Stochastic Modeling Workflow for Well Drilling Zones Delineation: Integrating Probabilistic Models and Production Data to Reduce Risk*

Marcela Feilhaber[1] and Marcelo Pubill[1]

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[1]Pluspetrol, Buenos Aires, Argentina, South America (mfeilhaber@pluspetrol.net)

Abstract

To build a robust reservoir model, integration of both data and disciplines is key. To define drilling spacing, injection patterns and associated reserves it is necessary to evaluate the uncertainty of the reservoir distribution. To reduce risk in decision making and planning it is necessary to combine multiple stochastic models and production data. The classic workflow previously used by our company was based on deterministic volumetric models, adding a recovery factor and well type to estimate the necessary number of wells to develop the studied area. The limitation was that it did not take into account the geological model, sand distribution or uncertainty estimation. By integrating a 3D model (Petrel) with an analytic reservoir model (SAHARA) we were able to generate multi-realizations, evaluate different development cases, optimizing calculation time and economic return. The resulting models are not only an integration of technology but also a collaborative work of reservoir engineers and geoscientists.

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Marcela Feilhaber

Marcelo Pubill

pluspetrol

Agenda

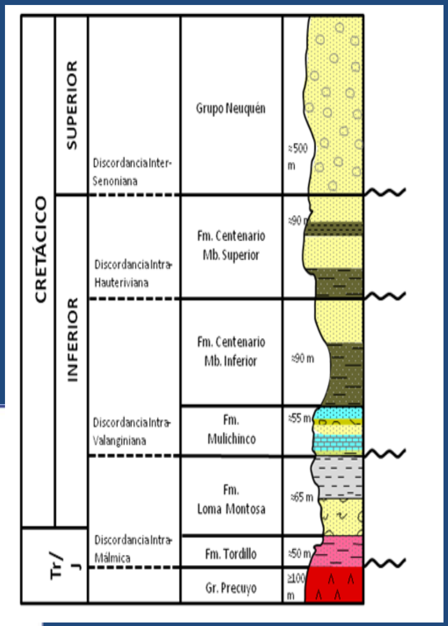
- Introduction and objectives
- Field description
- Previously used workflow
- Advantages of an Integrated workflow
- Static Model Workflow
- Analytical Model
- Uncertainty Analysis
- Development plan
- Conclusions

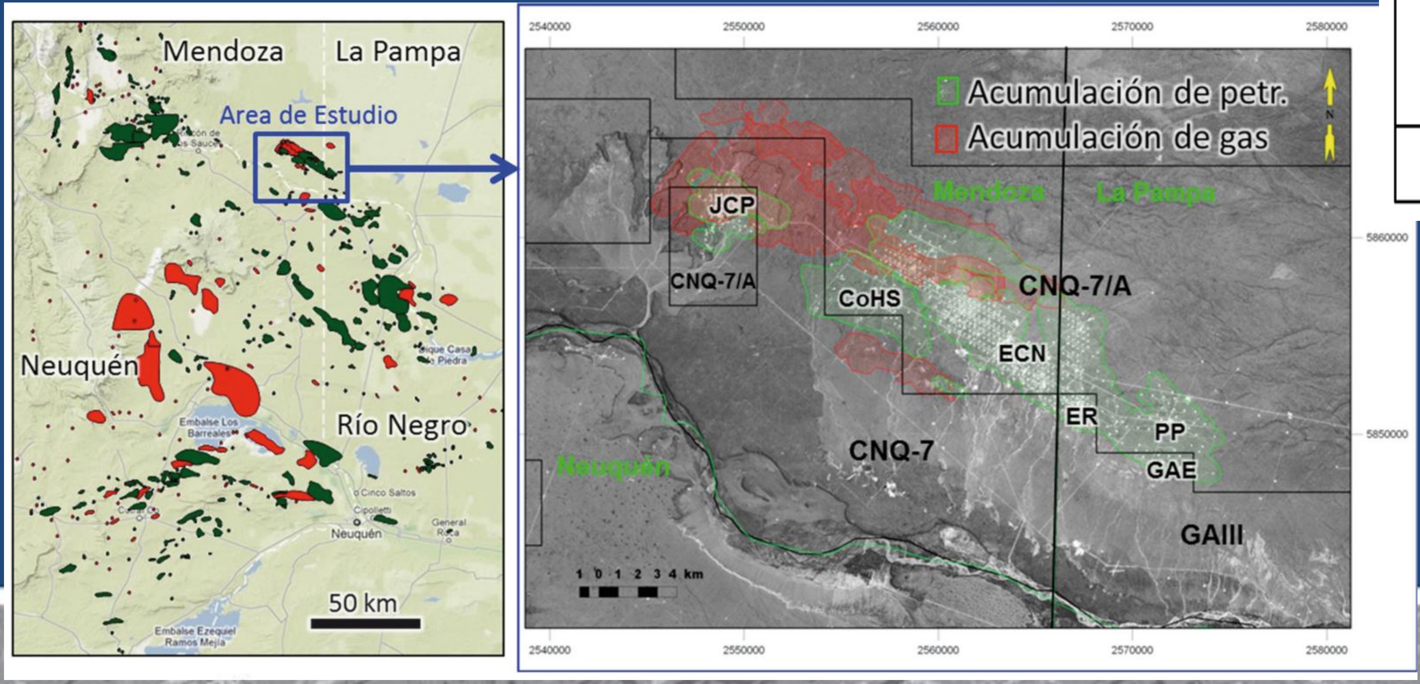
Introduction

- Studied area:
  - 10 years production
  - over 1000 perforated wells with water flooding
- Objective of the study:
  - Identify new areas with development potential through drilling of new wells.
  - Rank opportunities
  - Present 3 development scenarios for each zone
- Integrate different models of producing fields and extended areas in a single stochastic model
- Stochastic model as a support to delineate proposals and reduce risk, providing:
  - Sand body spatial distribution (connectivity) and associated probability
  - Volumetrics
- Used for supporting drilling scheme decisions and economic evaluations.

Field description

- Neuquén Basin – Argentina
- Stratigraphic trap
- Non consolidated sand reservoir
  φ=15-34% K= 0.5-4 Darcy





Previously used Workflow

Properties Distribution

Montecarlo Simulation

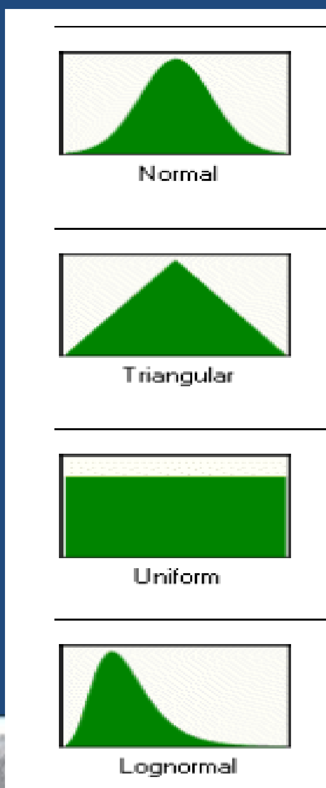
Volume Distributions

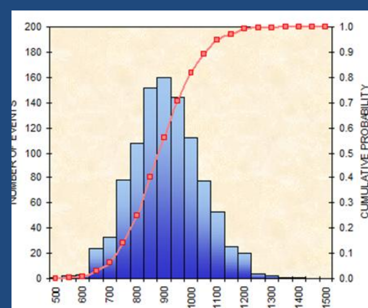
OOIP Recoverable Oil

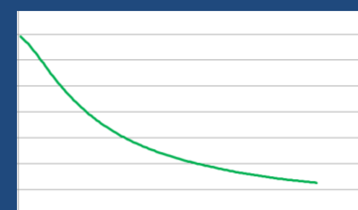
Producer Well Type

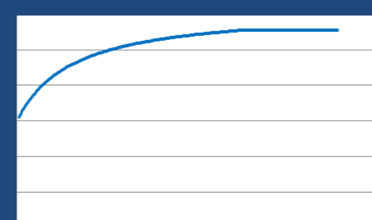
Injector Well Type

Development Wells





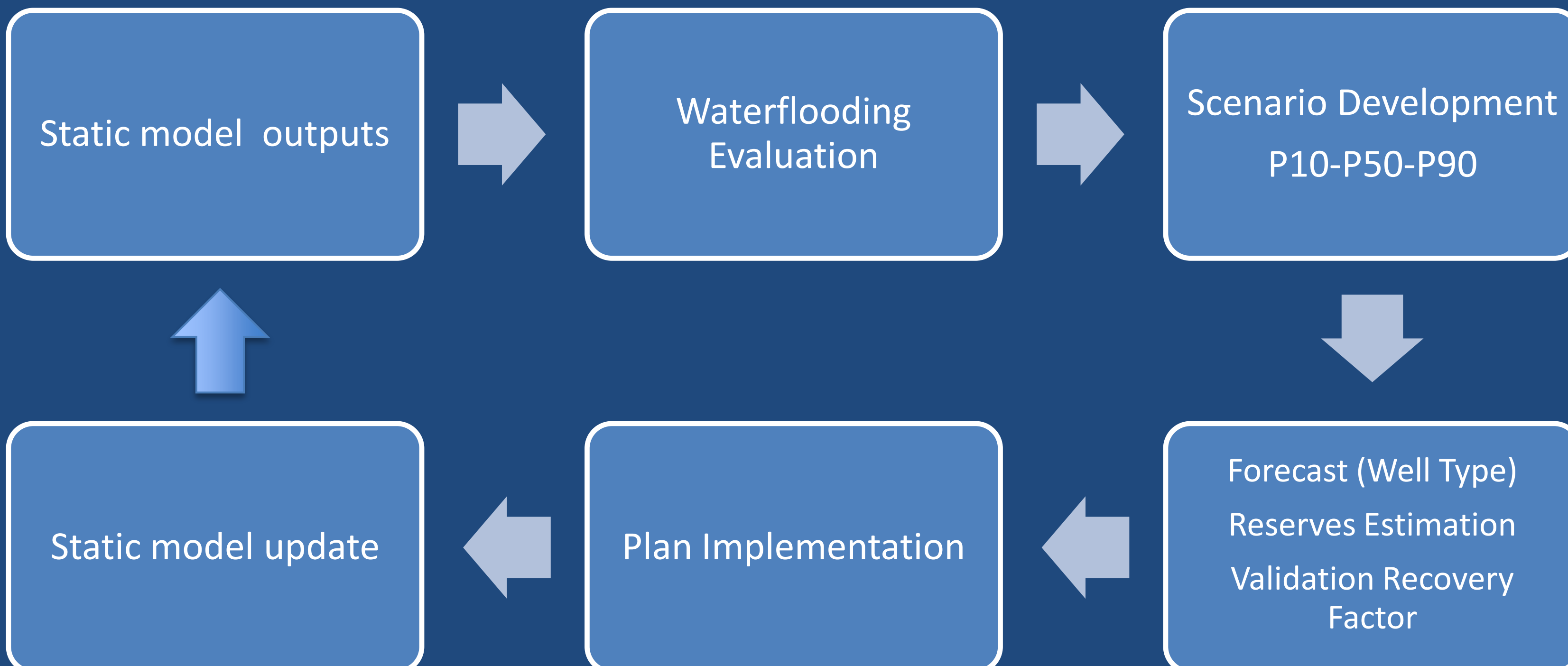




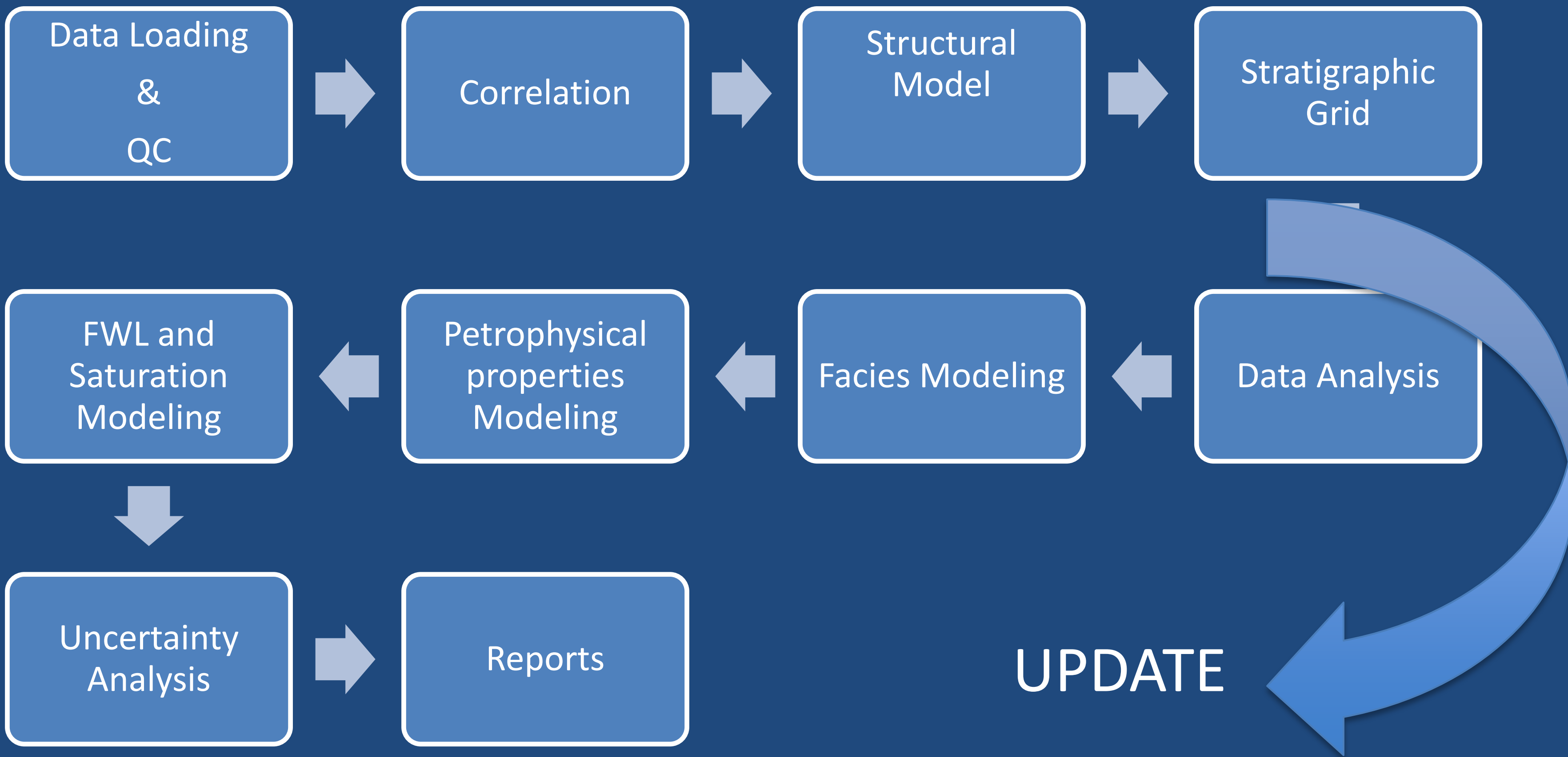
Methodology disadvantages

- The Monte-carlo simulation in crystal ball does not consider the reservoir sand distribution.
- The lack off geological considerations affect the injection pattern.
- This method does not consider the sweet spots

Integrated Workflow

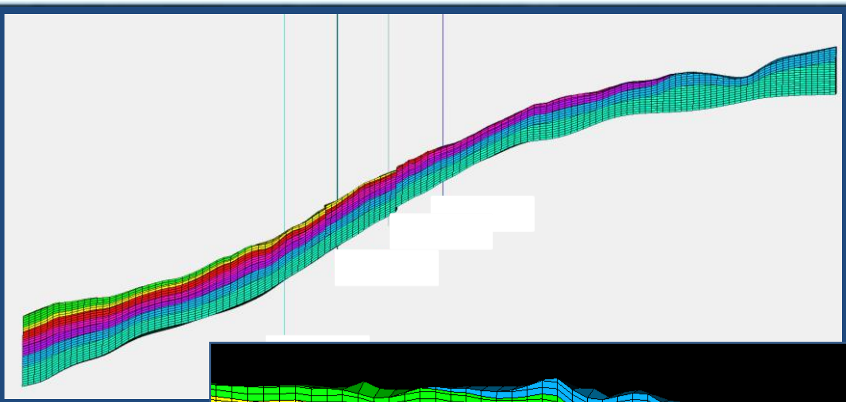


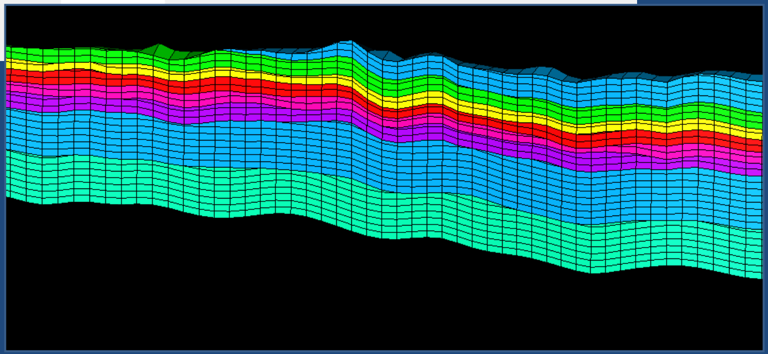
Static Model Workflow

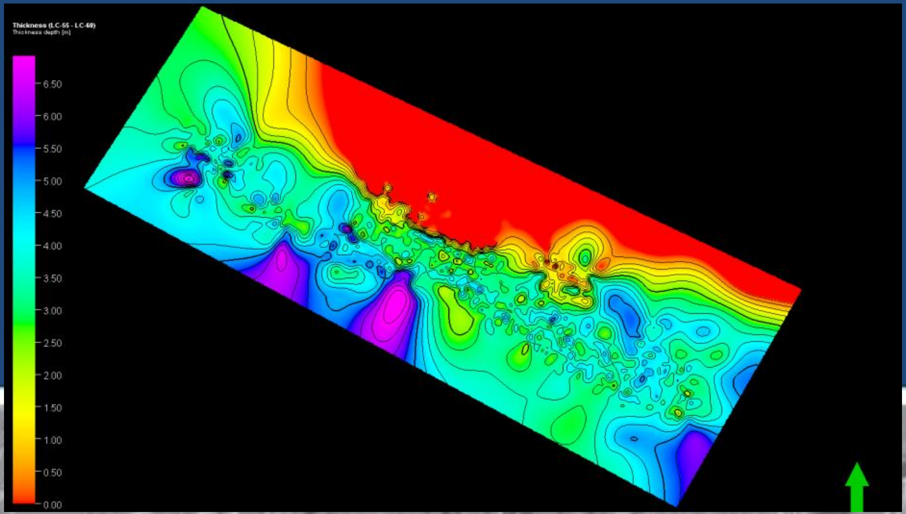


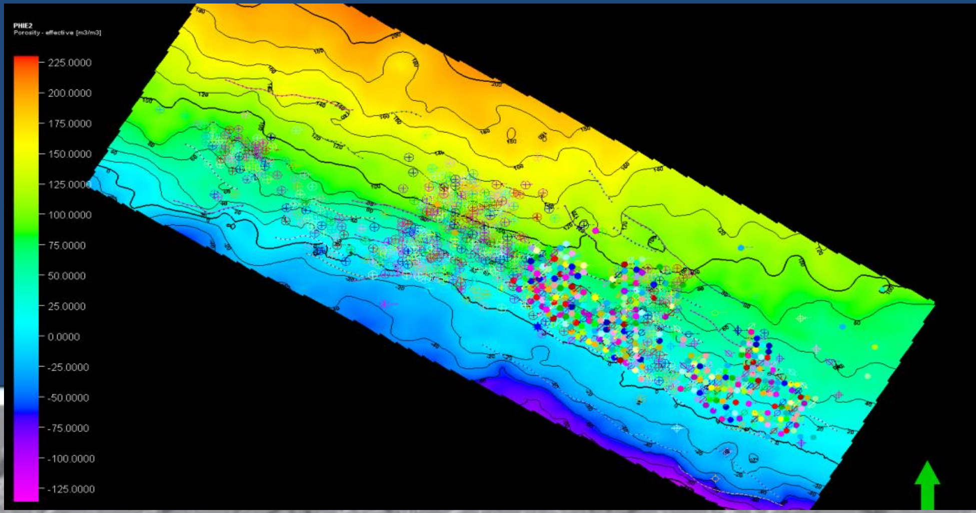
Structural modeling and Grid

- The integration of the different fields implied an extended revision of the correlation.
- The structure is delimited on the north by a truncation.
- The model used seismic interpretation of faults, the unconformity and base surface, the intermediate levels were model using isochores maps and well tops



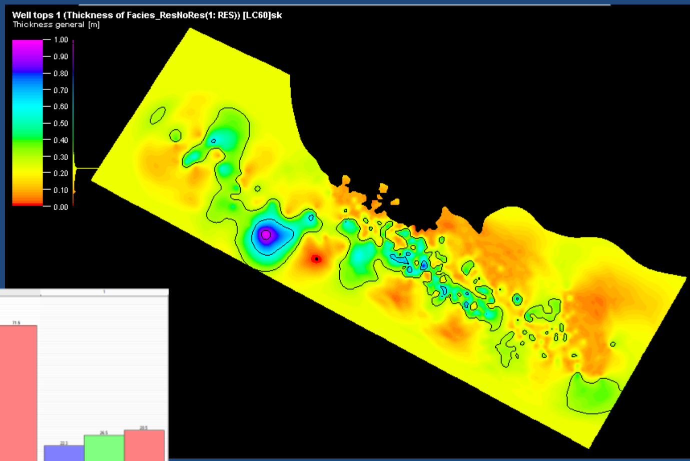


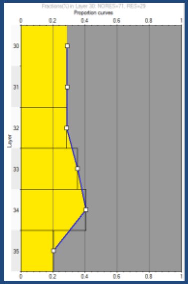


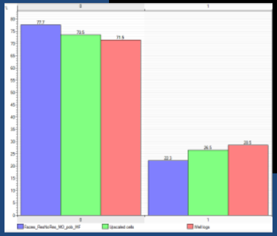


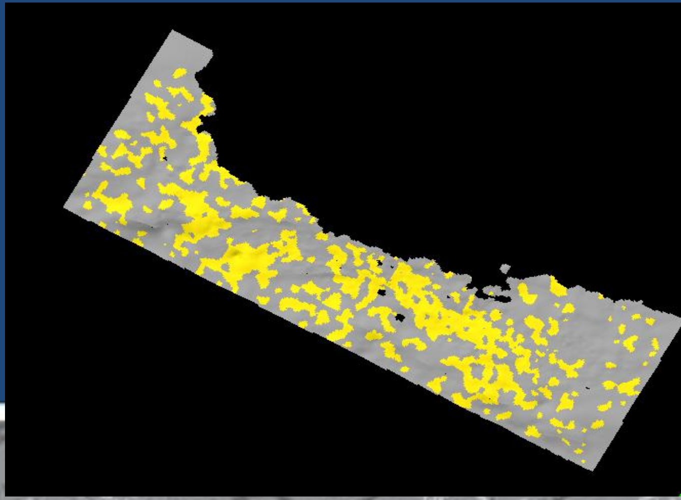
Facies Modeling

- Data Analysis and previously studies on the area guided the workflow.
- Reservoir /Non reservoir Facies calculated from a Vclay (<0.4) and porosity (>0.15) cut-off
- Well log upscaling
- Sequential Indicator Simulation
  - Variogram
  - Vertical Proportion Curves
  - Smoothing
  - Kriging
- Trend maps from wells
  - Challenge was to represent spatial heterogeneity
  - Properly cover zones with very few well data (clustered data)
- Facies proportion
  - Bias and over estimation of sand proportion
  - Uncertainty



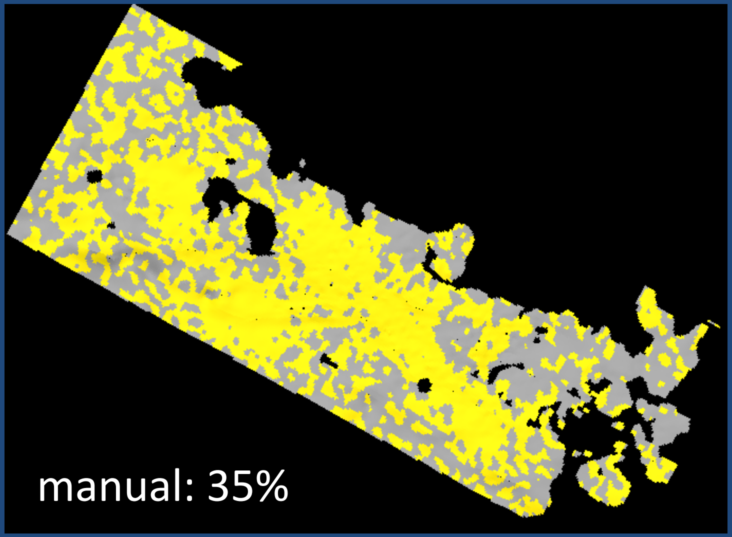




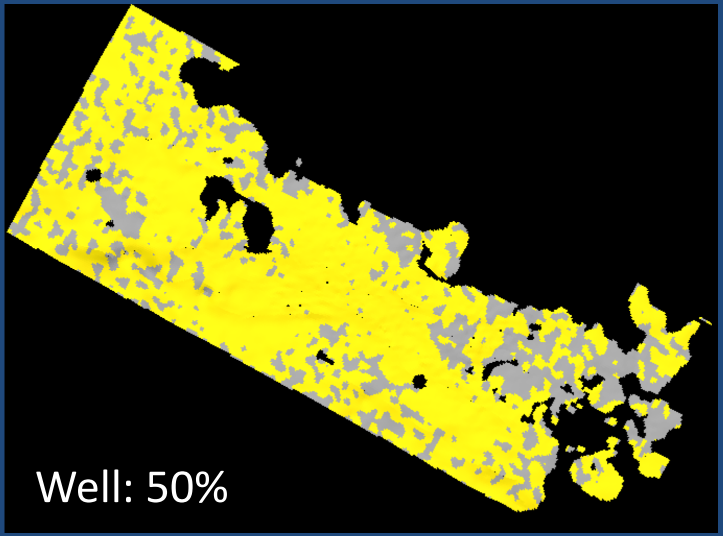


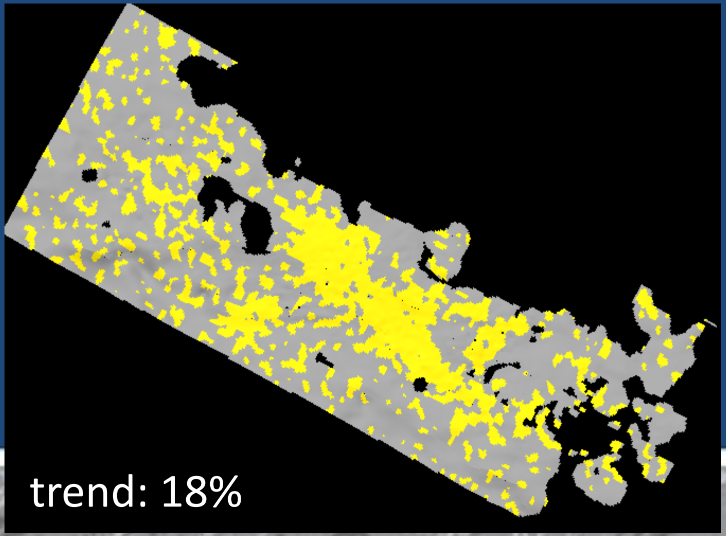
Sand proportion

- Sand proportion calculated from wells was too optimistic on main layers.
- Data is clustered and has a bias.
- Important to evaluate the impact of proportion on volumes.



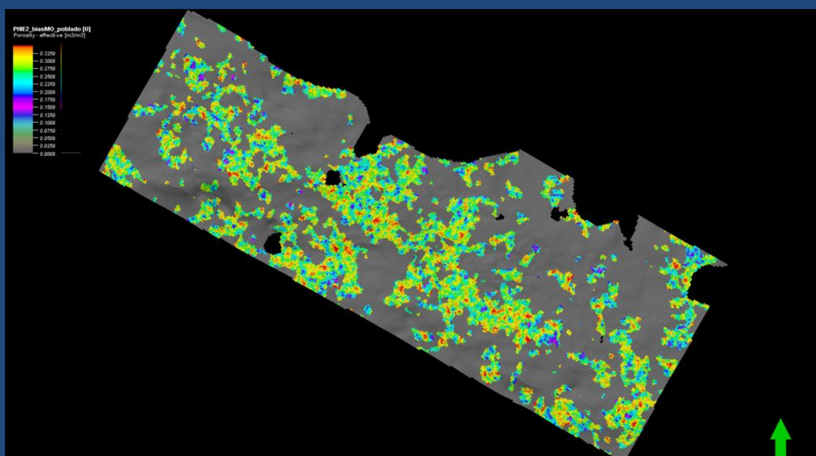
Comparison of proportion calculated from well logs, trends and imposed (manual)

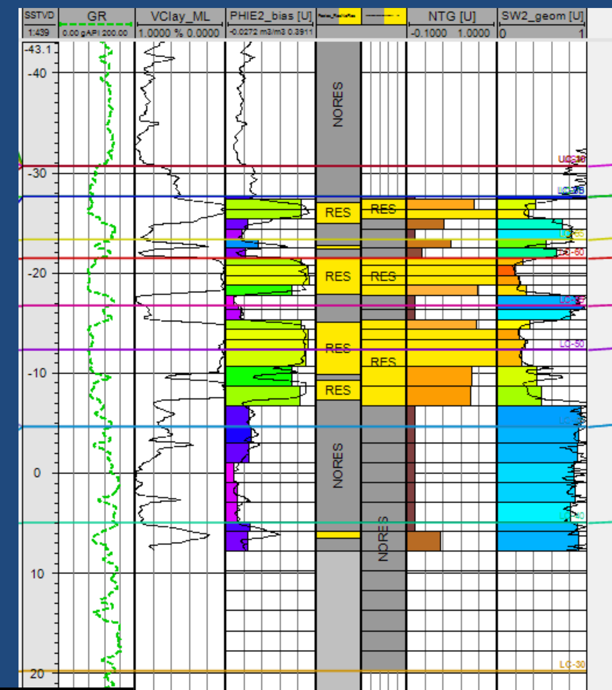


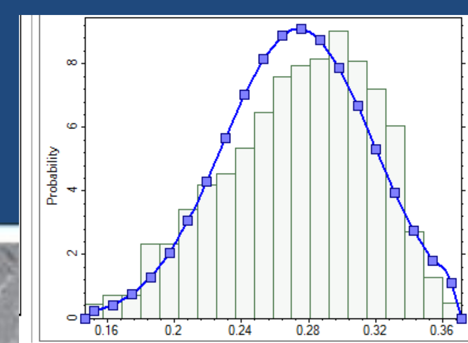


Petrophysical Modeling

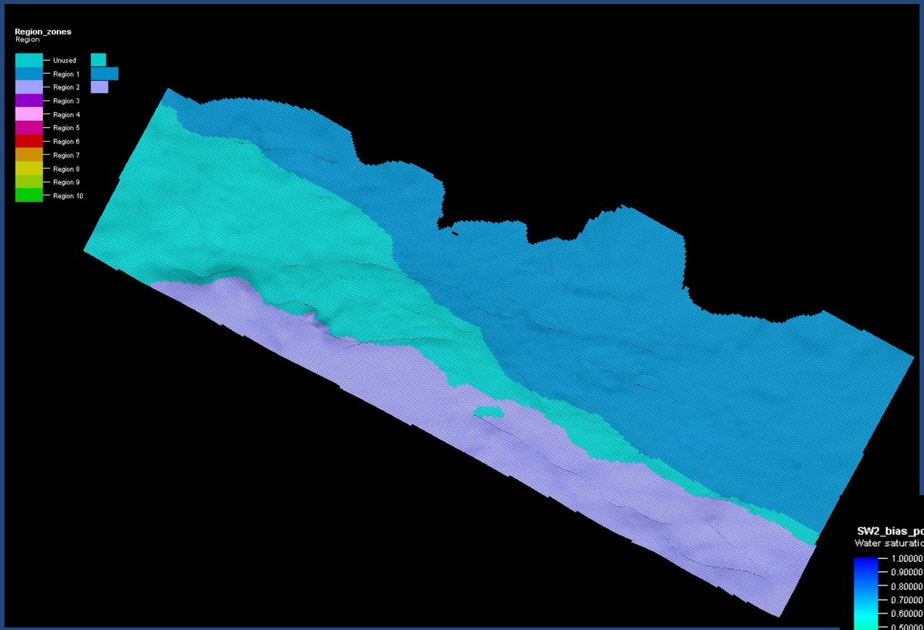
- Porosity, NTG guided by Facies
  - Sequential Gaussian Simulation
  - Distribution and variogram from wells

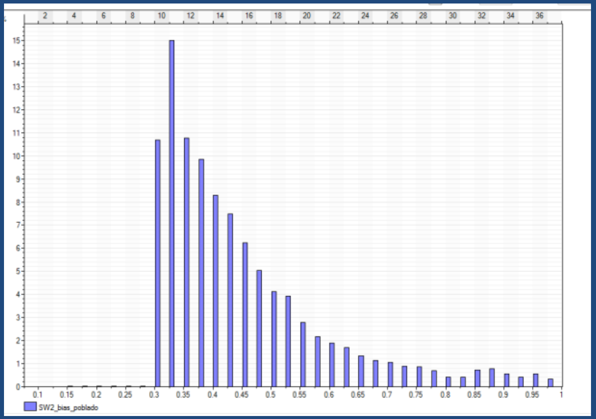




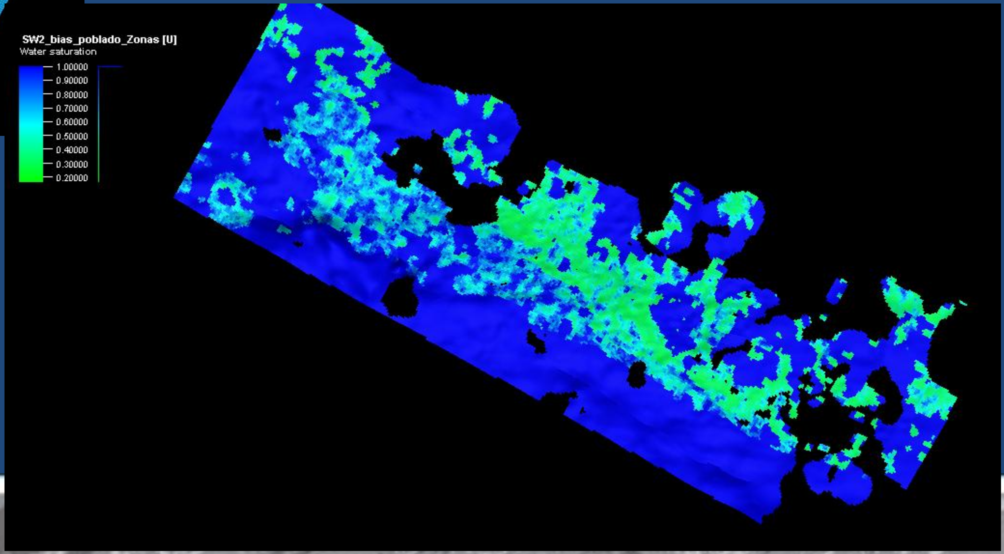


Petrophysical Modeling



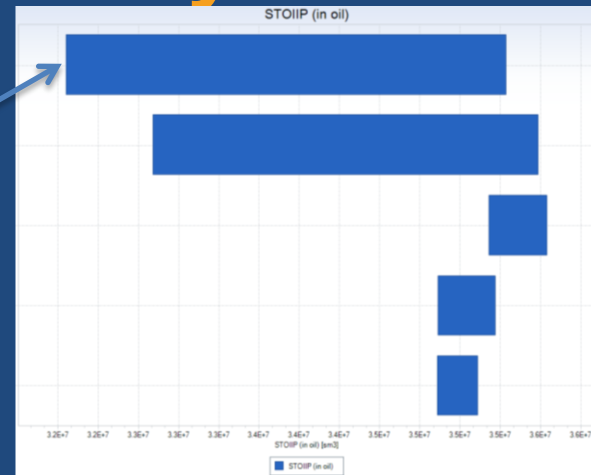


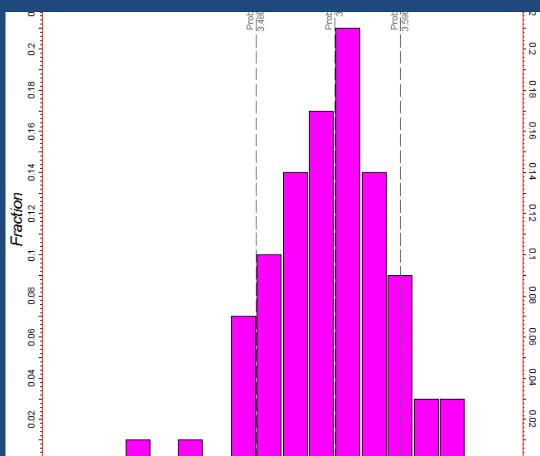
Saturation modeled by zones and Facies



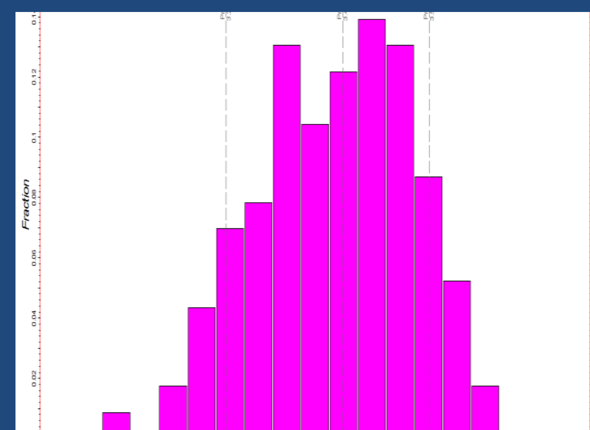
Sensitivity Analysis

Sand proportion on main producing units





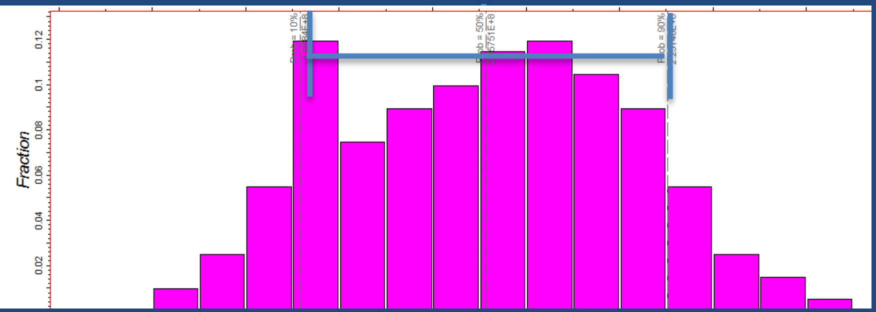
100 realizations



100 Realizations with sand proportion uncertainty

Uncertainty Analysis Workflow

- Sensibility analysis determines the sand proportion is the variable with most impact
- 200 realizations with a sand proportion triangular distribution
  - Monte-Carlo sampling /latinhyper-cube / nested simulation of other properties (porosity, NTG, SWAT)
- Volume Calculation and ranking



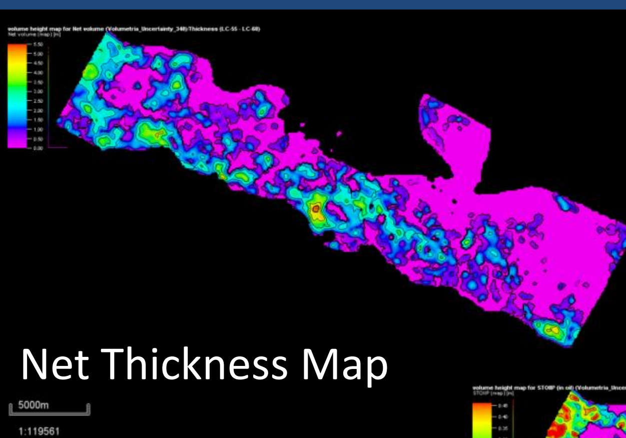
Type	Pr	Int	Name	Base value	Distribution	Arguments					
Uncertain			$Ar_70	34	Triangular	Min	25	Mode	34	Max	36
Uncertain			$Ar_65	20	Triangular	Min	20	Mode	25	Max	27
Uncertain			$Ar_60	23	Triangular	Min	20	Mode	23	Max	27
Uncertain			$Ar_55	30	Triangular	Min	25	Mode	34	Max	54
Uncertain			$Ar_50	50.11	Triangular	Min	30	Mode	40	Max	49
Uncertain			$Ar_45	10	Triangular	Min	5	Mode	7	Max	10

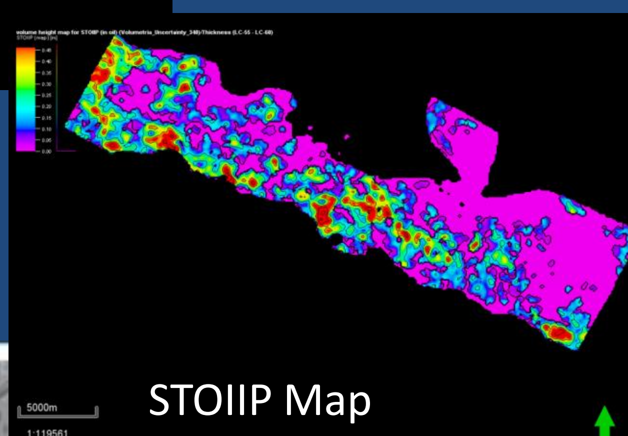
STOIIP Distribution
Spreading P90-P10 of 21%

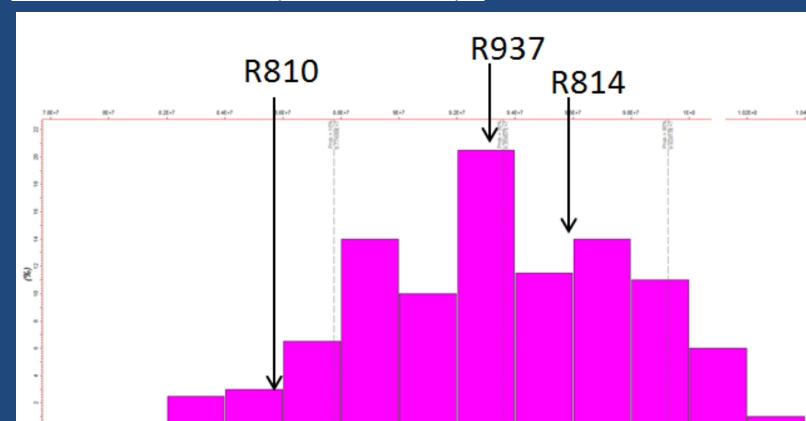
Ranking and realization selection

- First ranking based on total Volume (OOIP)
  - Selection of 3 realizations for each percentil
- Second ranking based on main reservoir of interest
- Volumetrics Maps generated

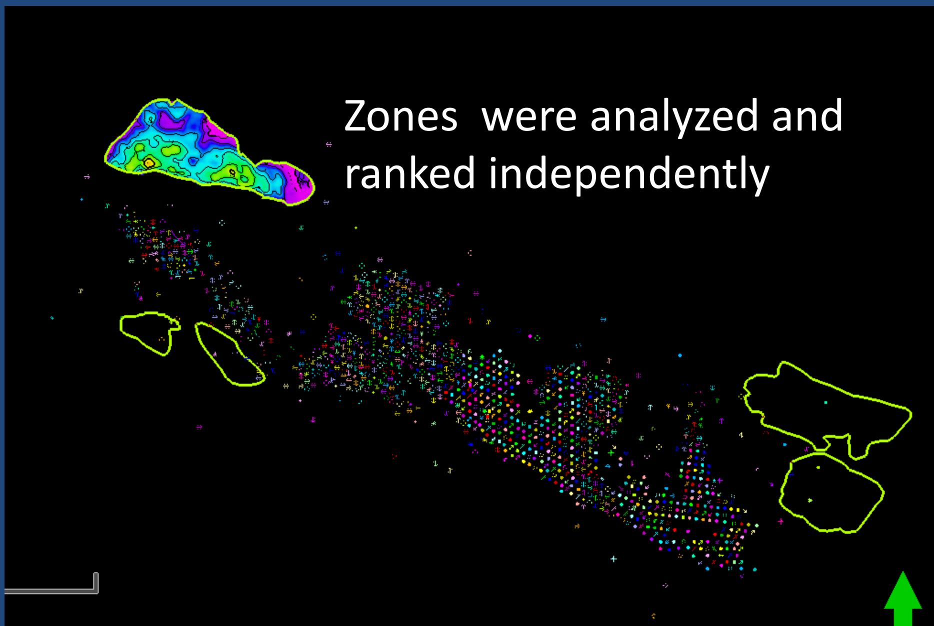
Volumetria_Uncertainty_800	53.25
Volumetria_Uncertainty_845	52.75
Volumetria_Uncertainty_870	52.25
Volumetria_Uncertainty_812	51.75
Volumetria_Uncertainty_869	51.25
Volumetria_Uncertainty_937	50.75
Volumetria_Uncertainty_810	50.25
Volumetria_Uncertainty_814	49.75
Volumetria_Uncertainty_901	49.25
Volumetria_Uncertainty_856	48.75

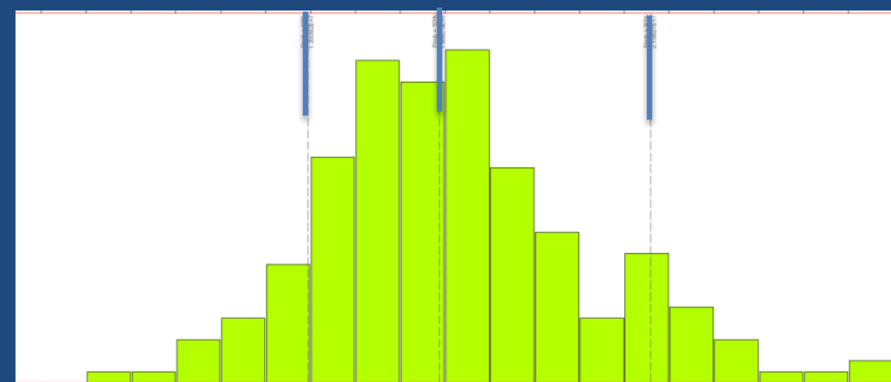






Analysis and ranking per zones

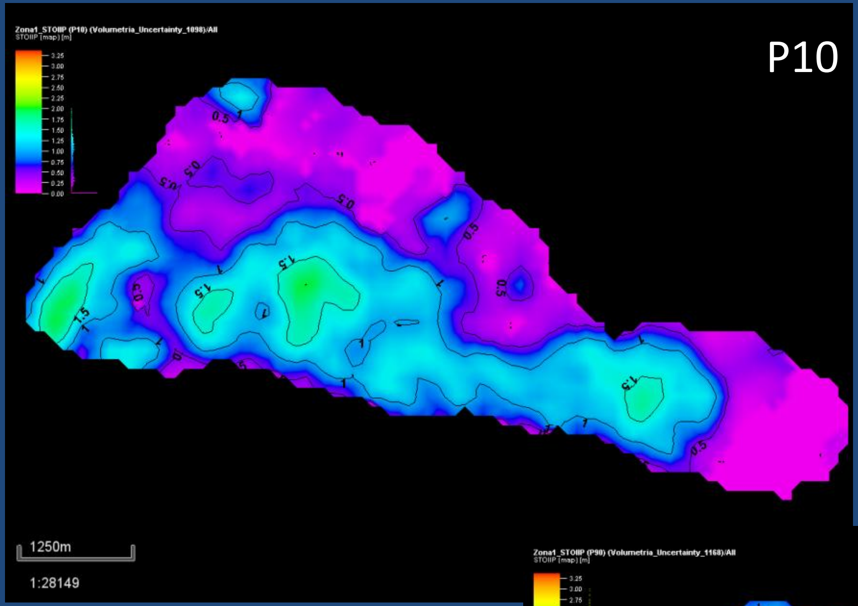


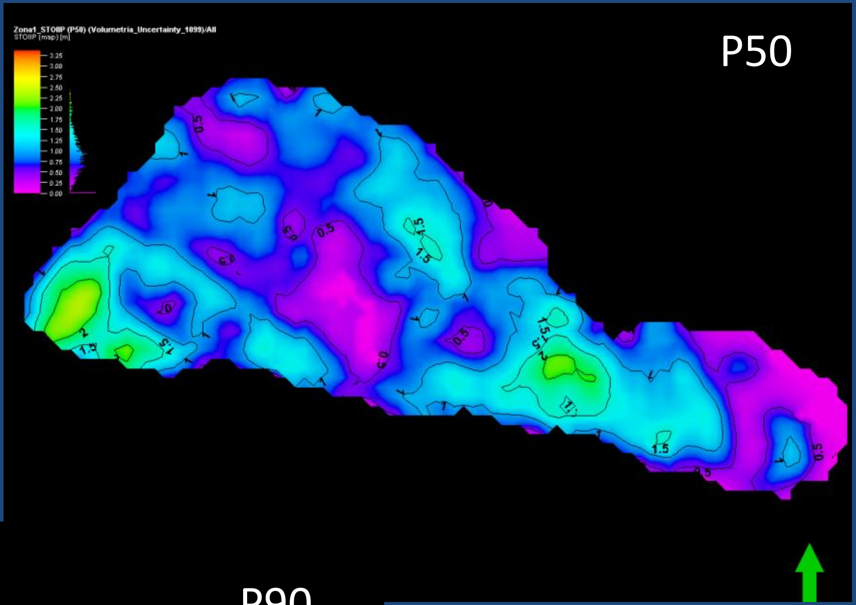


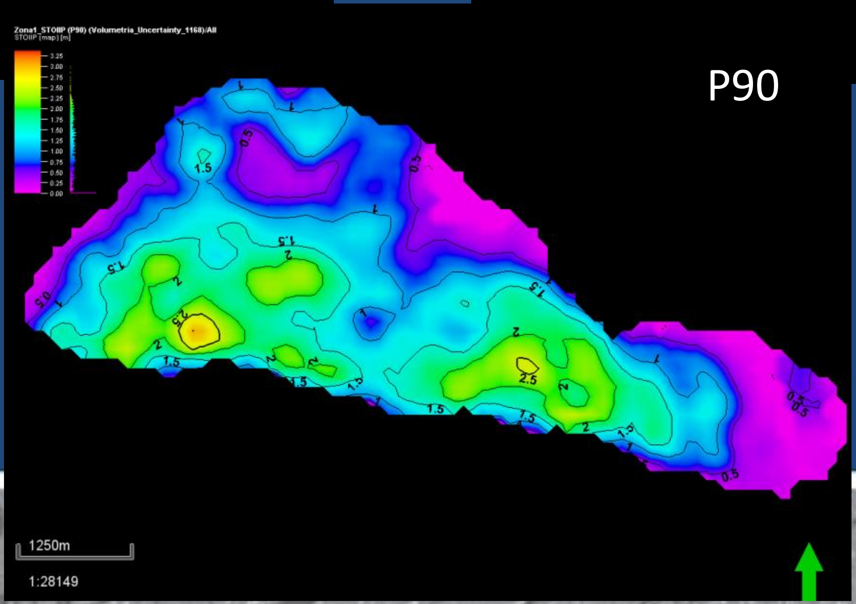
STOIIP Spreading P90-P10: 35%

- For well pattern waterflooding planning , the workflow was re-run focusing on the studied zone
- To keep the consistency of the geological model, the simulation is done on the entire model , honoring all available data
- The volume is calculated and ranked per zone volumen
- The percentile maps are done for the specific studied zone

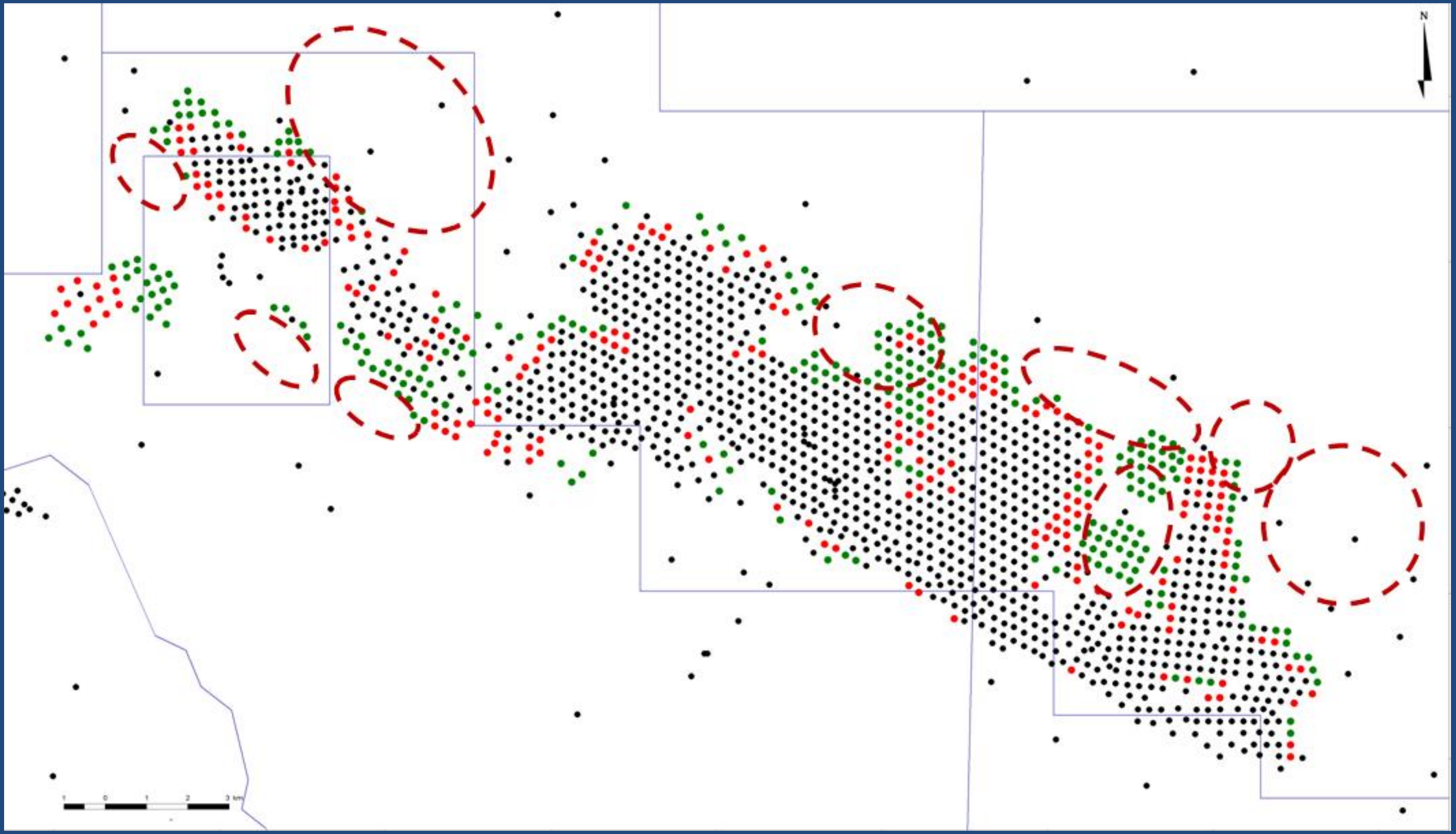
Analysis and ranking per zones





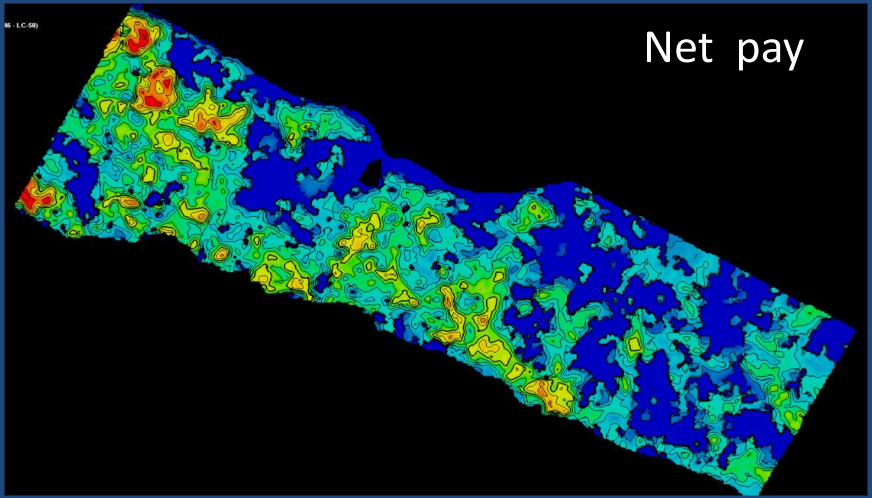


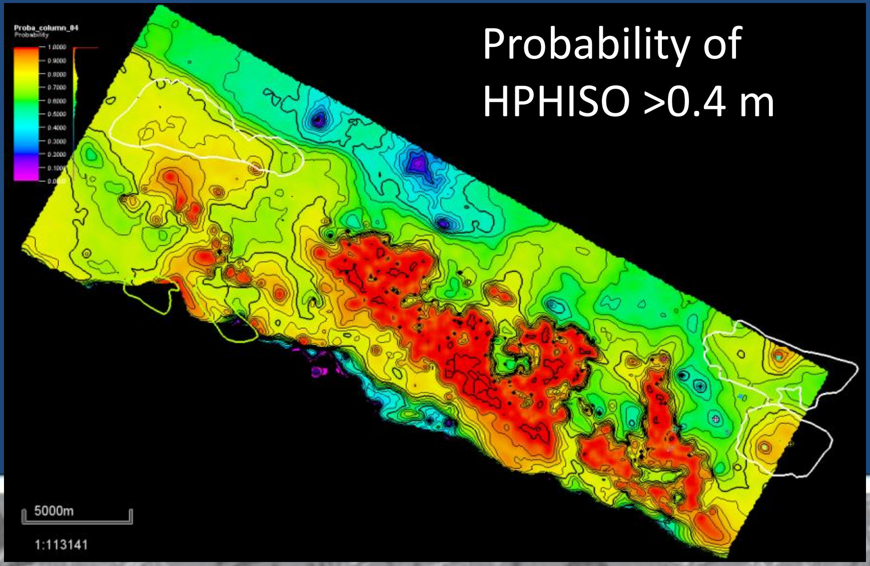
Zones evaluation



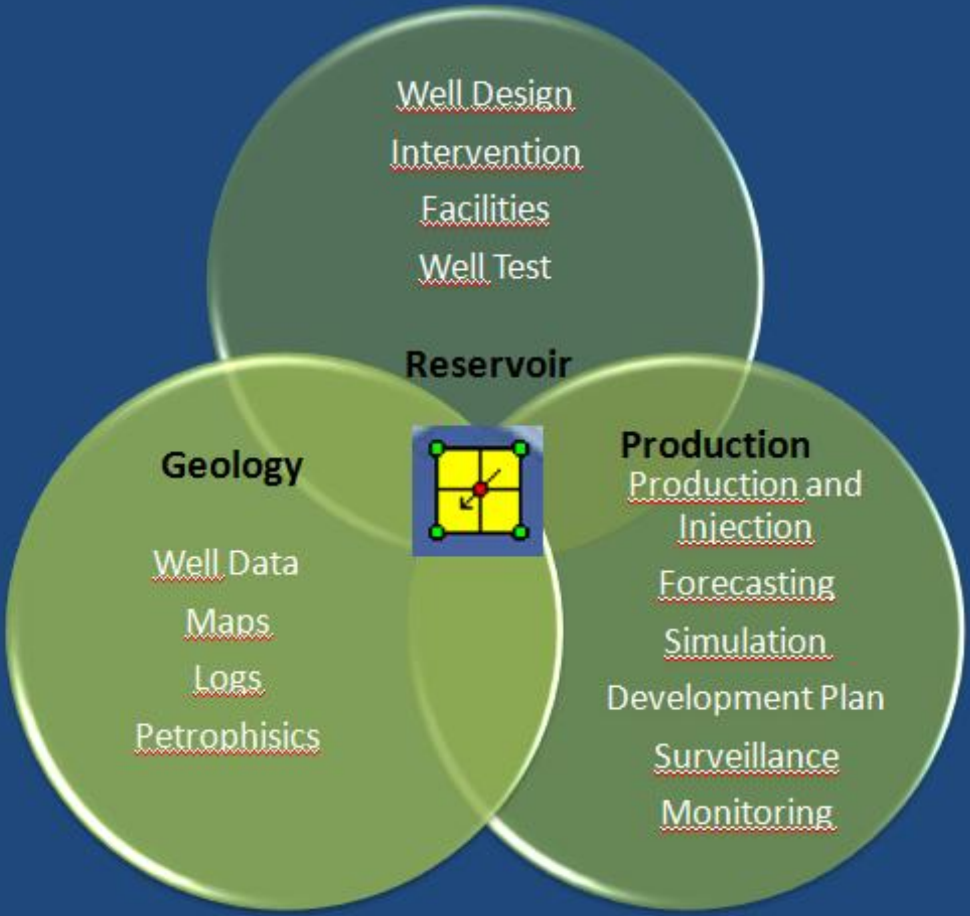
Outputs

- Structural Maps:
  - Faults /erosion lines
- Volumetric Maps:
  - Net Volume
  - Pore volume
  - STOIIP (HPHISO)
- Thickness Maps:
  - Net thickness
  - Net pay (SWAT cut OFF)
- Property Maps:
  - Mean Porosity
  - Mean Swat
- Probability Maps
  - Give support for well location
  - Calculated from 200 realizations
  - Mean and standard deviation
  - Cut off can be selected

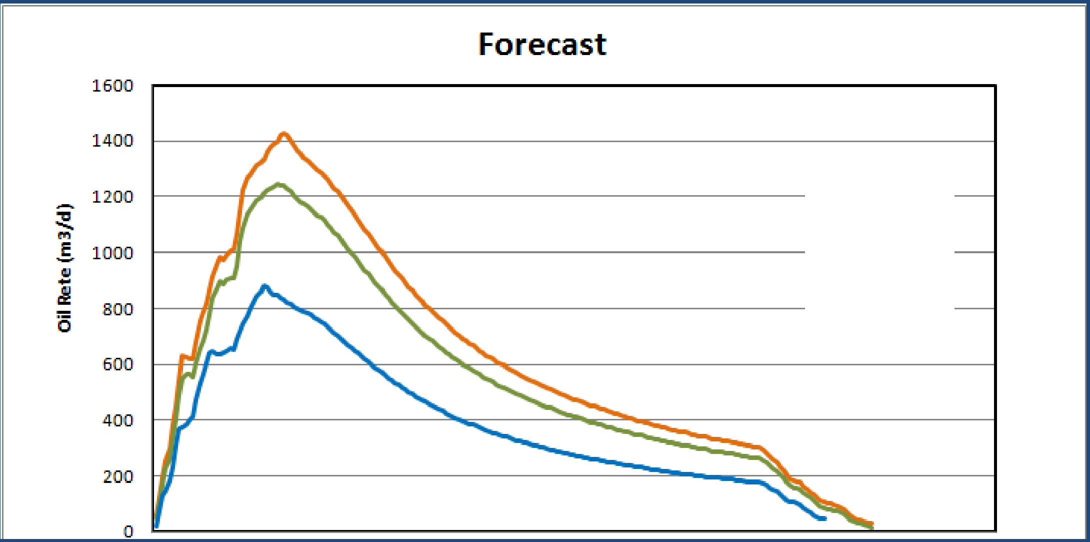


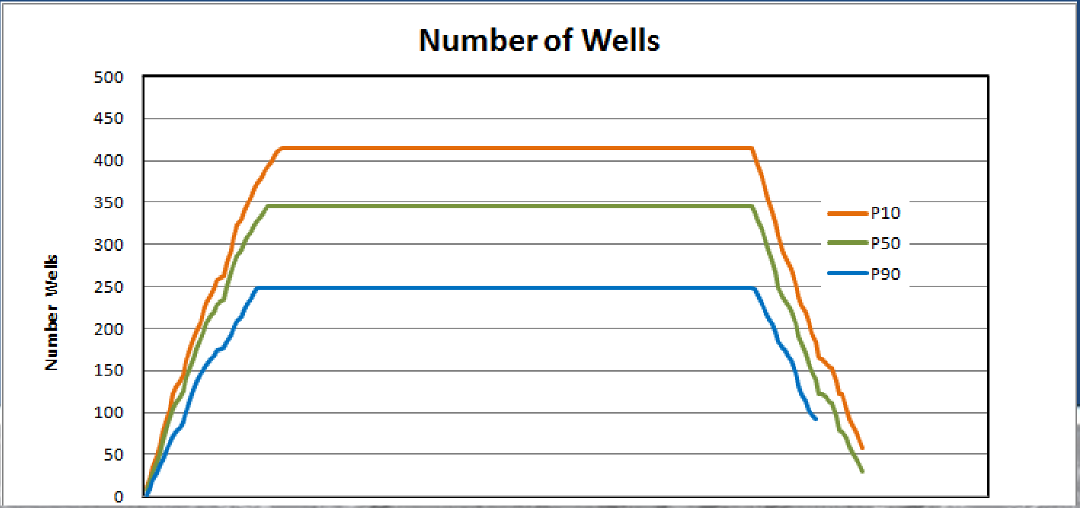


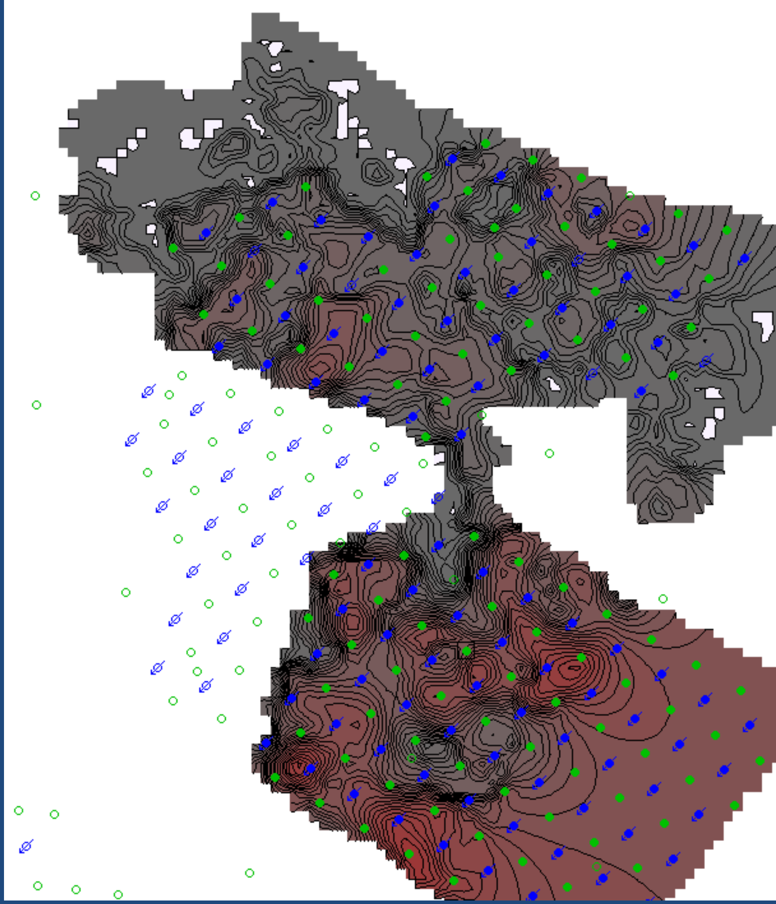
Analytical Model



Development Plan







Conclusions

- An integrated workflow builds a more robust model
- The use of stochastic simulation provides tools to identify, quantify and model uncertainty
- The study allowed to identify and rank the zones with more potential
- The outputs of the model gave support for drilling planning and economic evaluation of opportunities.