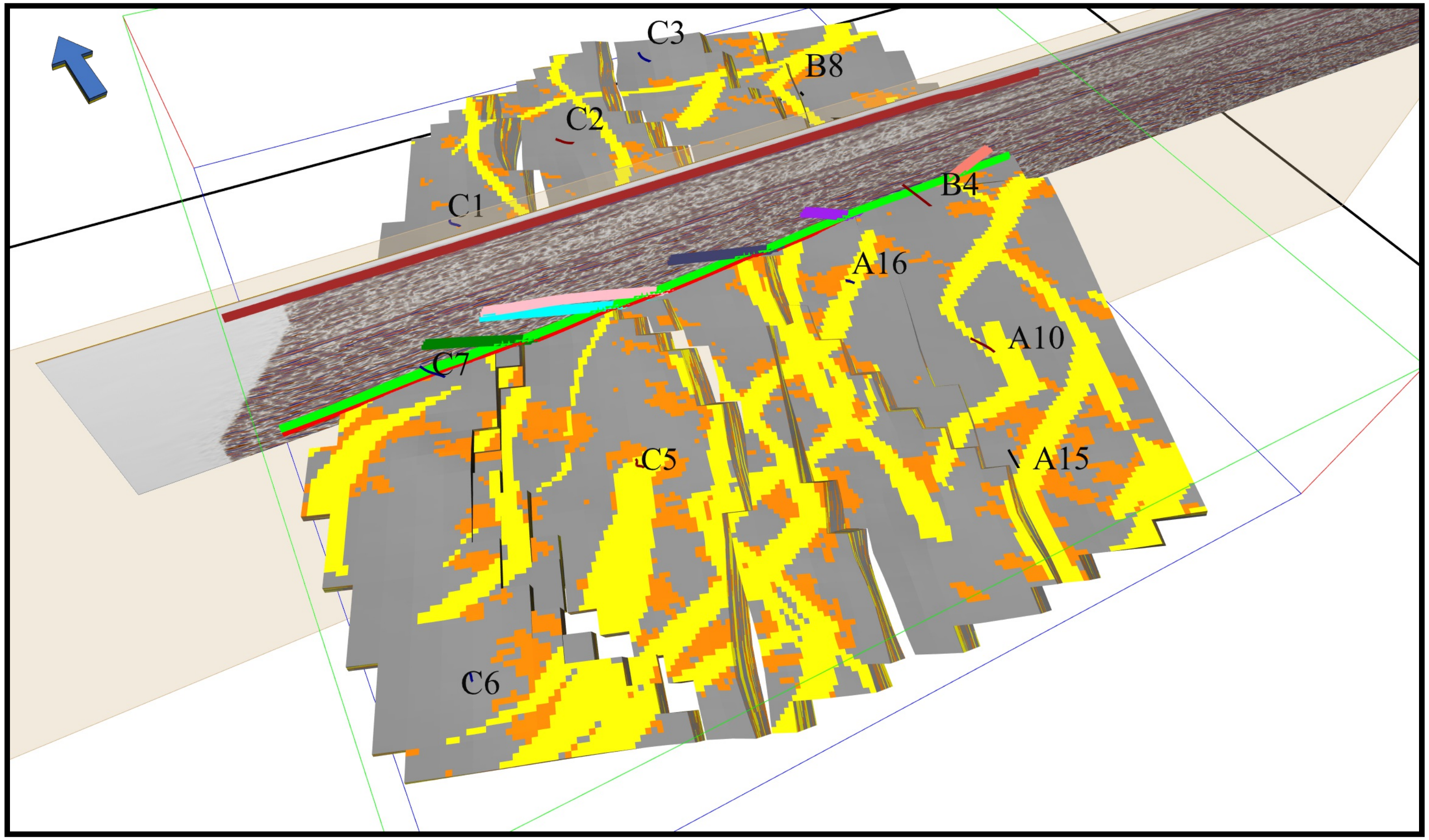
History matching interdisciplinary workflows incorporating uncertainty

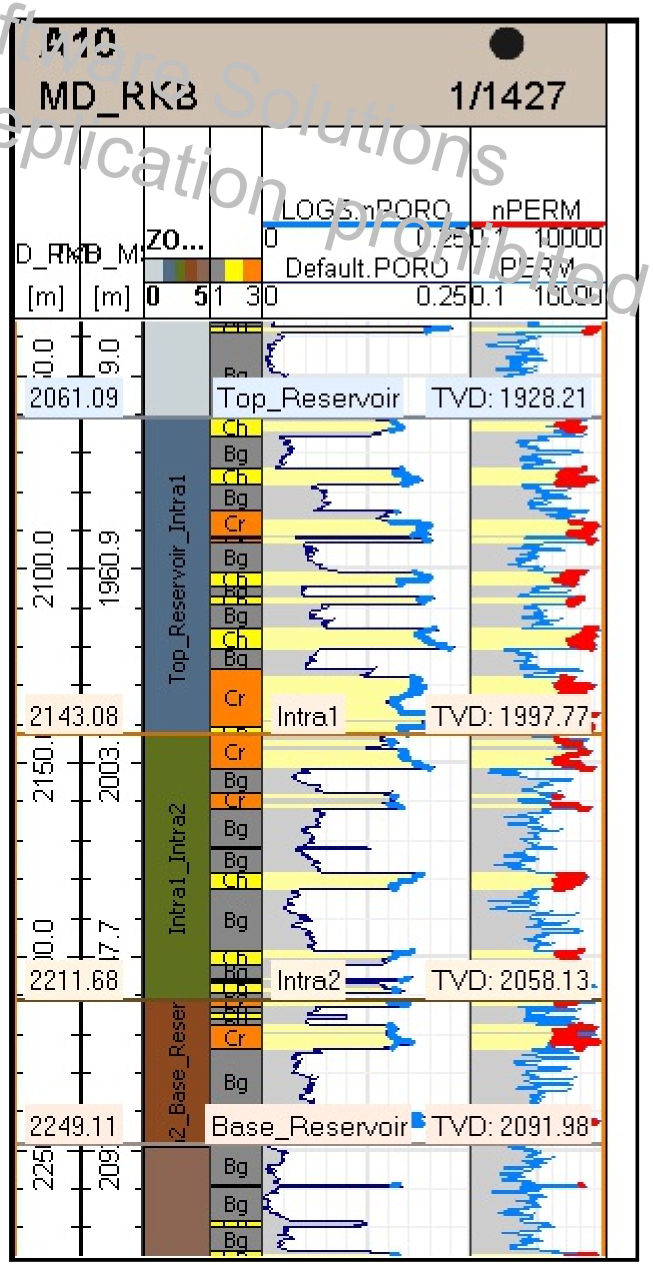
Steve Walsh & Henning Nottveit
Roxar Emerson

EMERSON.

Synthetic Project

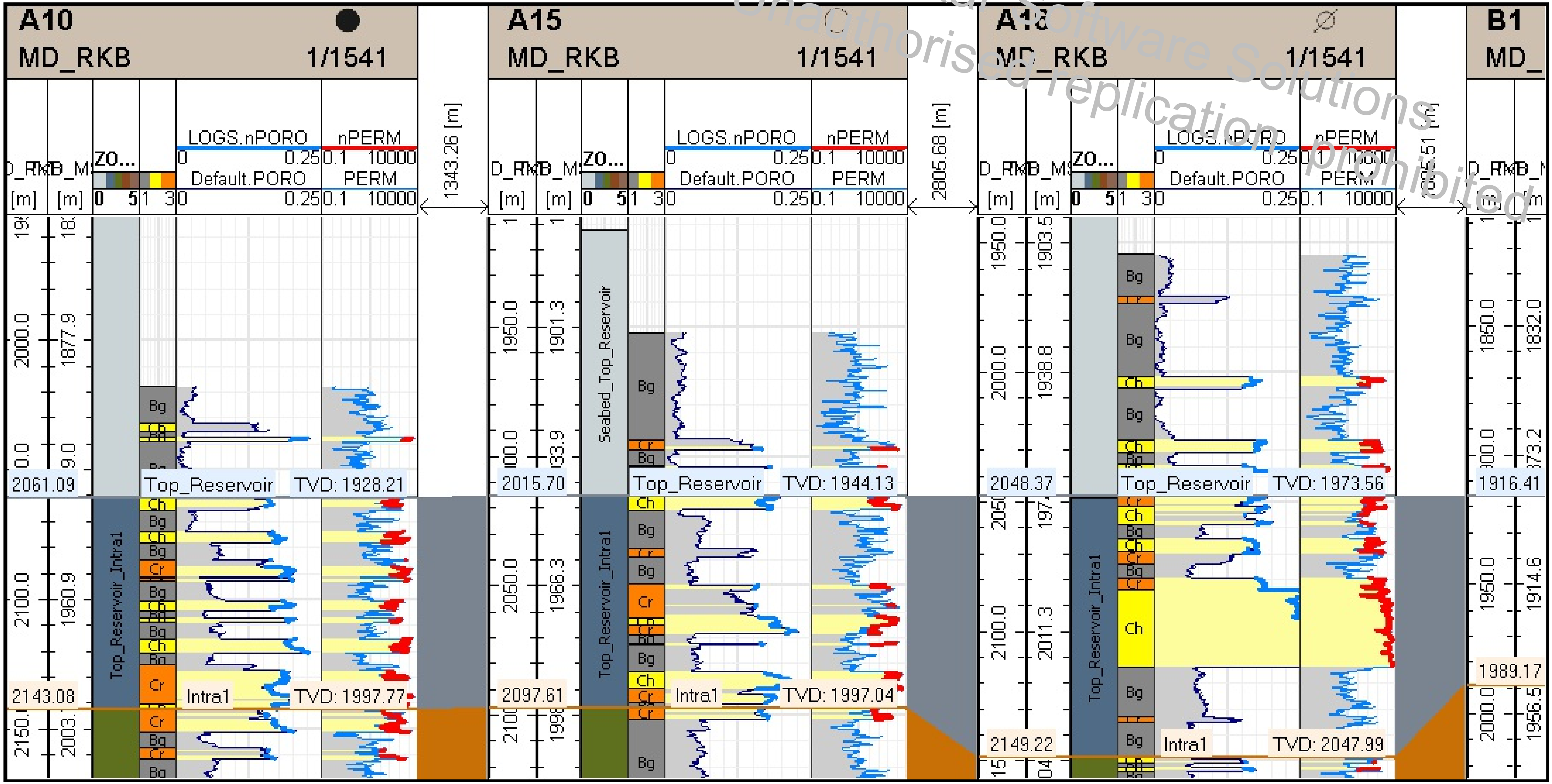
- Workflow based on 2 'BigLoop' uncertainty studies performed by Roxar in 2016, extended to include structural uncertainty & utilize stochastic proxy
  - Specific studies presented in more detail at EAGE conferences*
  - Here a synthetic test project is used for demonstration purposes
- 15 wells, (7 producers, 6 injectors)
- AOI 8km x 9km. 10 faults, extensional structure
- 3 reservoir zones (oil, clastic sandstones)





* EAGE 3rd Integrated Reservoir Modelling Conference, Kuala Lumpur, Dec 2016, Walia *et al.*
& upcoming EAGE Exhibition, Paris, June 2017, Abd-Allah *et al.*

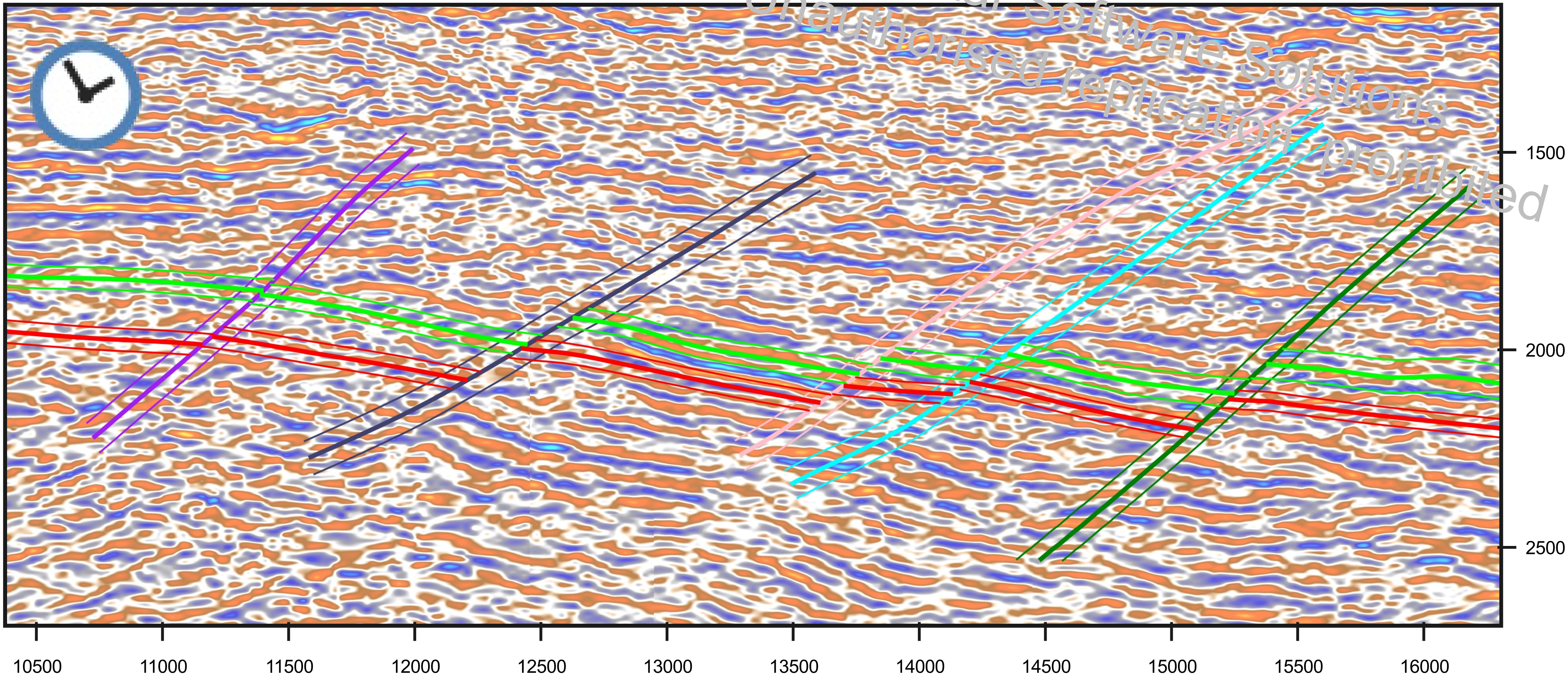
Uncertainty in Well Data



- There is uncertainty in the petrophysical logs at the raw well level
  For example, here NTG defined by porosity, permeability cut-offs on the raw well logs:
  ENABLE can adjust the cut-off values, allowing easy investigation of the impact of NTG definition uncertainty
- Other well uncertainties: pick MD (interpretation uncertainty) & trajectory (MD->XYZ) positional uncertainty

EMERSON

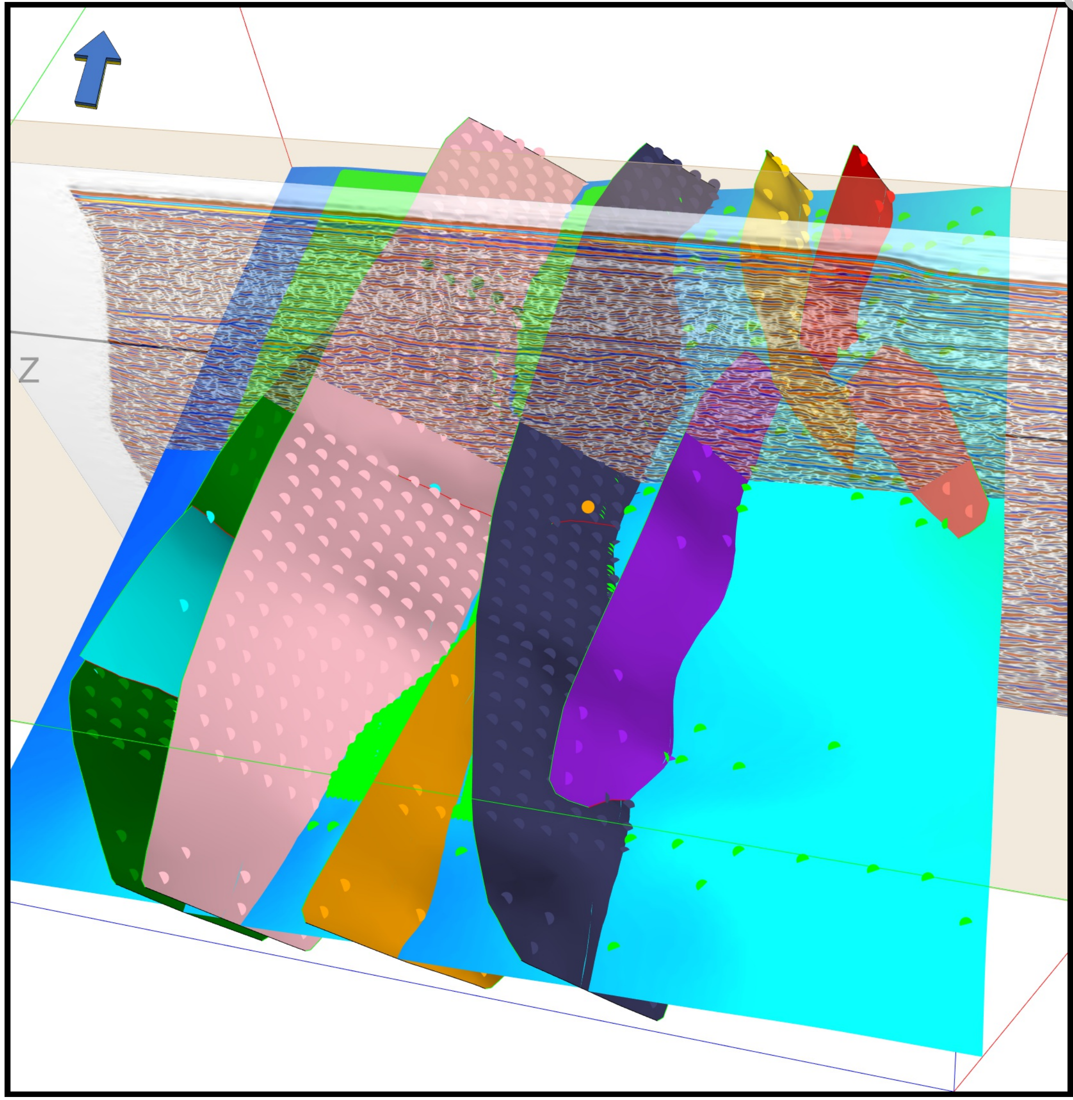
Interpretation in Time with Uncertainty

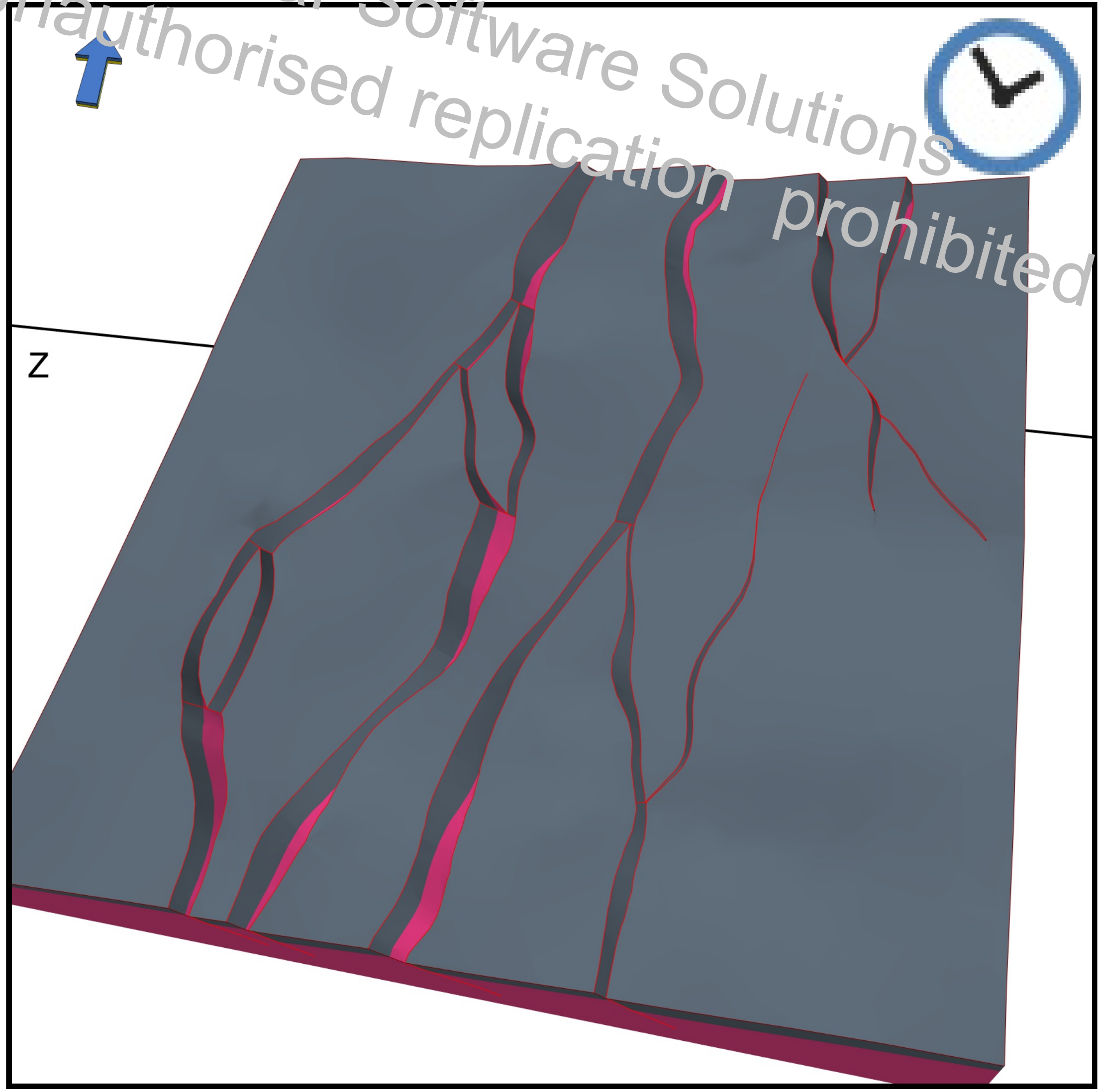


- RMS MDI interpretation - all interpretation points have an associated uncertainty ellipse - which define uncertainty envelopes around the surfaces & faults

  These uncertainty envelopes (defined by the Geophysicist) are carried into the modelling phase

Interpretation used to make structural model





- Base RMS Structural model constructed from seismic interpretation
  Structural model constructed in *time,* not depth

Horizon Uncertainty Modelling (HUM) tool

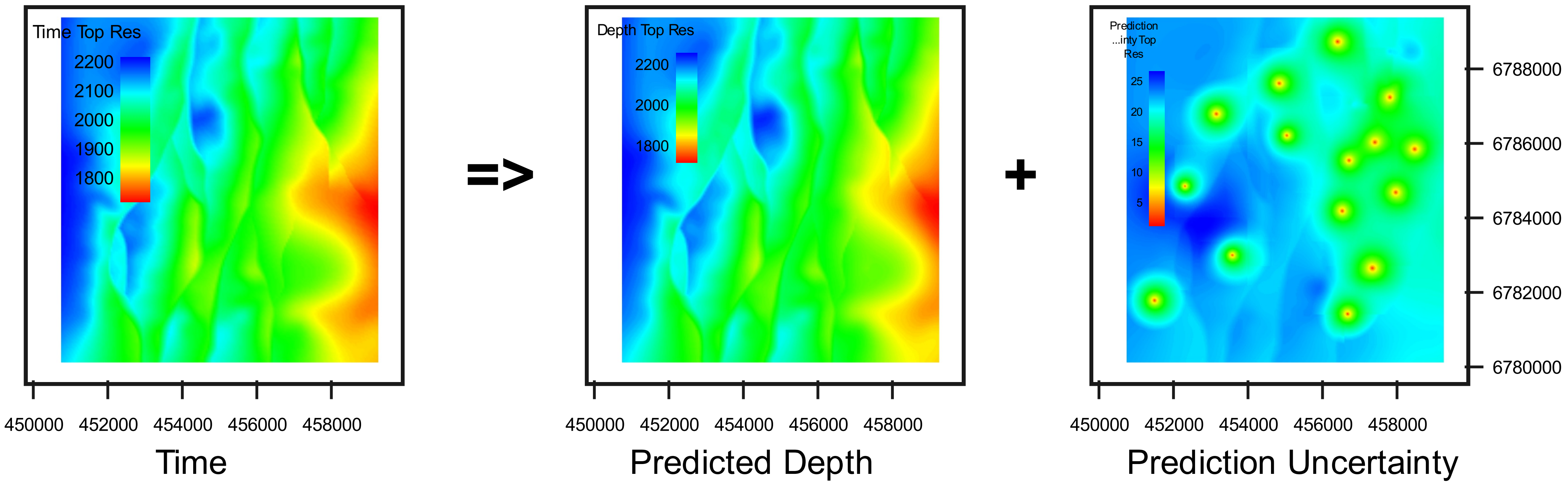
HUM inputs:

- TIME: Time structural model surfaces & the associated 'picking uncertainty' envelopes
- DEPTH: Well picks, and associated uncertainties (pick (MD) & trajectory (MD->XYZ))
- VELOCITY: Interval velocity maps & interval velocity uncertainty

HUM Outputs (Prediction mode):

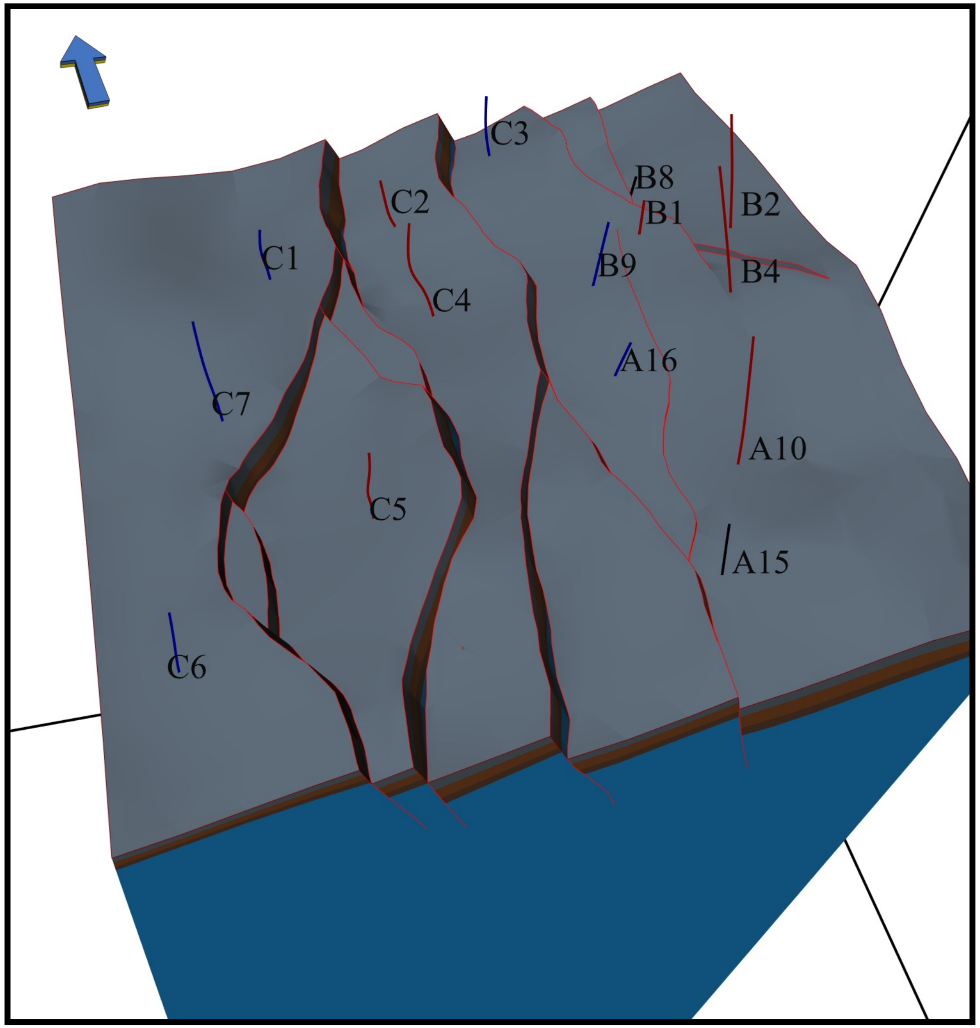
- Predicted Depth Maps
- Prediction Uncertainty

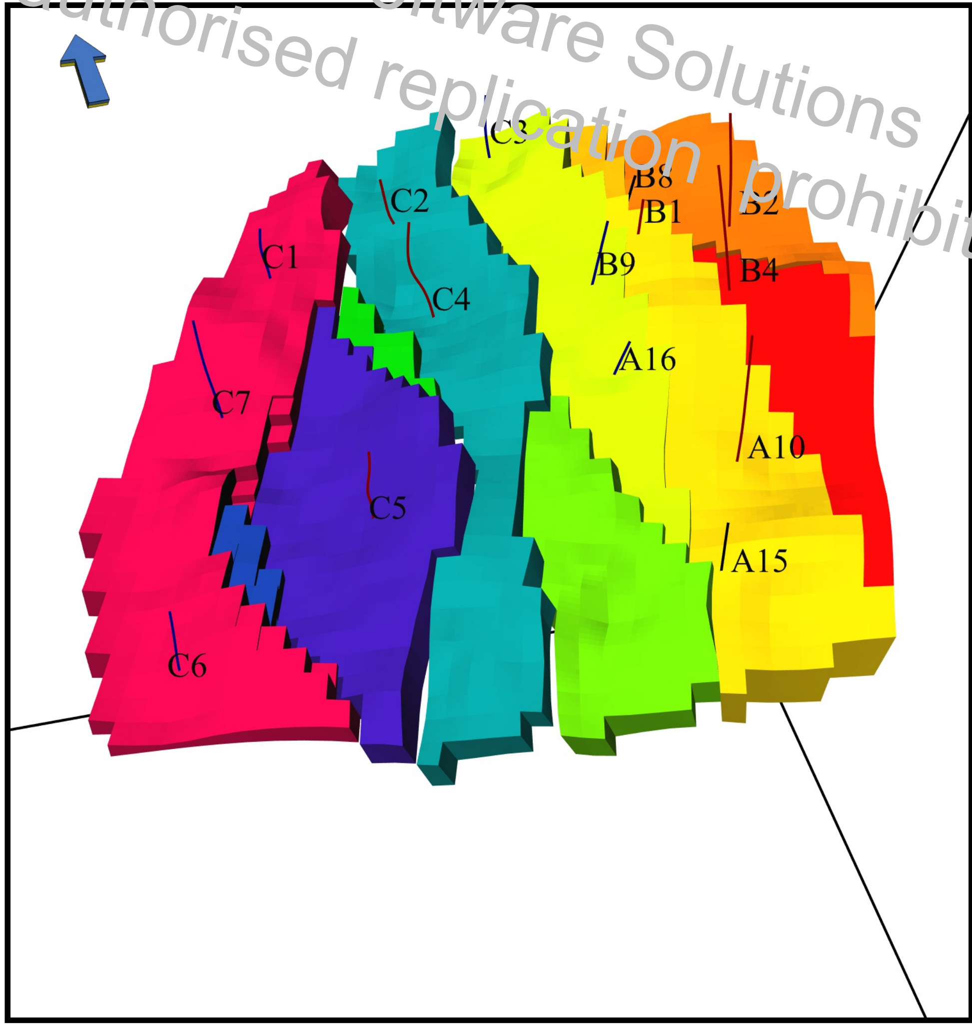
- ENABLE modifier adjusts HUM predicted depth map *within the envelope defined by the HUM prediction uncertainty*
- Adjusted depth maps used to generate a revised velocity model for depth conversion of fault & horizon interpretation
  Allows ENABLE to investigate impact of structural uncertainty within constraints of the input data uncertainty



EMERSON

Depth structural model + FUM -> Grid

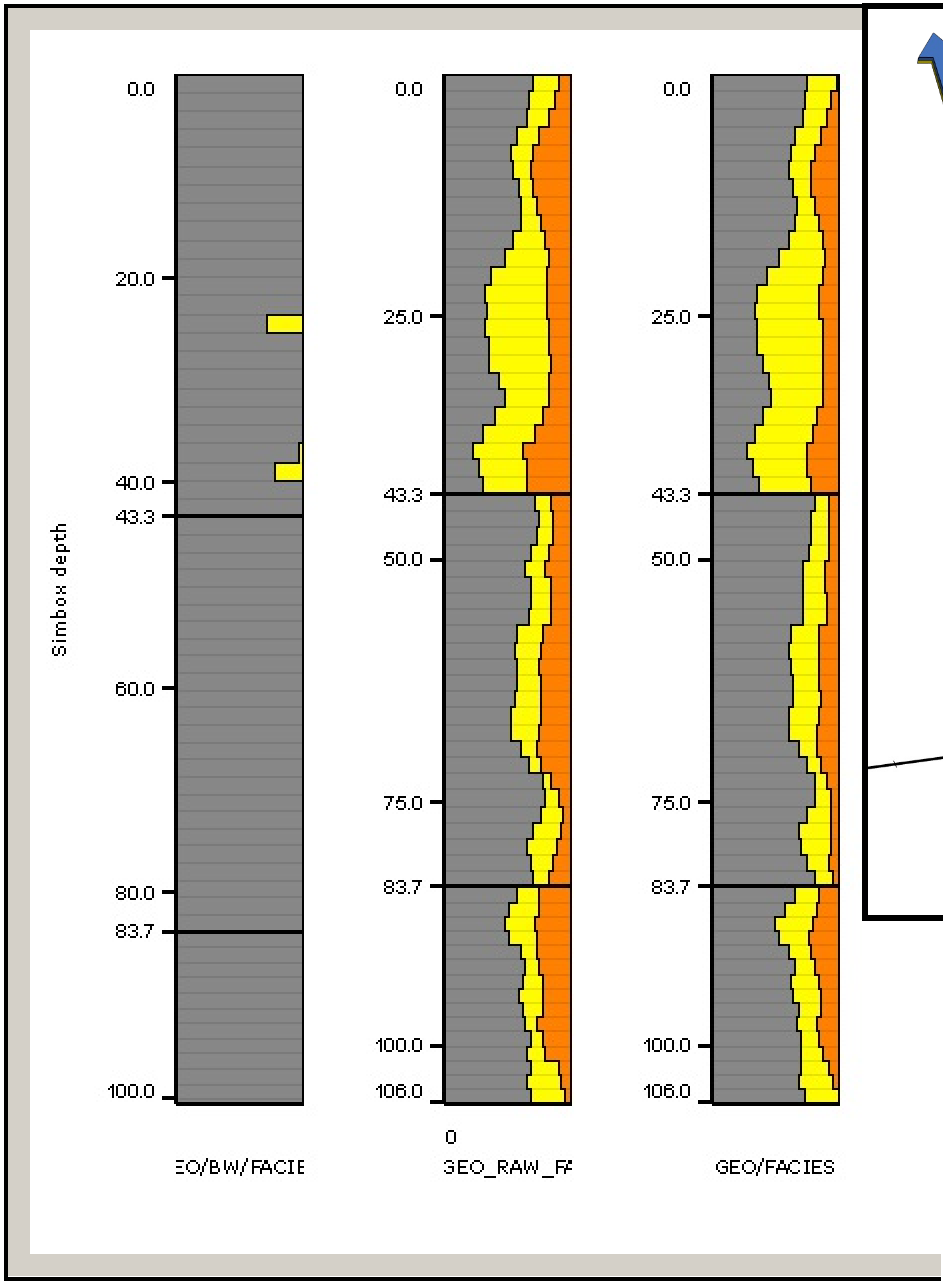


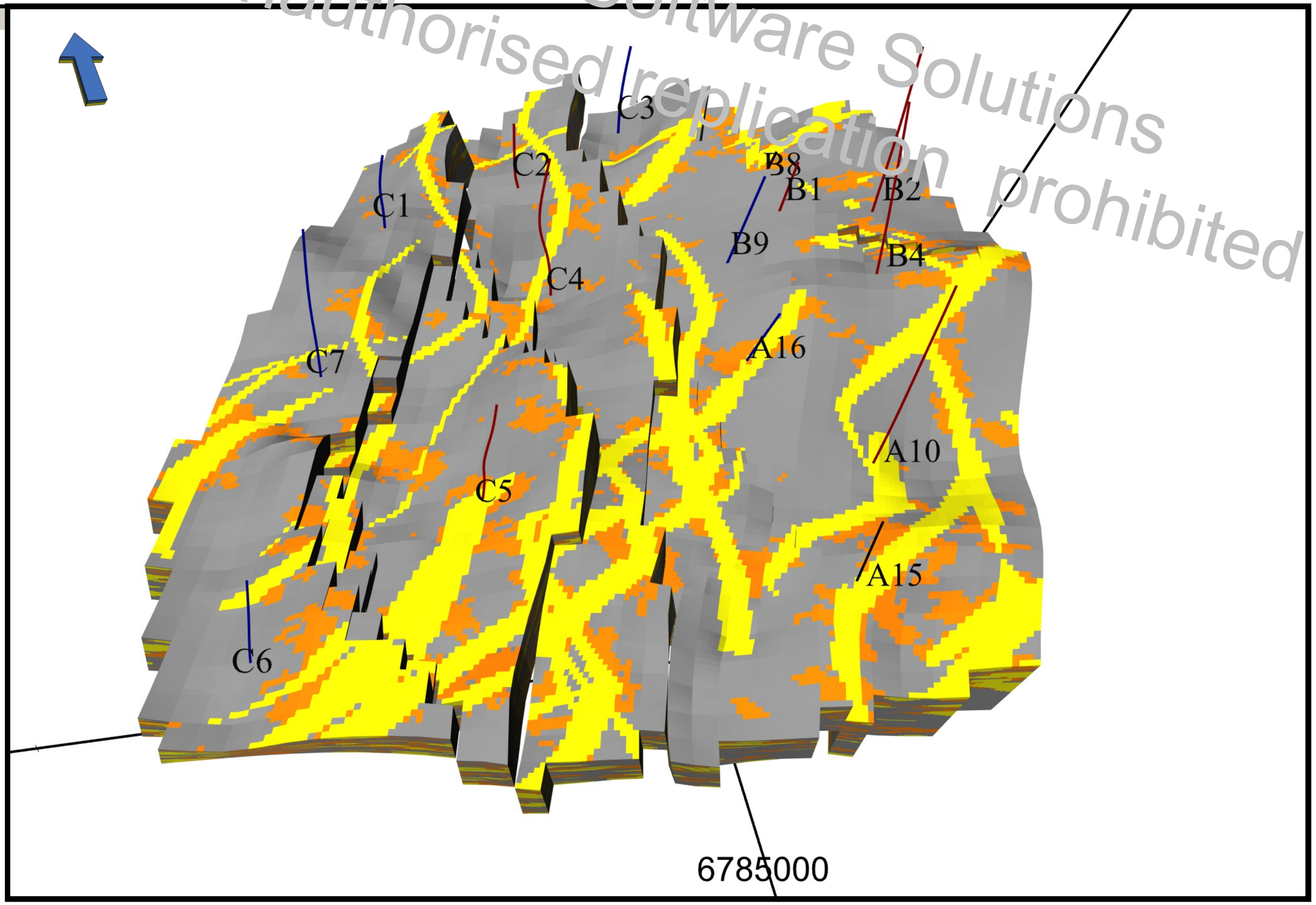


- Depth converted interpretation (via revised velocity model) used to generate depth structural model
- Fault Uncertainty Modelling (FUM) used to adjust fault position
  ENABLE modifier controls fault movement, *within the interpretation uncertainty envelope*
- Intermediate reservoir surfaces added using Isochore Modelling from thicknesses defined by well pick pairs
- Final depth structural model is then generated & geocellular grid constructed

EMERSON

Facies Modelling



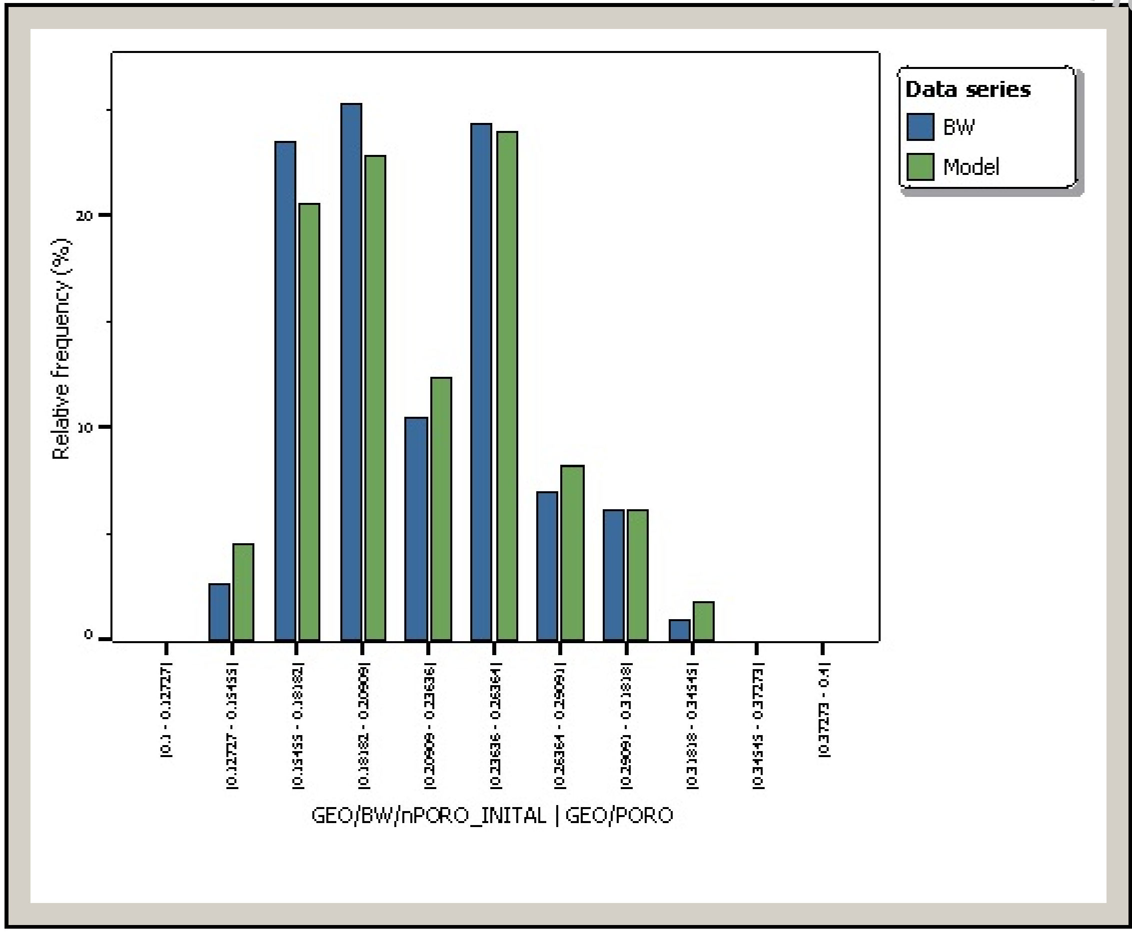


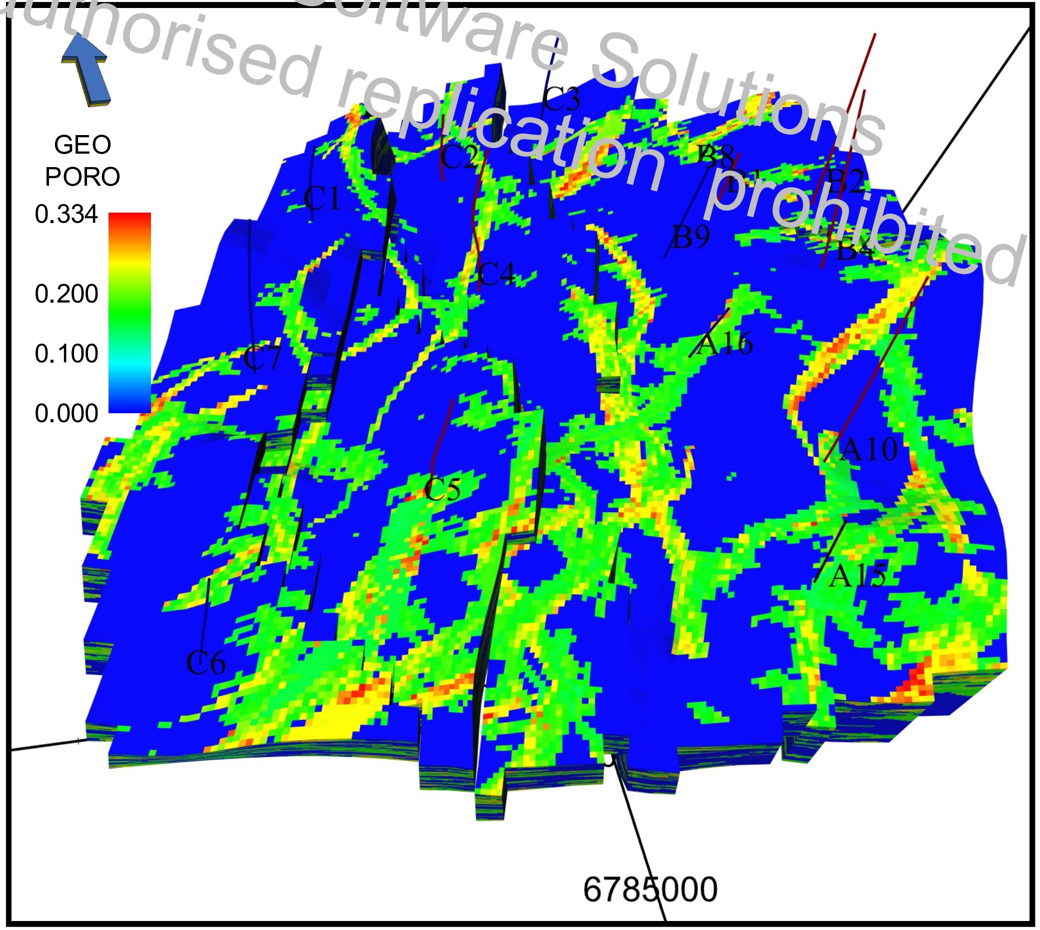
Here we are using combined object & pixel based facies simulation
ENABLE can adjust (per zone & facies)

- Volume fraction
- Width, length, thickness
- Azimuth

EMERSON

Property Modelling





Petrophysical simulation of Porosity, Permeability & NTG per zone/facies

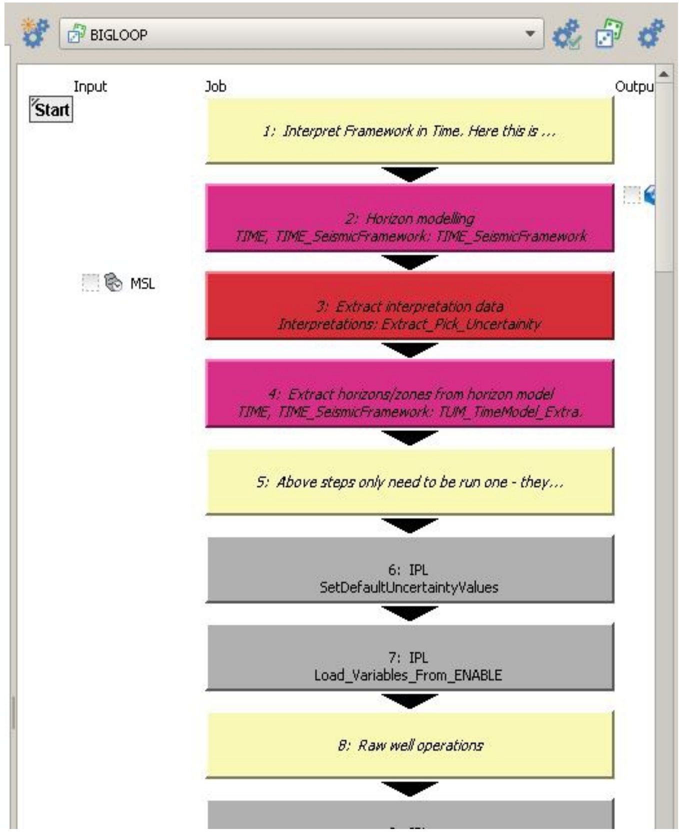
ENABLE can adjust Porosity per zone/facies - reflecting uncertainty in how representative the BW well data is of the field as a whole. (Could have also included perm/NTG)

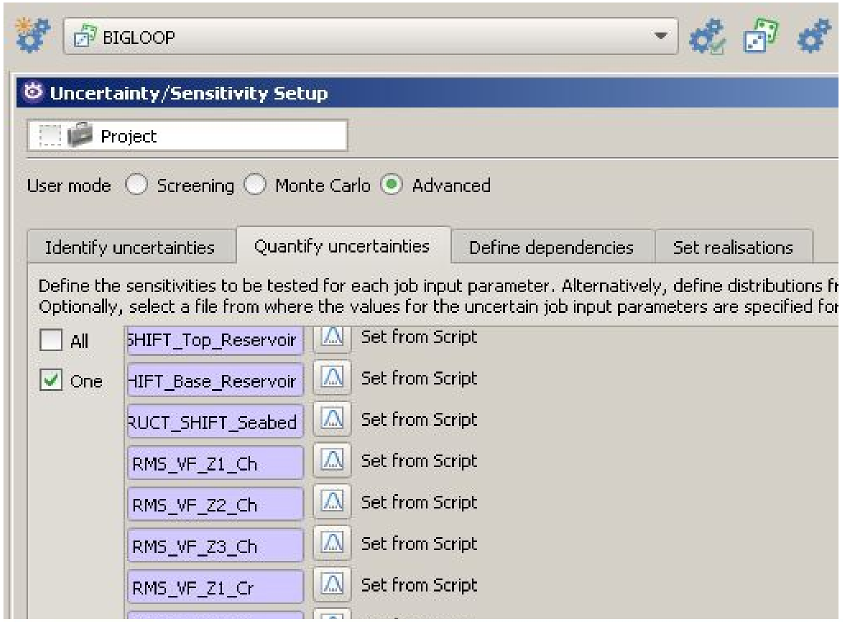
- KVKH ratio also controlled by ENABLE
- Results upscaled to simulation grid
- Well events generated
- Grid geometry, property arrays, faults & well events exported to simulator

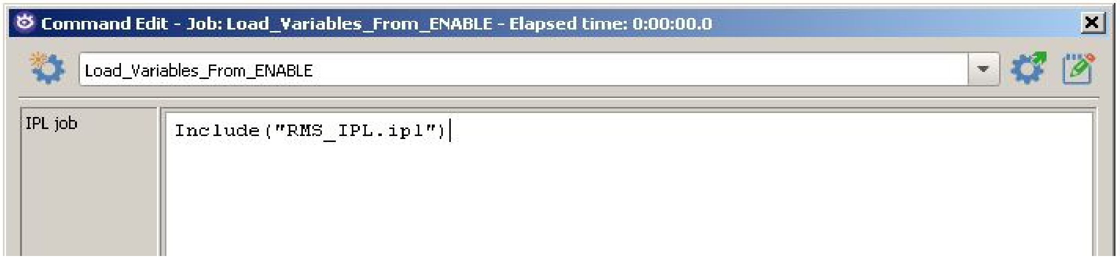
EMERSON

RMS Workflow complete - over to History Matching

- 'Standard' RMS workflow: Automated from seismic interpretation to export for simulation
- Adjustments reflecting uncertainty defined & implemented at the appropriate modelling step and propagate through the rest of the workflow
  Uncertainty in: interpretation, velocity model, petrophysical logs, structure/grid, facies model and property model
- Automation of these adjustments allows efficient generation of the implied models. And these can be tested/ analysed by history matching software in *combination with traditional dynamic uncertainties*
- ENABLE controls settings, currently by writing a simple script file that is read by the RMS workflow

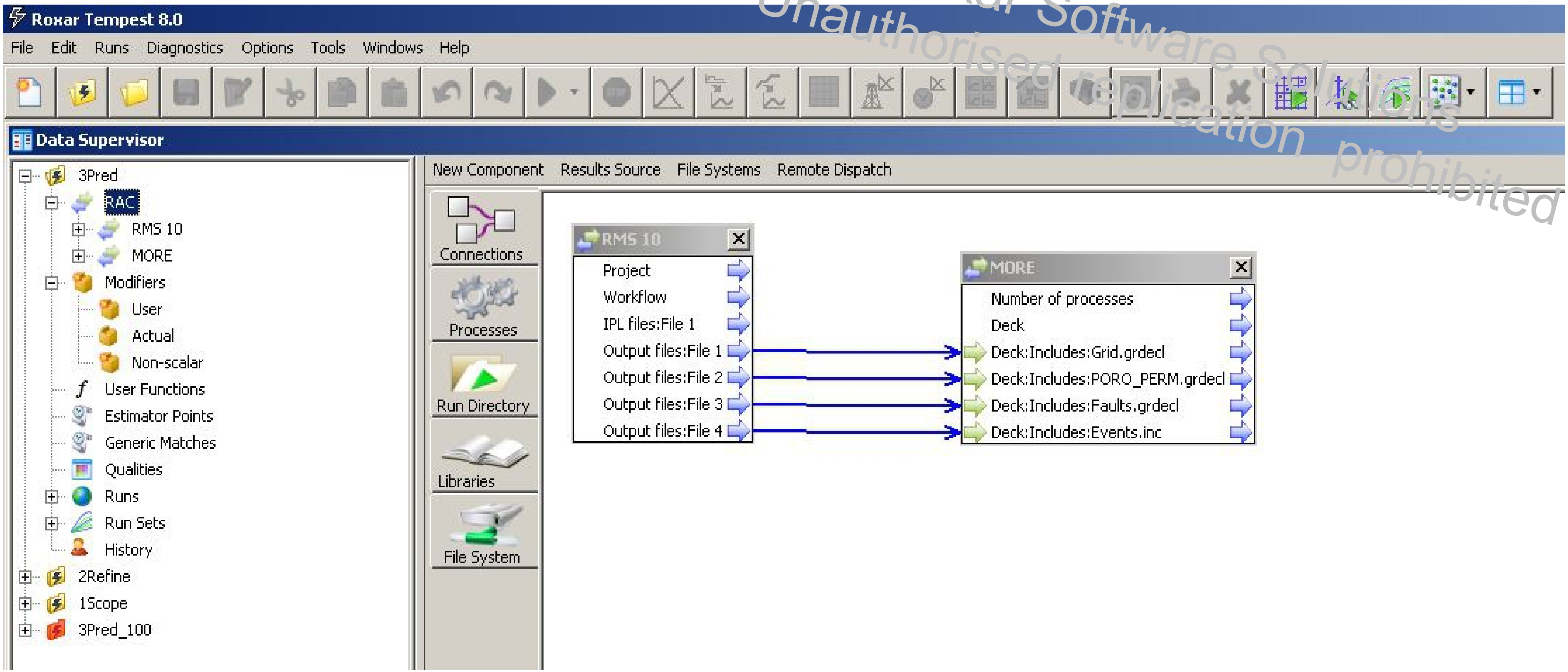






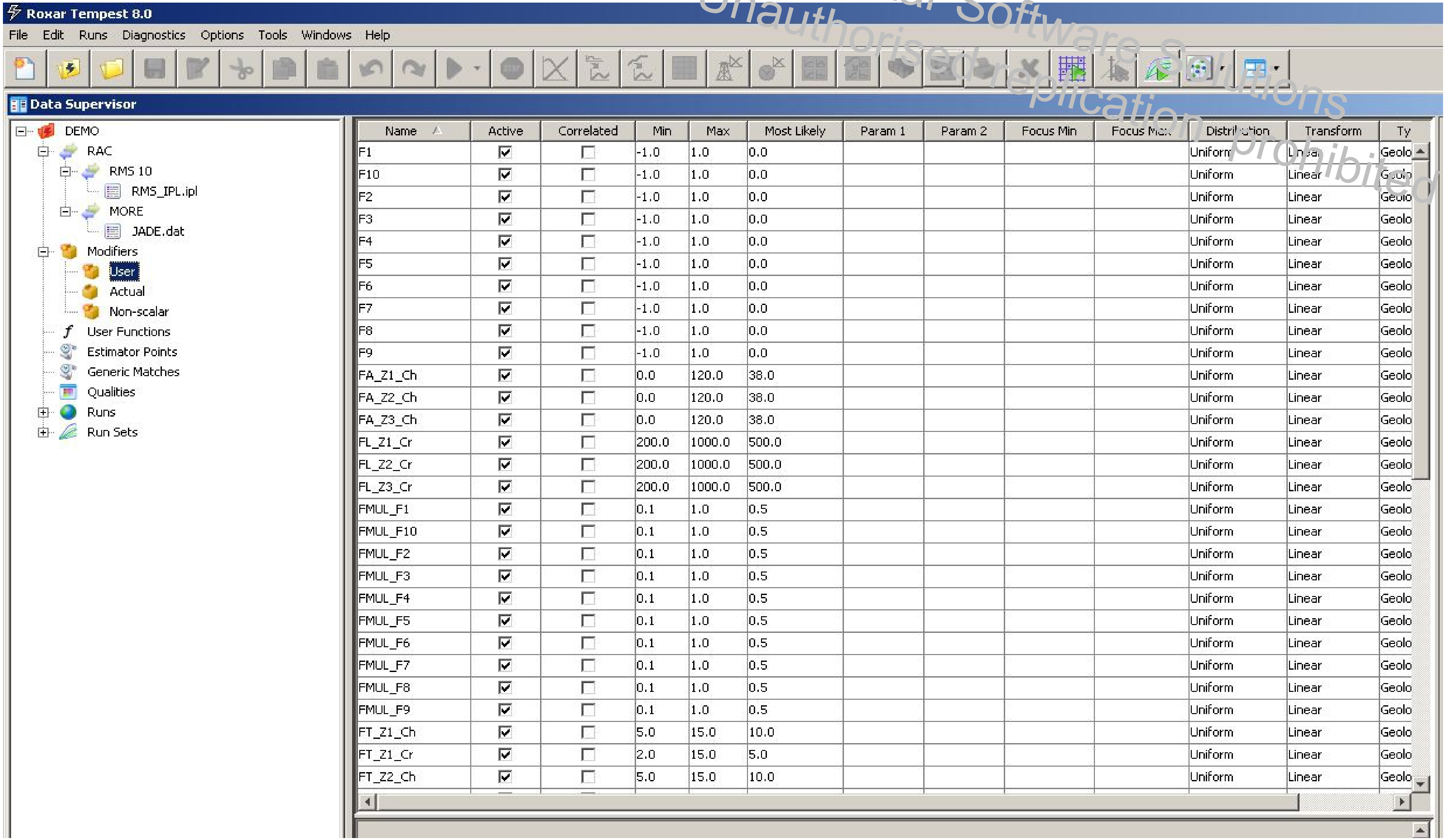
EMERSON.

Tempest ENABLE & Roxar Application Connector (RAC)



- Tempest ENABLE: Roxar's Assisted History Matching tool. RAC: Roxar Application Connector
- Define RAC 'Components' and how exported data from one is be used as input to another. Here using just 2 Roxar components, RMS for the Static model and MORE for Simulation
- In principle a component could be any external application or script that can be run/suitably controlled from a command line. But it should be capable of running on a cluster to allow simultanous processing of large numbers of runs
- Using the proxy modelling approach, every Enable run will be generating a new realization of the static model (structure, grid, properties) using a different stochastic seed & modifier values, which is used as input for dynamc simulation

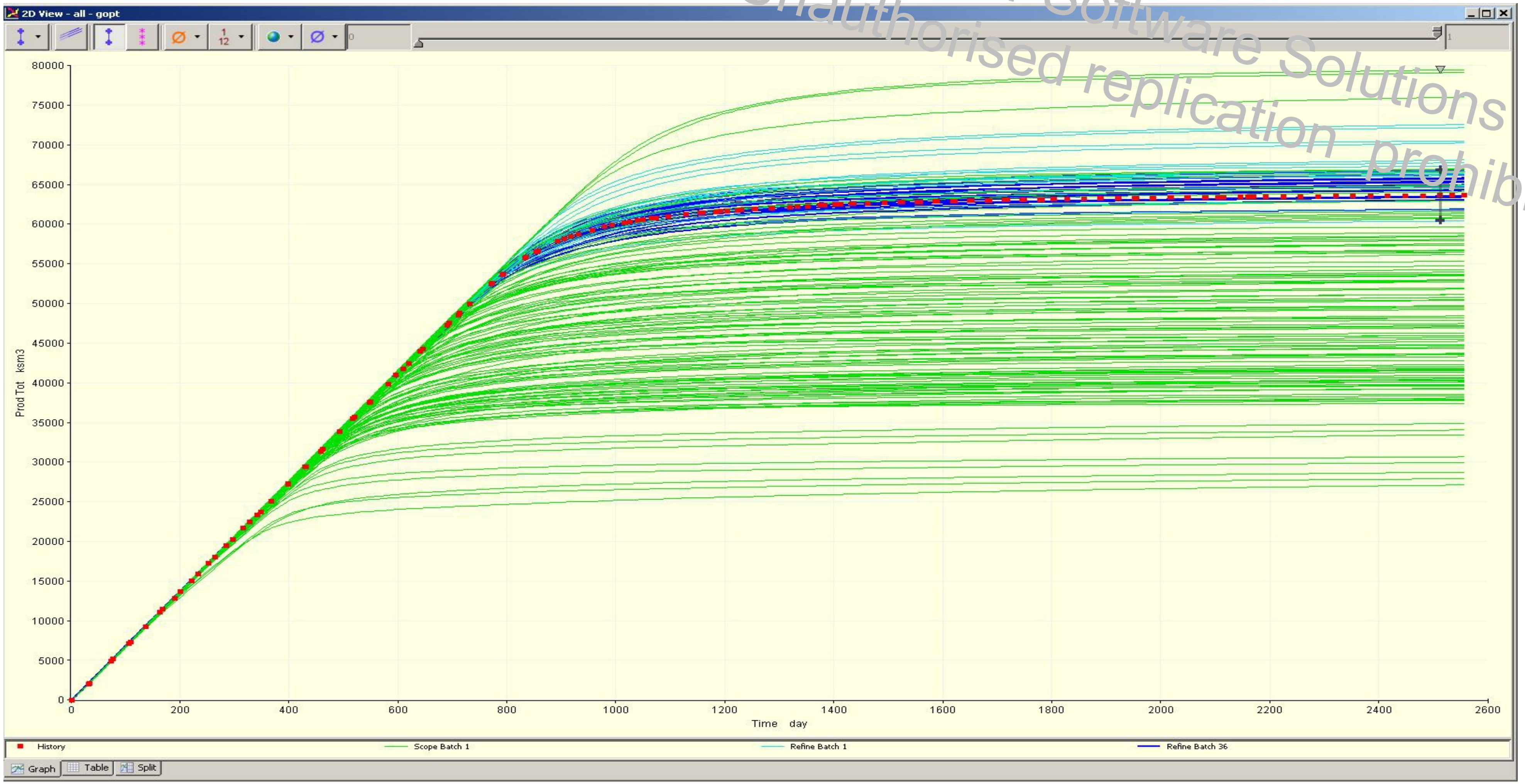
ENABLE: Define 'Prior' modifiers, ranges and correlations



Name	Active	Correlated	Min	Max	Most Likely	Param 1	Param 2	Focus Min	Focus Max	Distribution	Transform	Ty
F1	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F10	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F2	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F3	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F4	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F5	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F6	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F7	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F8	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
F9	☑	☐	-1.0	1.0	0.0					Uniform	Linear	Geolo
FA_Z1_Ch	☑	☐	0.0	120.0	38.0					Uniform	Linear	Geolo
FA_Z2_Ch	☑	☐	0.0	120.0	38.0					Uniform	Linear	Geolo
FA_Z3_Ch	☑	☐	0.0	120.0	38.0					Uniform	Linear	Geolo
FL_Z1_Cr	☑	☐	200.0	1000.0	500.0					Uniform	Linear	Geolo
FL_Z2_Cr	☑	☐	200.0	1000.0	500.0					Uniform	Linear	Geolo
FL_Z3_Cr	☑	☐	200.0	1000.0	500.0					Uniform	Linear	Geolo
FMUL_F1	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F10	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F2	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F3	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F4	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F5	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F6	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F7	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F8	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FMUL_F9	☑	☐	0.1	1.0	0.5					Uniform	Linear	Geolo
FT_Z1_Ch	☑	☐	5.0	15.0	10.0					Uniform	Linear	Geolo
FT_Z1_Cr	☑	☐	2.0	15.0	5.0					Uniform	Linear	Geolo
FT_Z2_Ch	☑	☐	5.0	15.0	10.0					Uniform	Linear	Geolo

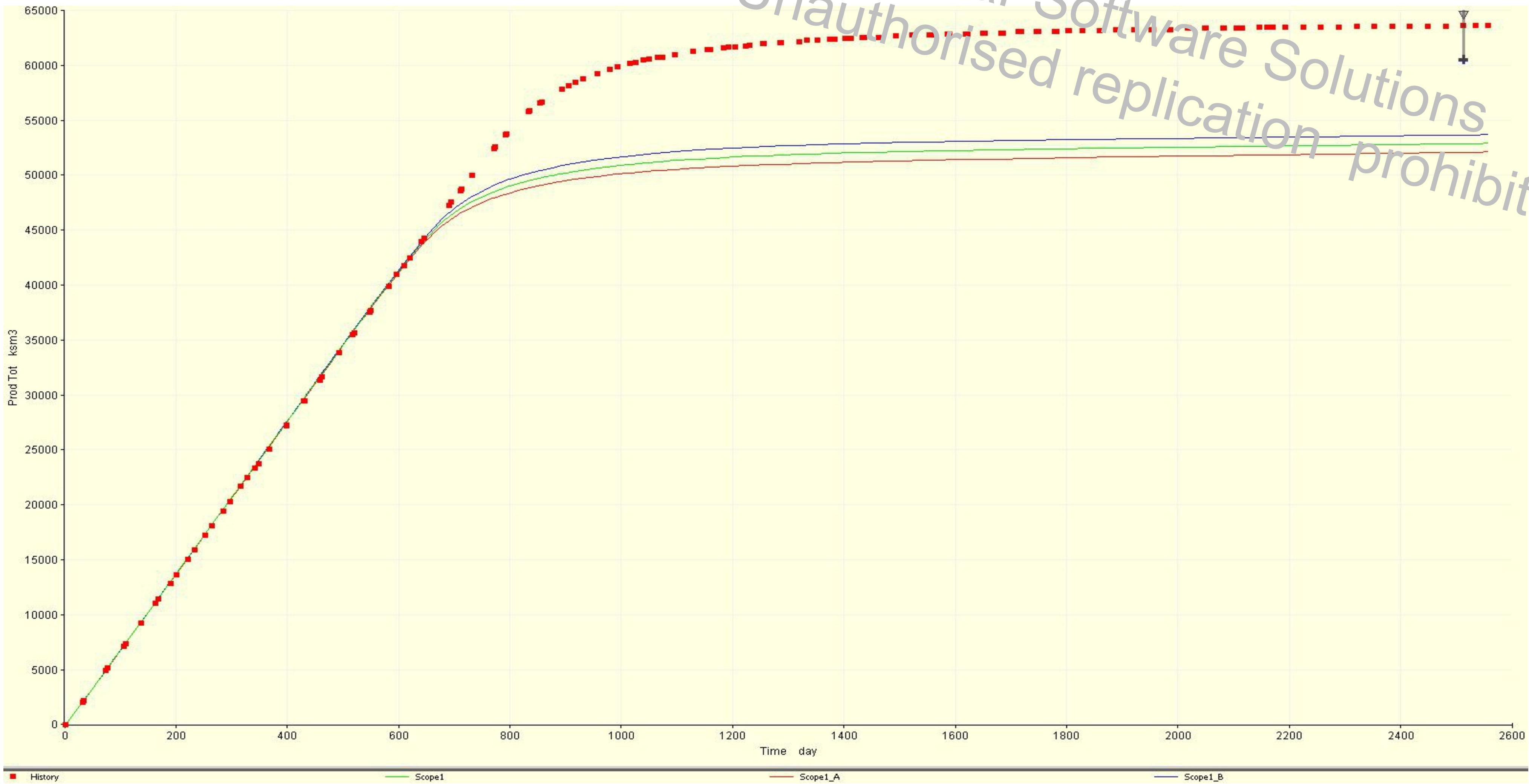
EMERSON

Scoping then Refinement runs to give a reliable Proxy Model



- Refinement runs are only partly aiming to acheive good history matches. Primarily these runs are testing the response of the simulator at each estimator point to the modifer ranges/combinations
- History Matching is considered completed once the internal proxy model is judged to be sufficiently "refined", such that it is capable of reliably predicting the response at the estimator points for a given set of modifer values

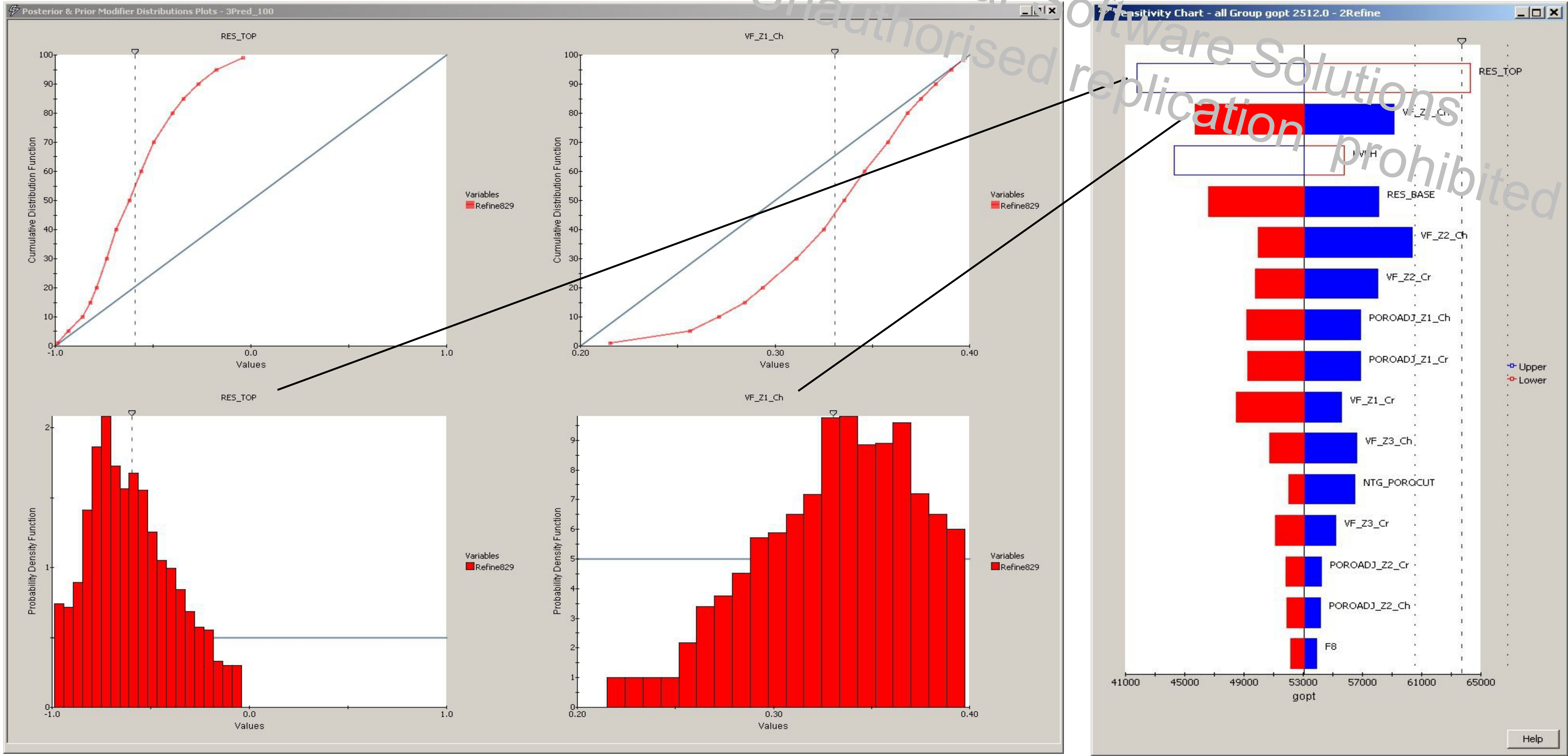
The Stochastic Proxy



- Several modelling processes are often stochastic - different seed numbers result in different equiprobable models from identical inputs. Such as facies or petrophysical modelling
- ENABLE Proxy model uses "Repetition Runs" to quantify the impact of this stochastic noise on simulation results
- Runs are automatically generated that use the same modifier values with different seeds, and the results incorporated into the proxy calculations. Without this "Stochastic Proxy", a proxy model would incorrectly attempt to "fit" this noise.

EMERSON

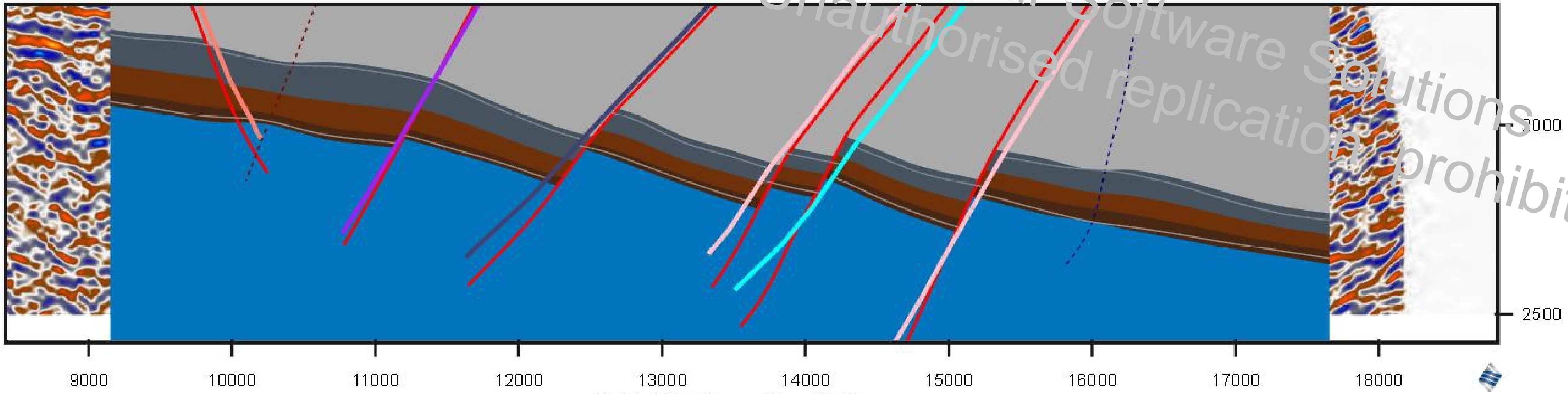
Prior vs Posterior Modifier Ranges

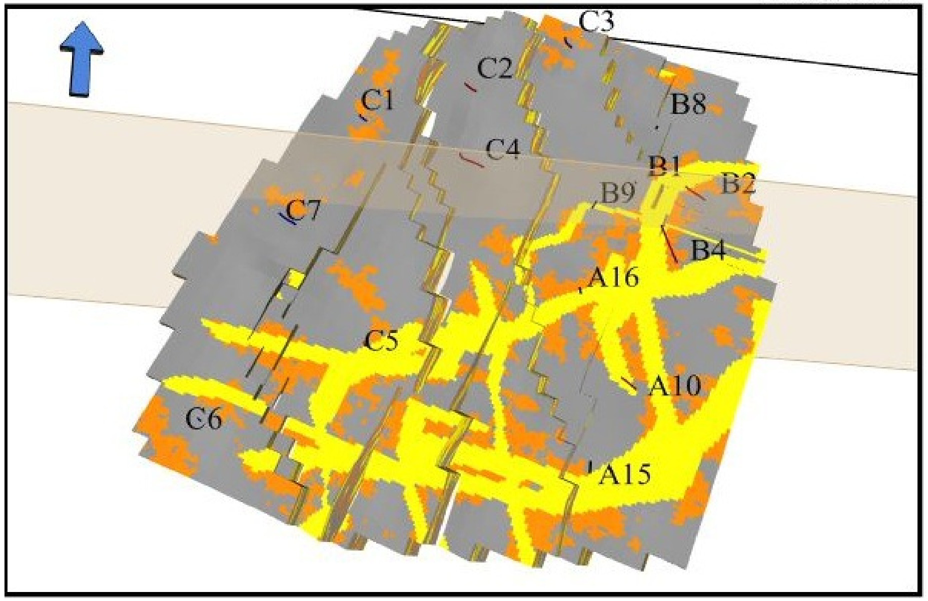


- Combined assesment of both static and dynamic uncertainty modifiers is now possible
- Proxy model reveals the changes to the modifer distributions that were required to achieve models that are consistent with the dynamic data obervations. Prior (grey) and Posterior(red). Top structure and zone 1 facies volume fraction modifiers shown.

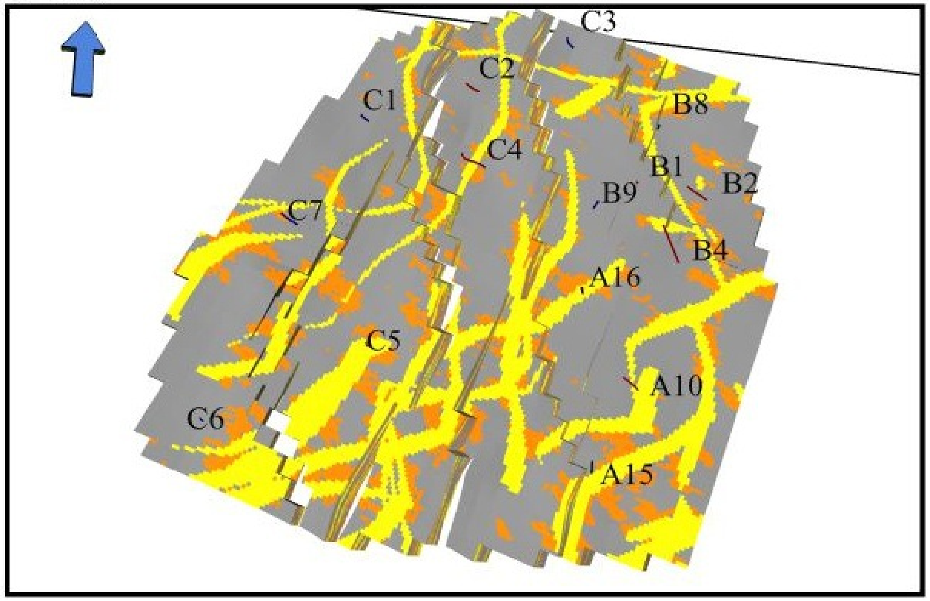
EMERSON

Updated Geological Model Realizations





Updated Model

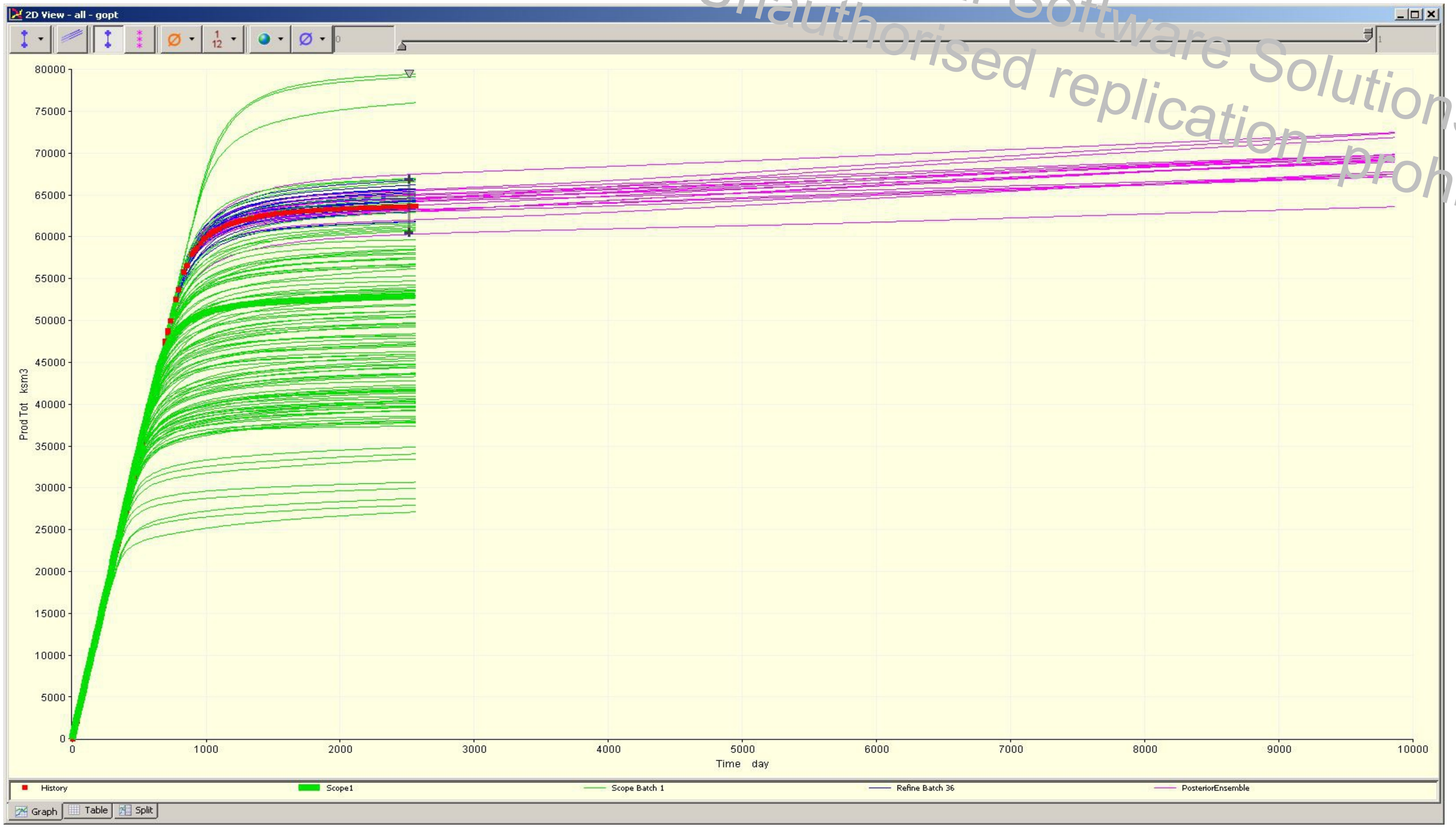


Base Model

- Investigation of selected static model realizations that give good history matches while still honouring the input data given the specified uncertainty ranges
- See impact here of the modifiers on velocity model, structure, fault position, facies volume fraction and facies deposition direction in this realization of the static model that have resulted in the improved history match

EMERSON

MCMC sampling from proxy model to generate prediction ensemble



- Modifier values for a new Ensemble then generated by MCMC sampling from the proxy posterior distributions.
- Modifier values are being applied at the applicable point in the combined static & dynamic workflow to generate the models used in each simulation. Adjustments are therefore being made in a geologically consistent manner, as opposed to traditional manual modifications applied to the dynamic simulation grid in isolation.
- This Ensemble should therefore give a more reliable prediction of response and uncertainity ranges.

BigLoop: History matching interdisciplinary workflows incorporating uncertainty

Steve Walsh & Henning Nottveit
Roxar Emerson

EMERSON