs from producing assets and similar depo-environments

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Well Data Inventory and Planned Acquisition

Lithology	Fluid	Velocity	Hole and casing integrity	Rock-Fluid	Well Test	Special logs	Remarks on data quality
DATA ACUIRED FROM KAPPA EXPLORATION WELL							
Gamma ray	Resistivity	Compressional Sonic	Caliper	SWC	MDT	Special Resistivity Rv Rh for thin beds	
Neutron	MR Scanner	Shear Sonic	CBL	Mud log		Magnetic Resonance	
Density	RT Scanner	VSP				Lithologs for mineralogy, TOC and TIC	
Spectral GR						OBMI	OBMI only for some intervals
ADDITIONAL DATA EXPECTED TO BE OBTAINED WITH THE APPRAISAL WELL(S)							
GR, Neutron, Density, SGR	Resistivity	Sonic (Shear and Compressional), VSP	Caliper, CBL	Conventional Core	MDT	OBMI	

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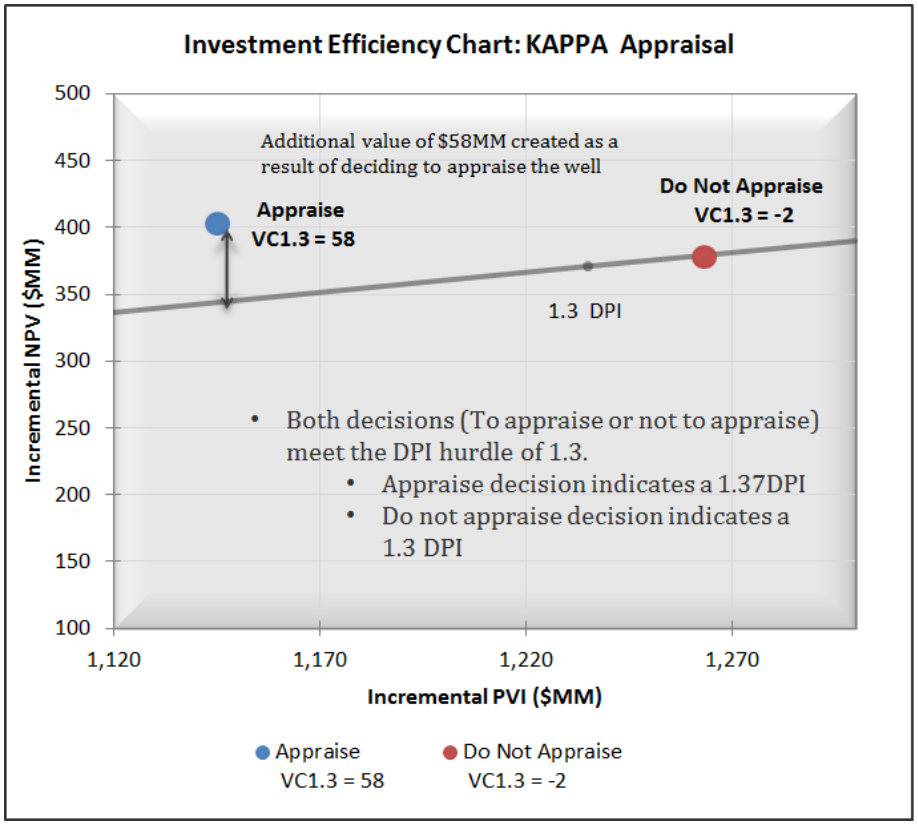
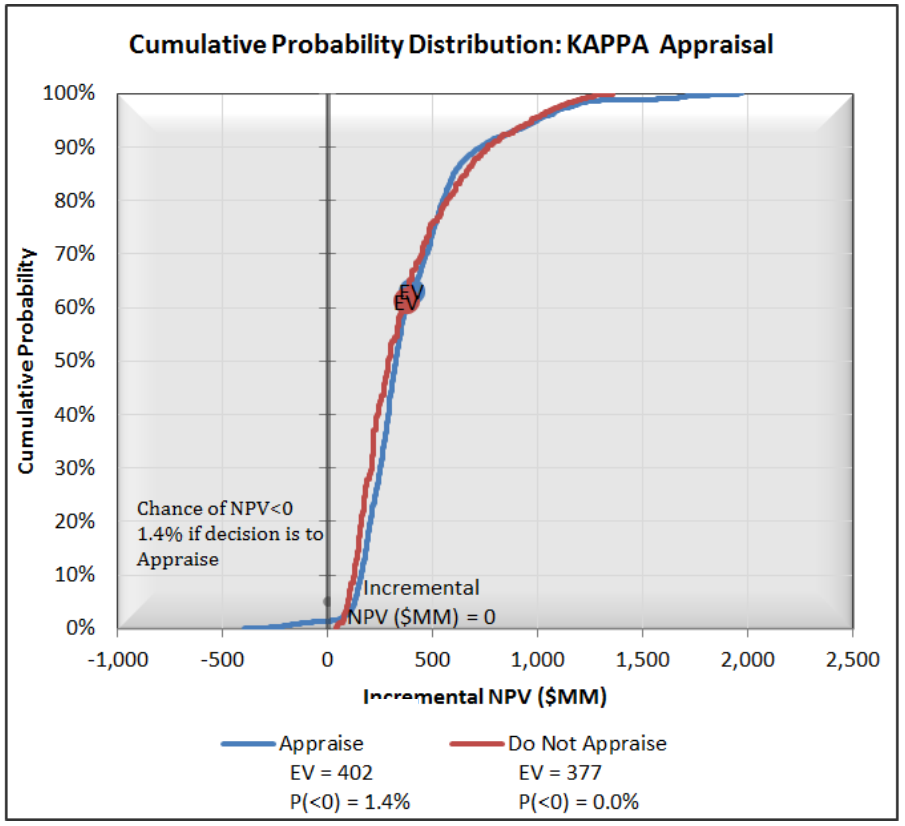
VOI: KAPPA Appraisal Program
Incremental Economics





Economic considerations	NPV_{10} ($MM)	DPI_{10}	ROR (%)	Value Creation ($MM)
Develop but Do not Appraise	377	1.30	18%	-2
Assumes Imperfect Information	402	1.35	18%	58
Value of Imperfect Information (VOI)	**25**			**60**

Lessons Learned and Best Practices

- Lessons Learned
  - We need to keep the upstream resource factory going by actively replacing our reserves.
  - Standalone developments of discovered resources may be economically challenging. Creative alternatives such as tie-backs to existing infrastructure or co-development of satellite fields could help improve project viability.
  - An appraisal plan should be robust and sufficient to enough to address key uncertainties that will impact the next development decision , FEED and eventually the FID

- Best Practices
  - After a commercial discovery it is expedient to follow an appraisal plan that will address the uncertainties associated with the discovery and the resource estimates
  - Let the UMP drive the data acquisition program
  - Let the VOI drive the data acquisition decision
  - It is key to constitute a multi-functional appraisal team with a mandate to developing an appraisal plan which may also include development scenarios.

- Challenges
  - Lower crude oil price and high costs is a challenge for project viability
  - Large discoveries are getting rare, while smaller discoveries are less viable as standalone developments.

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Common pitfalls in developing a robust appraisal program

- Start drilling appraisal wells without a definite pre-determined fit-for-purpose number of wells
- Not involving key stakeholders in the design of the appraisal program
- Anchoring and bias in EUR estimates reference case and not capturing a proper range of uncertainty could lead to poor investment decisions
- Lack of proper data inventory
- Lack of value of information analysis
- Being schedule and/or activities driven can lead to suboptimal appraisal program e.g. acquiring less impactful data.

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