MEERA SIMULATION

harnessing the power of conventional reservoir simulation coupled with modern machine learning approaches

Evergreen Production Forecasting made effortless.

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TARGET

Hybrid Simulation, Novel AI-Physics Based Reservoir Simulator, practical application

The Challenge

In today's operating environment, brown field incremental development activities offer the lowest cost "new oil" for the upstream industry. The need to minimize uncertainty remains paramount.

Traditional history match studies are very labor and time intensive. Limited scenarios and short cuts in history matching can lead to low quality decisions based on models with high levels of residual uncertainty.

Revised models are in turn left dormant due to lack of resources to keep them evergreen, leading to inefficient use of Petroleum Engineering staff to manage the assets

AI / ML techniques offer a Hybrid Solution

Combining AI/ML solution techniques with a traditional physics/geology-based simulator enables efficient, semi automated, Evergreening of existing reservoir models.

New well production data can be rapidly incorporated, and history matched to provide a platform for "What if" scenario planning for incremental activity (side-tracks/new wells, facility upgrades, etc.)

The Evergreen Forecast environment makes best use of staff insight and creativity to maximise asset value

… a viable, subsurface digital twin is created.

Applications of Reservoir Simulation

APPROACH	OBJECTIVE	MEANS of MEETING OBJECTIVE
Conventional Reservoir Simulation	**Prediction** • Development Concept Selection • Production Forecasting • Locating The Remaining Oil	**History Matching** • Labor-intensive process that can increase reservoir understanding • Quality of Production & Pressure Match determines reliability / uniqueness of forecasts.
HYBRID Reservoir Simulation	**Prediction** • Development Concept Selection • **Evergreen** Production Forecasting • Locating The Remaining Oil	**History Training** • **AI identifies data relationships** to aid reduction of uncertainty in results • Production “Blind Testing” illustrates reliability of forecasts

HYBRID Simulation Applications

HYBRID Simulation → **Applications**

FDP Studies

Application Highlights	Technology
Simulation	AI-Physics
Parameter Ranking	Data Mining

Conventional (Reservoir Simulators)	HYBRID
Based on **Physics**	Based on **Physics** & **Data**
Runs & updates are **slow**	Runs & updates are **fast**
Hundreds of runs required for HM	**1 Run** for each realization
Requires fine grids	Fine/Coarse grids
Rapidly **outdated**	Remains **up-to-date**

Asset Management

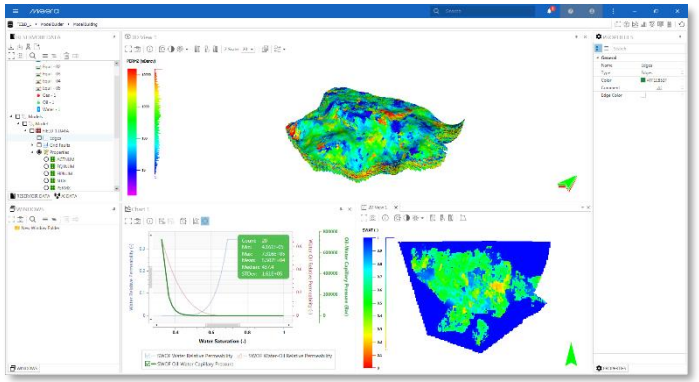
Application Highlights	Technology
Evergreen Forecasting	AI-Physics
LTRO	Data Mining

Conventional (Decline Curves & Conduit Models)	HYBRID
Based on **Data**	Based on **Physics** & **Data**
Physics **not incorporated**	Physics **incorporated**
Runs & updates are fast	Runs & updates are fast
Remains up-to-date	Remains up-to-date

Hybrid Simulation Methodology

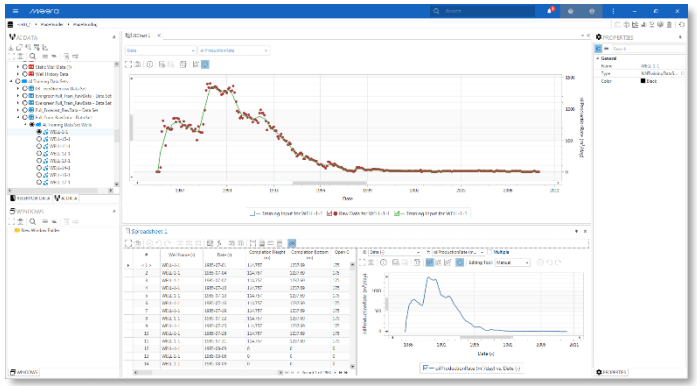
Combining a Physical Model with Artificial Intelligence

1. Build the dynamic model to be “AI ready”



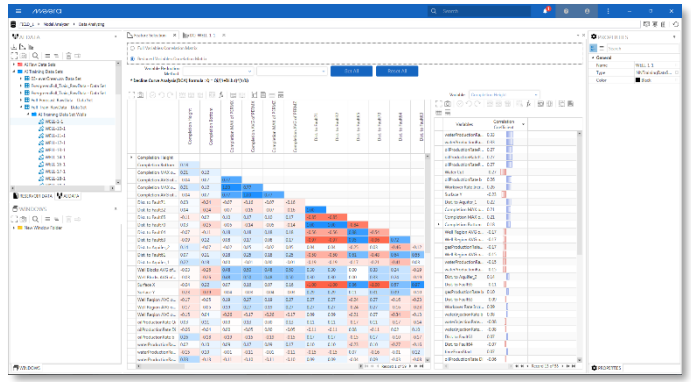
Existing static/dynamic models easily imported

2. Analyse the underlying dynamic data



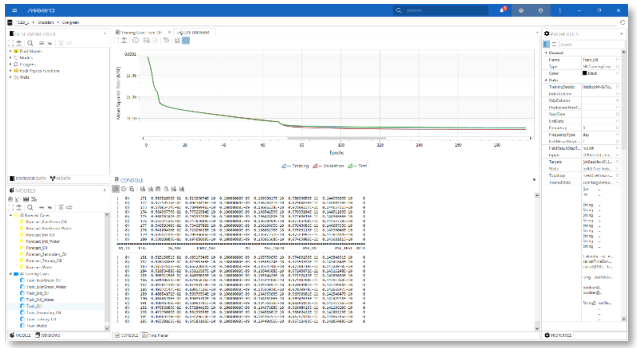
QA/QC, de-noise / smooth data where appropriate

3. Construct the AI-Physics framework



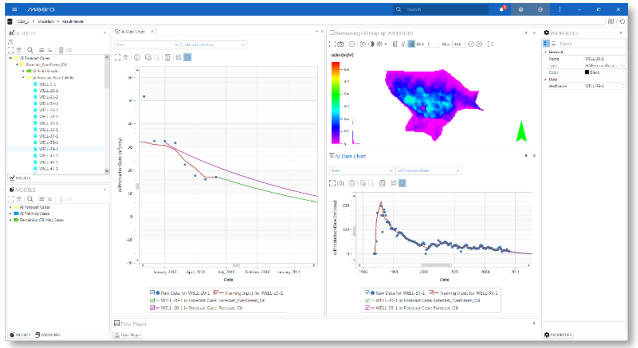
Assess parameter correlations and rank according to their influence on reservoir performance

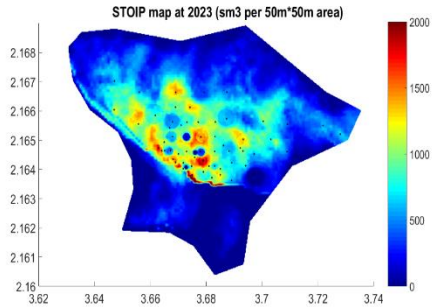
4. Match production history and build prediction cases



History match performed using deep neural networks supported by numerical simulation

5. Ensure the model remains “evergreen”



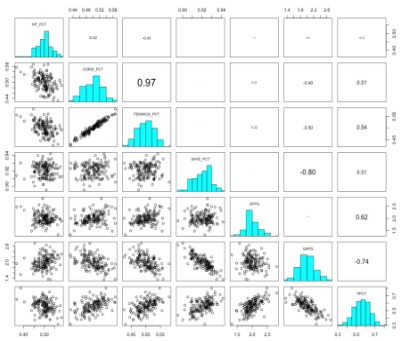


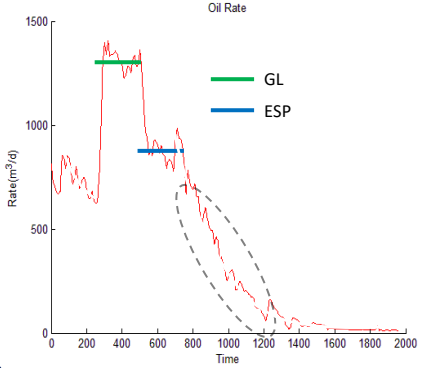
Run model updates as new data becomes available.

Hybrid Simulation Computational Core

User Input:
- Rank parameters
- Apply knowledge and experience

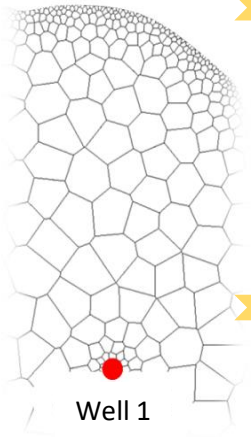
Data Mining/Analysis



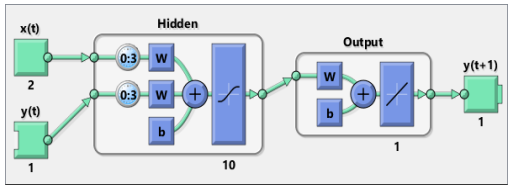


Hybrid Simulation Engine

Numerical Simulator (Analytics)



Deep Learning Training



Time Stepped Prediction

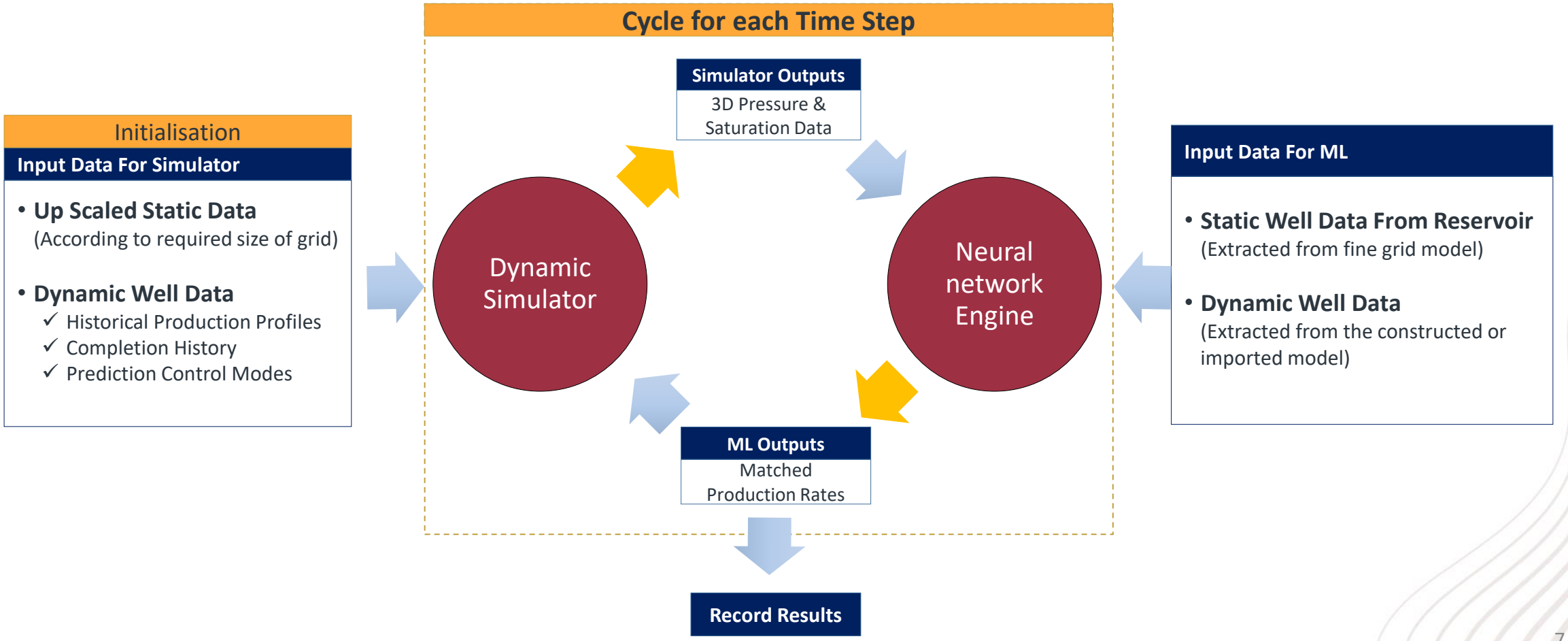
Input (t^n) → Trained Network → Output (t^{n+1})

Successive Substitution

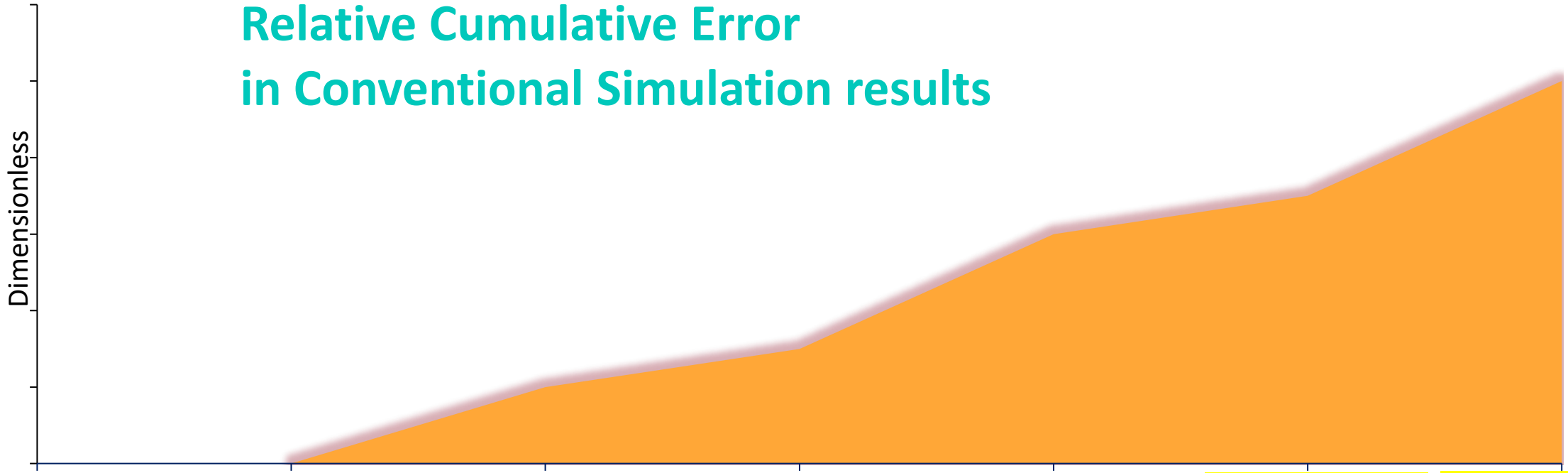
Algorithmic "Intelligence"

Global minimization of error to compensate for inconsistencies in input static data

Simulation Hybrid Engine – Data inputs

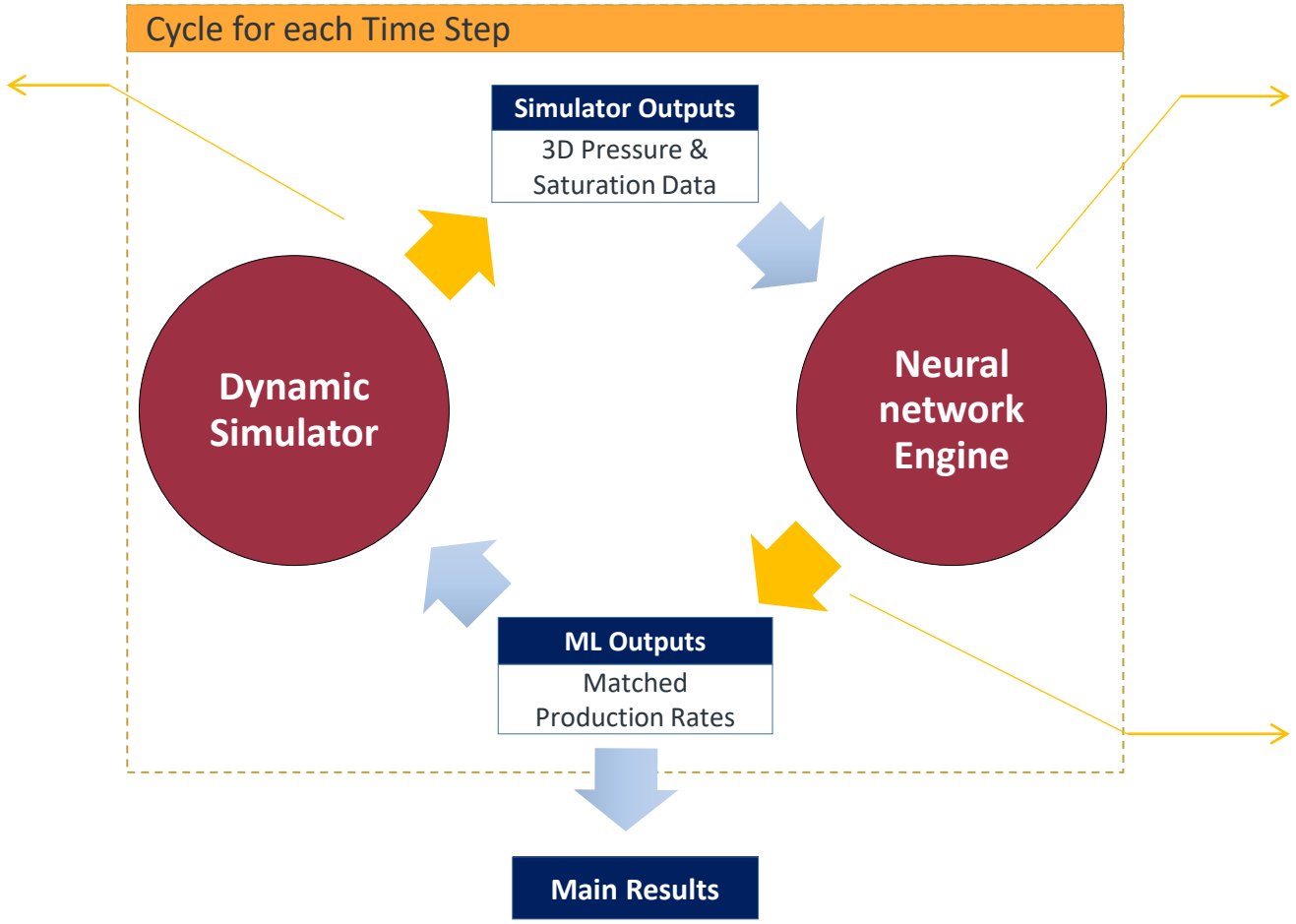


Error sources in a conventional simulation approach



Simulation Hybrid Engine – High level description

Relatively Coarse Grid
Can be selected for computational efficiency



Global minimization of production data error function though adjustment of pressure/Sat'n arrays

AI adjusts simulated production profiles against well model constraints for prediction

Case Study 1: Description

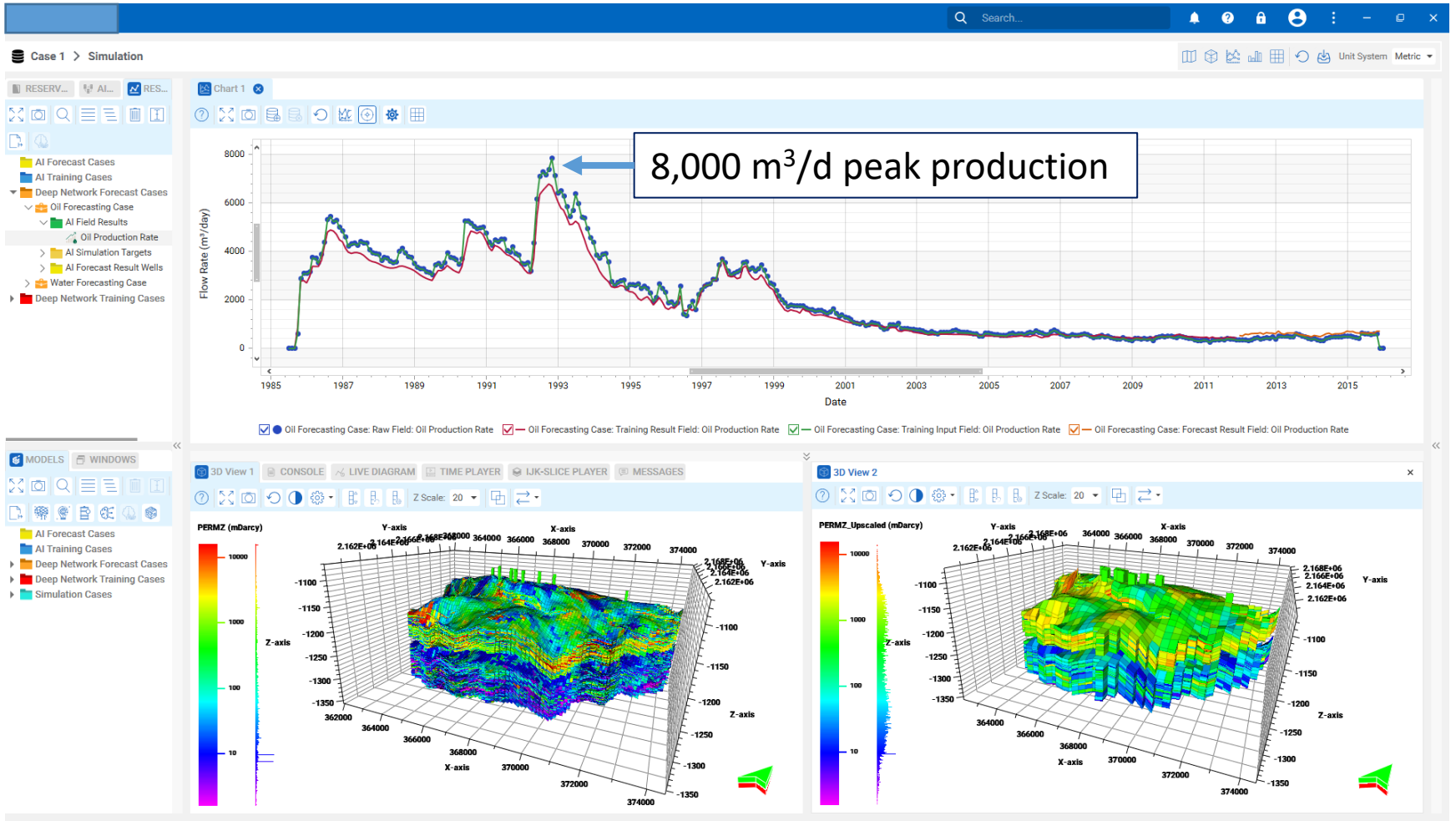
Case Study Description

- High perm fluvial clastics, with strong aquifer support
- Production of light oil started in 1985
- More than 80 (vertical) production wells drilled and produced using ESPs
- Production data matched until 2010 and period 2010-2018 used as a “blind test” prediction
- Each full field simulation requires 7-8 hours computing time using traditional simulators.

Hybrid Simulation Results

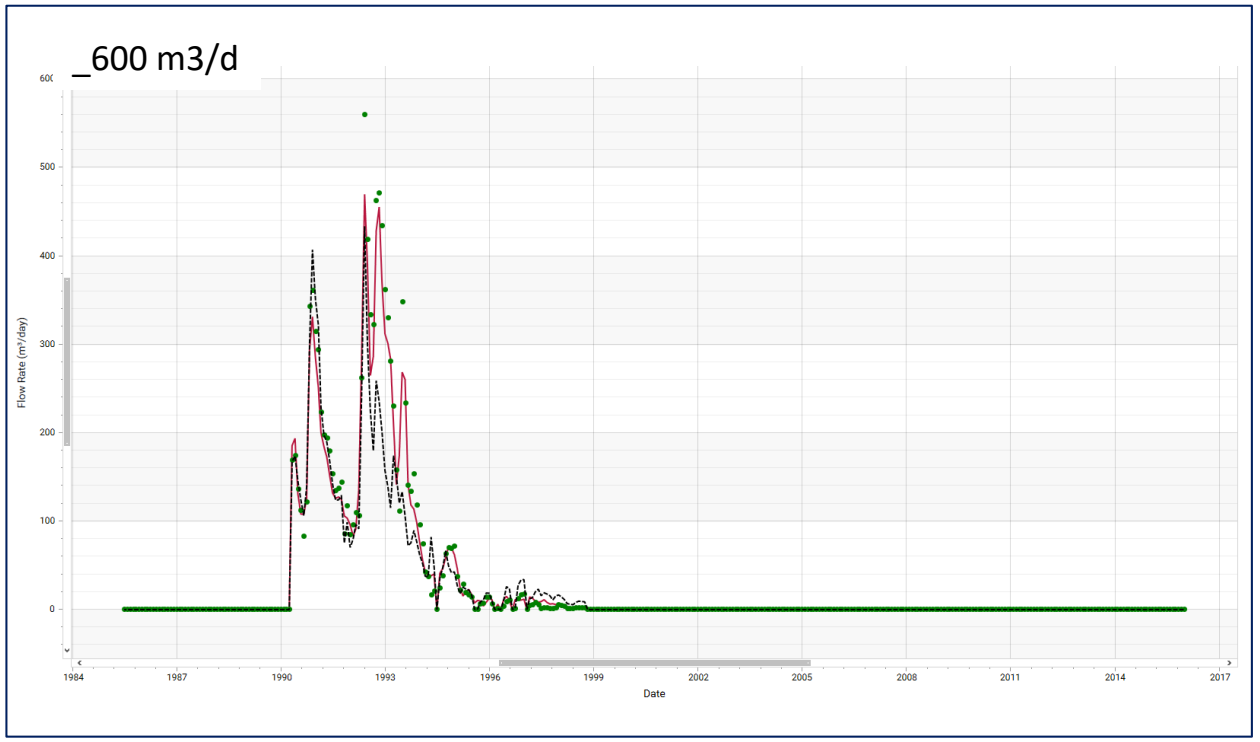
- History simulation achieved in 12 minutes computer run time
- Each prediction requires a run time of ~50-70 milliseconds
- The history match is superior to the traditional model results and in particular the “blind test” prediction (for individual wells) is much improved.

Case Study 1 – Field History: Oil Production

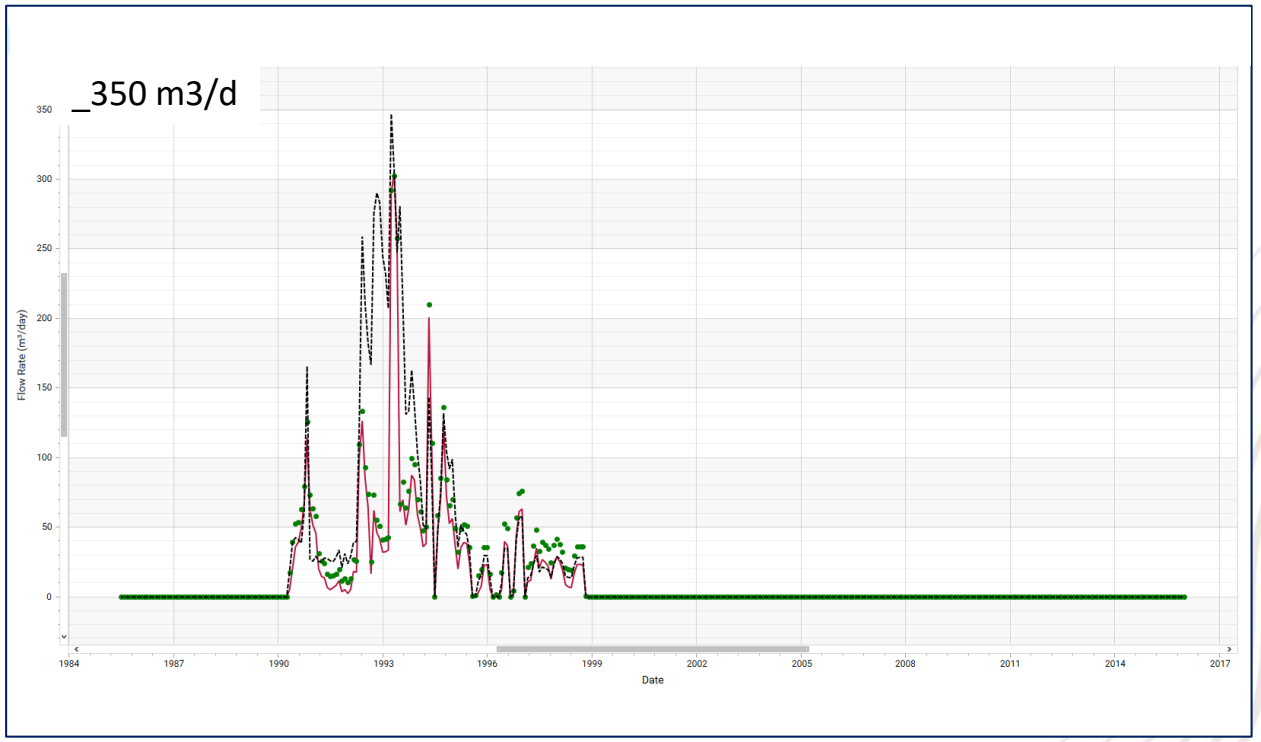


Case Study 1 – Well 1 Oil & Water Production

Oil Production Match



Water Production Match



HYBRID (Blind) Forecast

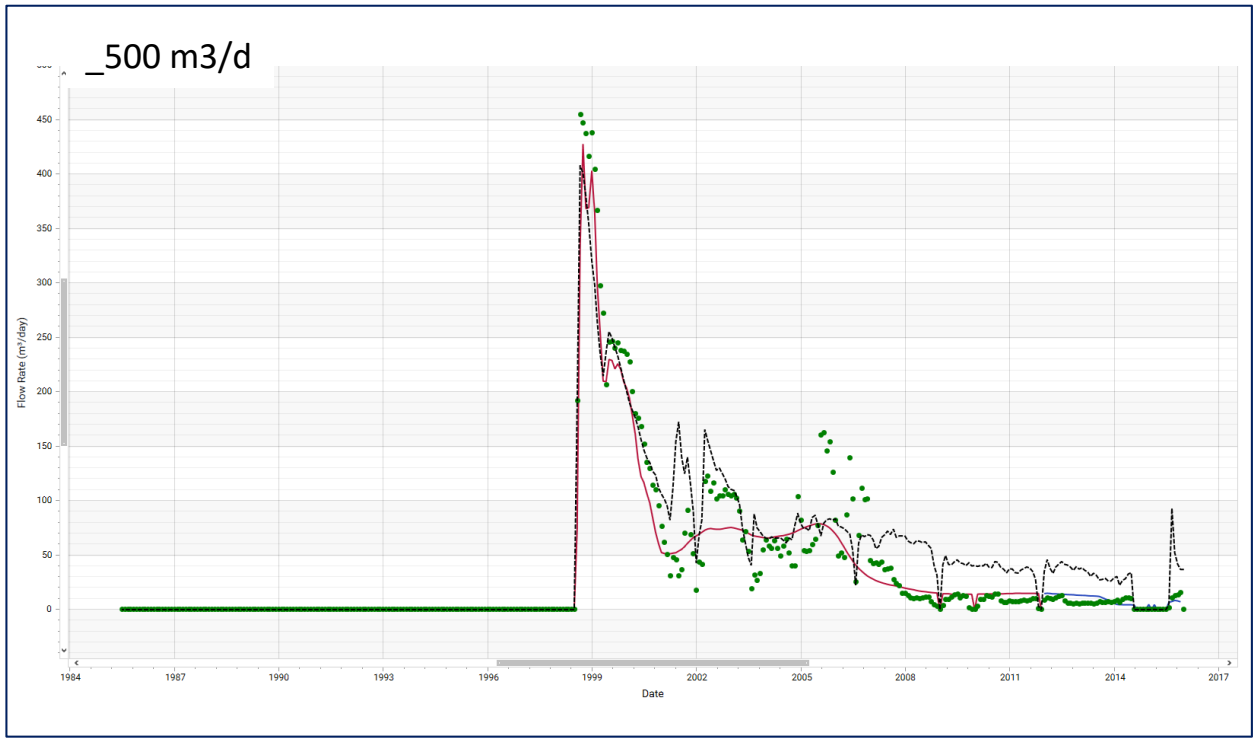
HYBRID History

Traditional Simulator

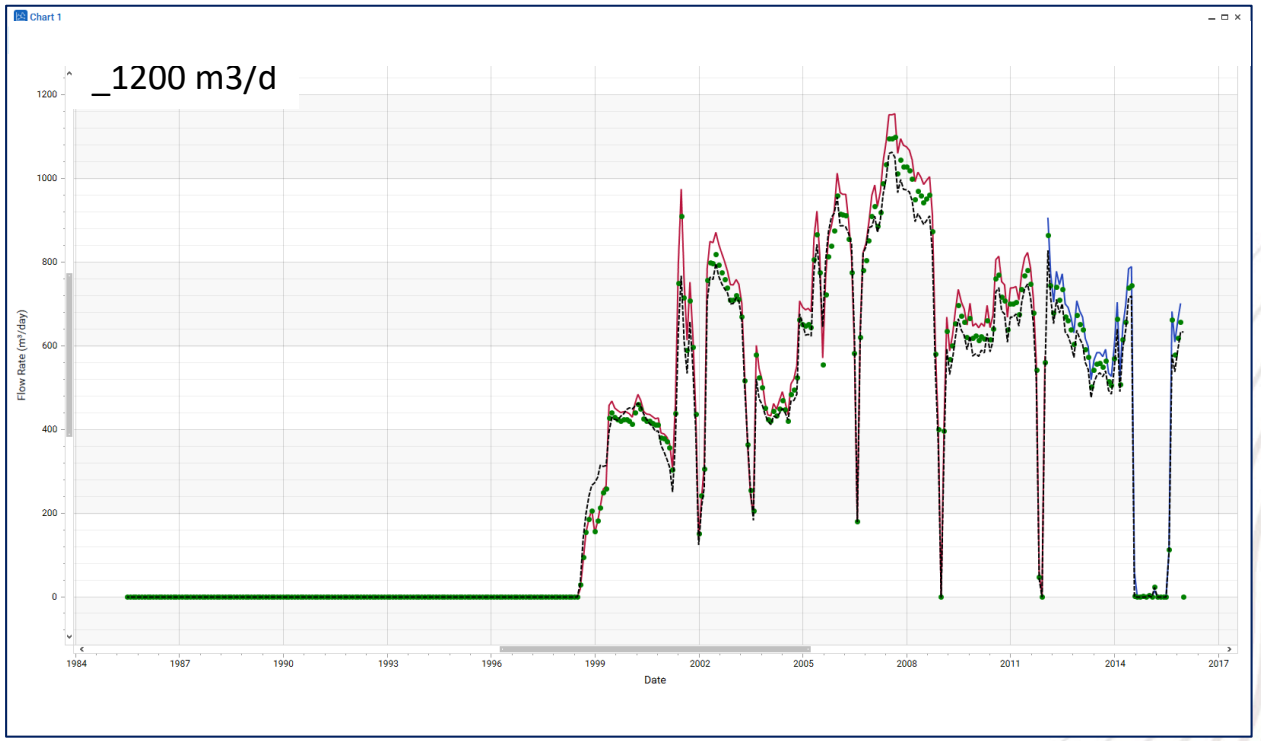
Observed Rates

Case Study 1 – Well 2 Oil & Water Production

Oil Production Match



Water Production Match



HYBRID (Blind) Forecast

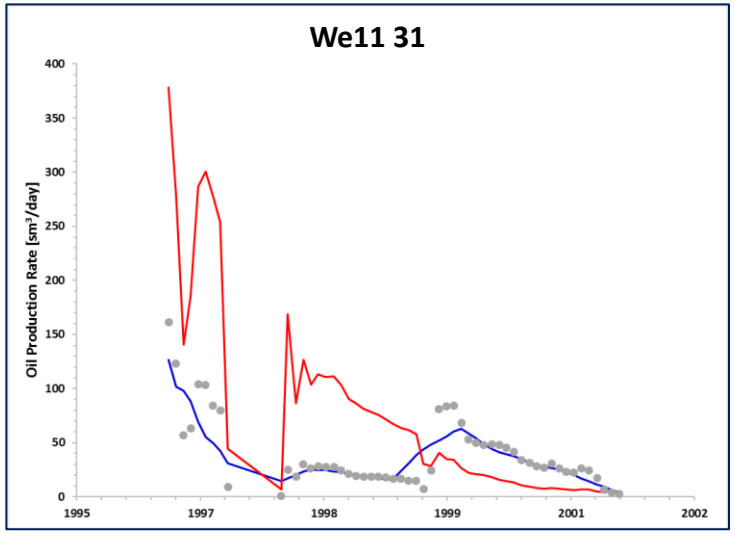
HYBRID History

Traditional Simulator

Observed Rates

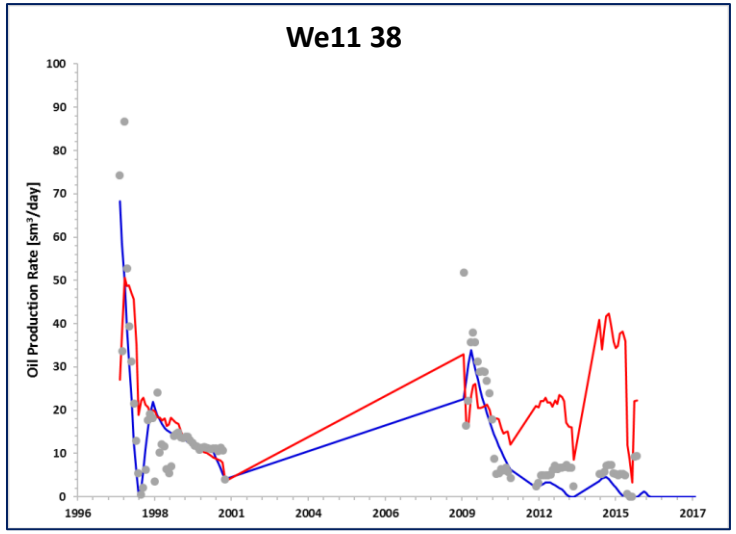
Oil production comparison in different wells

Producing in history



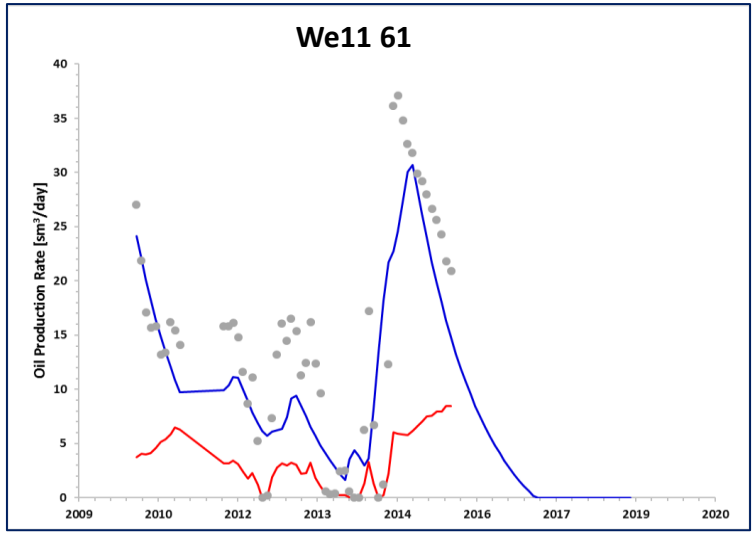
Producing in both history and prediction

(partial blind test)



Producing in prediction

(Blind Test)



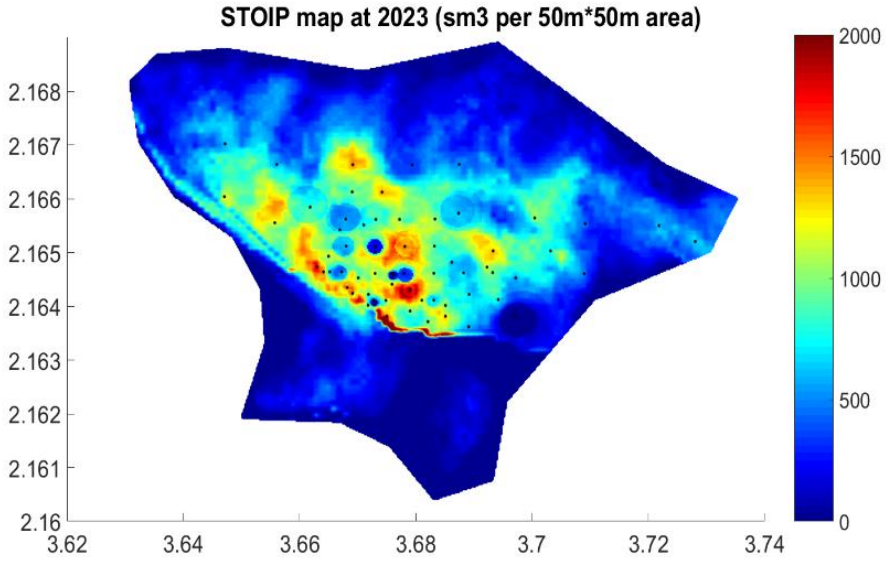
Hybrid Simulator

Traditional Simulator

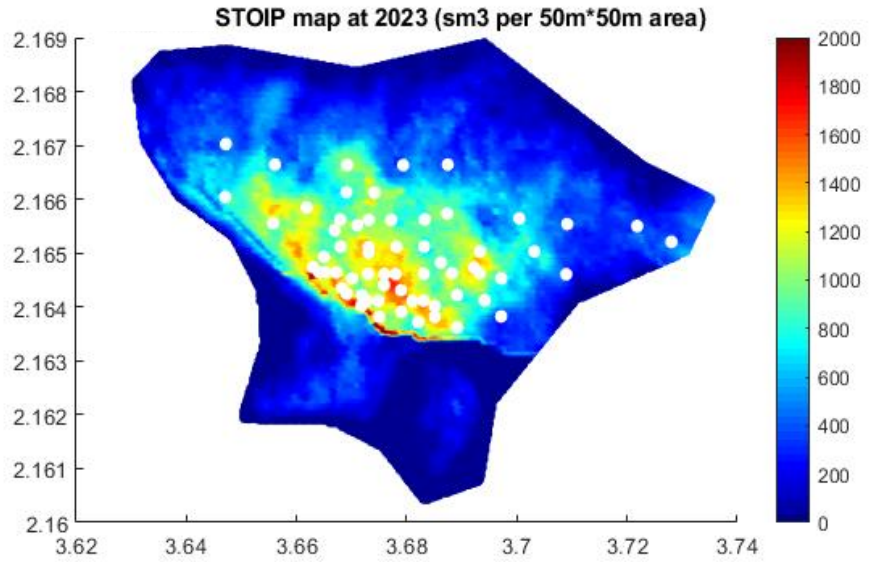
History Data

Comparison of STOIP maps at year 2023 – HYBRID vs. traditional simulator

HYBRID simulator Bypassed Oil map



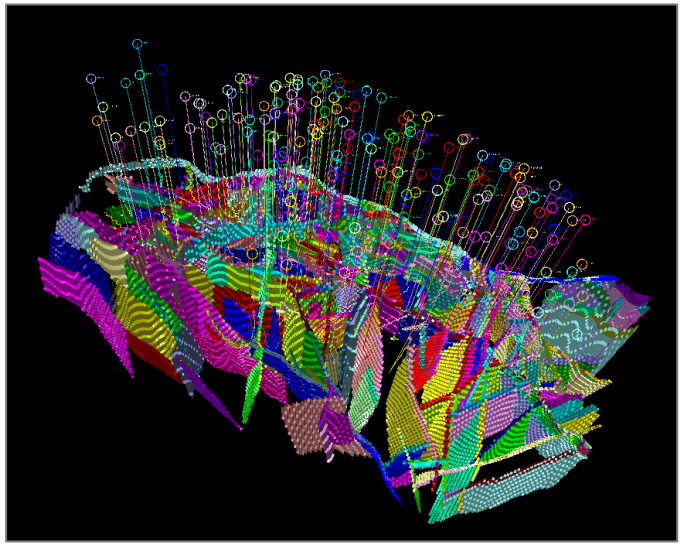
Traditional simulator Bypassed Oil map

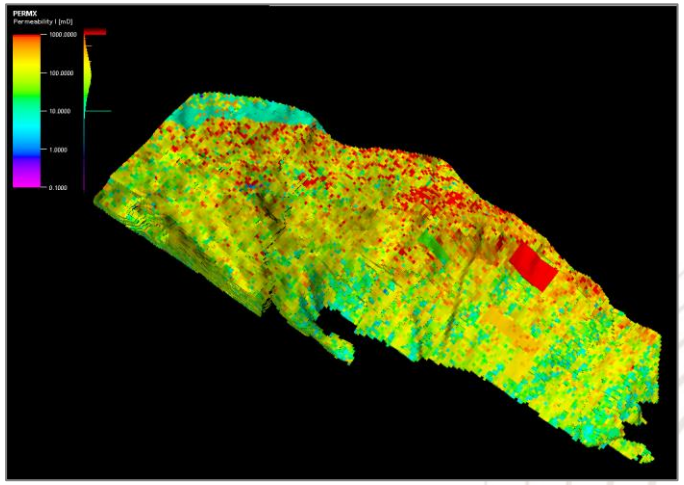


- Improved individual well Oil/Water matches yield more robust bypassed oil maps
- Hybrid map exhibits “bullseye” character due to channelized environment with relatively poor 3D connectivity
- Two infill wells subsequently drilled proved superior results from Hybrid vs. Conventional approach

Case Study 2 – Description of “old” traditional model

- Highly faulted/compartmentalised field with 202 existing wells
- Grid size X:110, Y:244, Z:275 → 7.4 mln GB→ 0.6 mln active
- Sat’n Height Functions rigorously implemented in original conventional model
- Carter-Tracy analytical aquifers implemented
- Good overall field match, however,
- Individual well matches obtained by:
  - ✓ Multiple local rock property modifications;
  - ✓ Rescaling of saturations at well locations;
  - ✓ Well PI Multipliers applied for numerous wells (PLT data used in few cases but most multipliers not substantiated).





Case Study 2 – Study Effort in the Hybrid Simulation

- Import of existing traditional simulation model (3 days)
- (Re) scaling of model: (7 days)
  - Number of (Z) layers decreased from 275 to 15 – (X/Y dimensions retained)
  - Well models reconstructed based on the new grid
  - Previously applied reservoir transmissibility and well PI manipulations ignored, as were completion saturation end points.
- Static features & observation data automatically extracted from the original model
- An appropriate AI-Physics framework was established based on the model behavior
- ML “Training” parameters selected based on data correlation and sensitivity analysis. (2 days)
- The field was history matched (5 days)
- Various forecast scenarios run to test the predictability of the model (1 day)
- Project was completed in 3 ½ weeks (Original operator study lasted more than 3 years)

Historical Blind Test

Historical Blind Test Description

Traditional Simulation (with the existing history matched model)

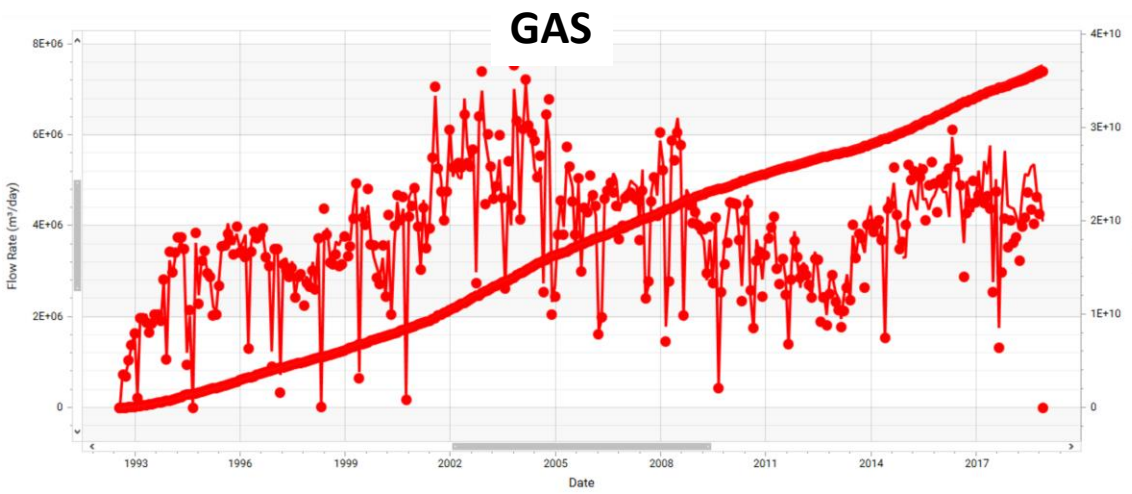
- Historical rates with reservoir rate constraints: Aug. 1992 – Dec. 2018

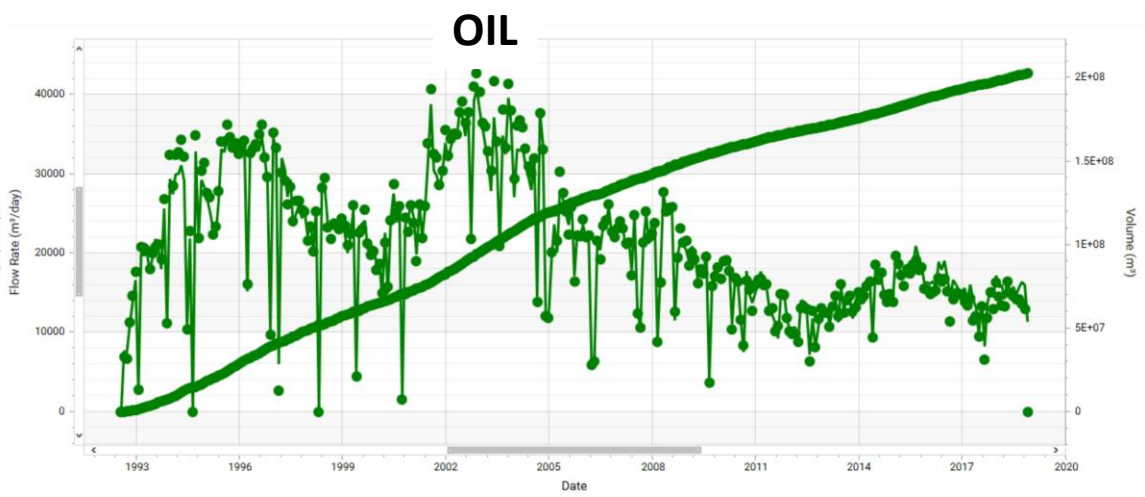
Hybrid Simulation

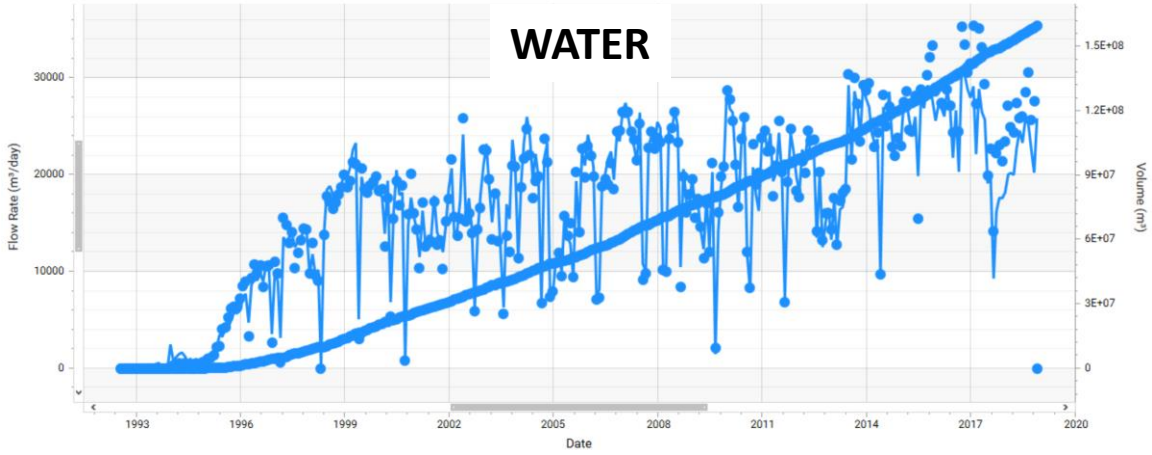
- History simulation: **Aug. 1992 – Dec. 2014**
  - Upscaled model: Historical reservoir rate constraints
  - AI/ML model: Training with historical rates
- Blind test prediction: **Jan. 2015 – Dec. 2018**
  - Upscaled model: Historical reservoir rate constraints
  - AI/ML model: Production rates forecast

Historical Production Rates: Aug. 1992 – Dec. 2018

Field Match-Hybrid Simulator



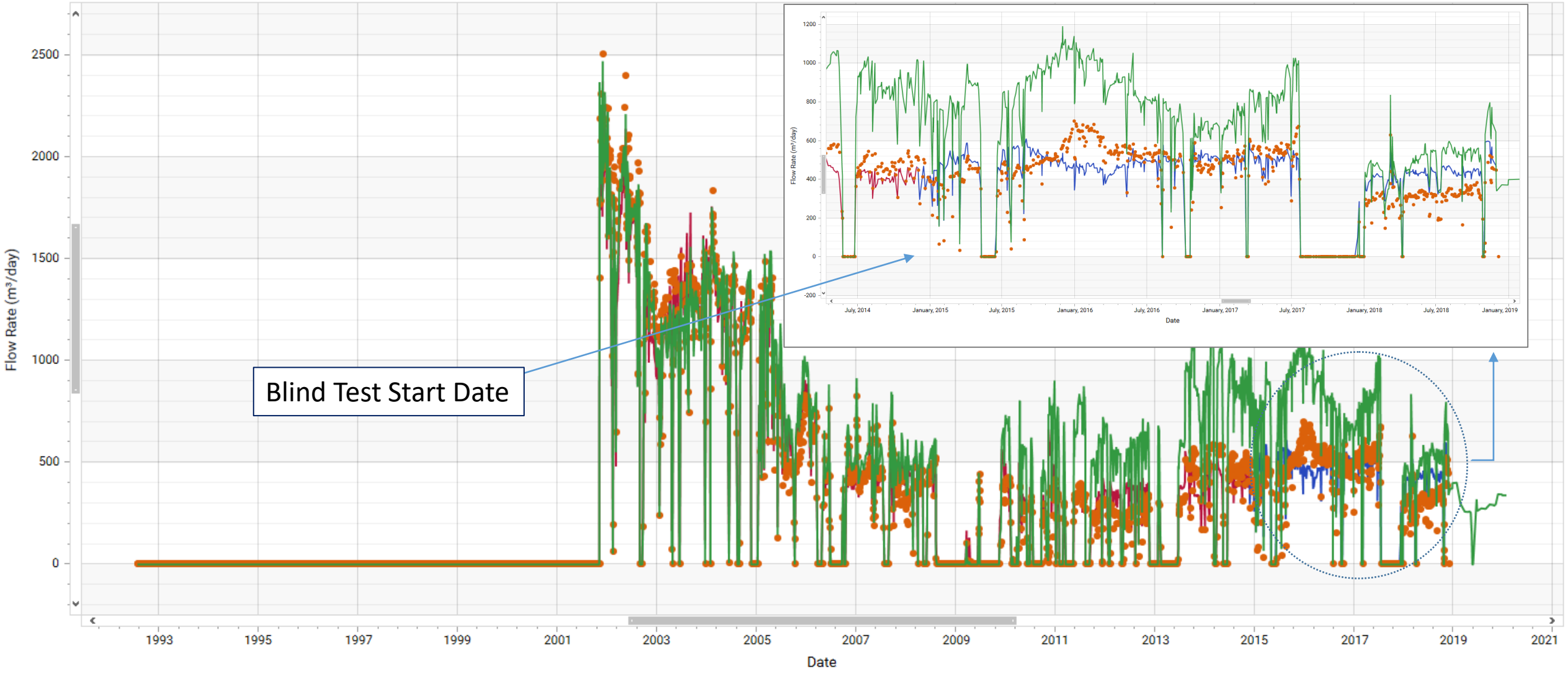




Field Oil Production Rate
Field Observed Oil Production Rate
Field Water Production Rate
Field Observed Water Production Rate
Field Gas Production Rate
Field Observed Gas Production Rate

All Fluid Phases matched in cumulative ➔ Good quality pressure and saturation match in the model

Well 1 Oil Production Profile m³/day (Historical Blind Test)

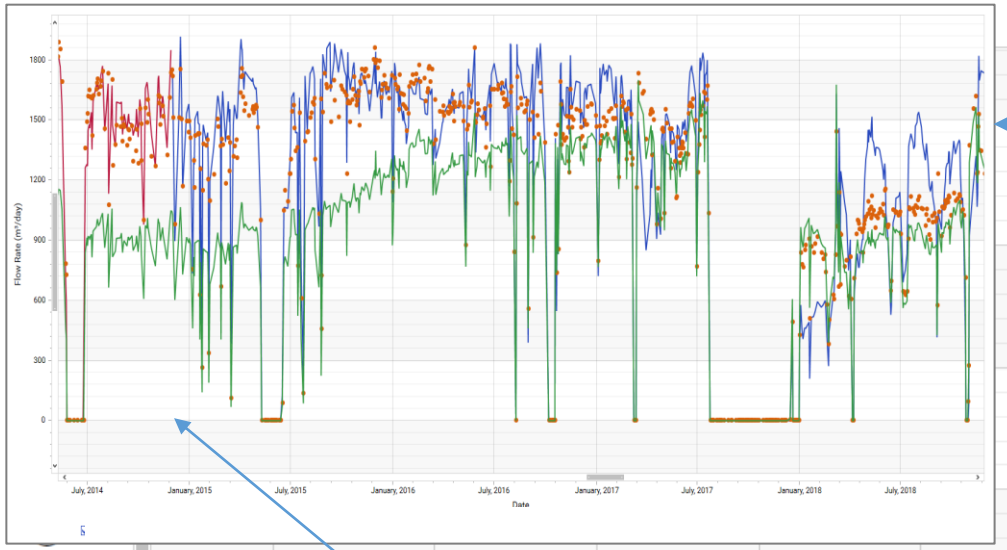


HYBRID (Blind) Forecast

HYBRID History

Traditional Simulator

Well 1 Water Production Profile m^3/day (Historical Blind Test)



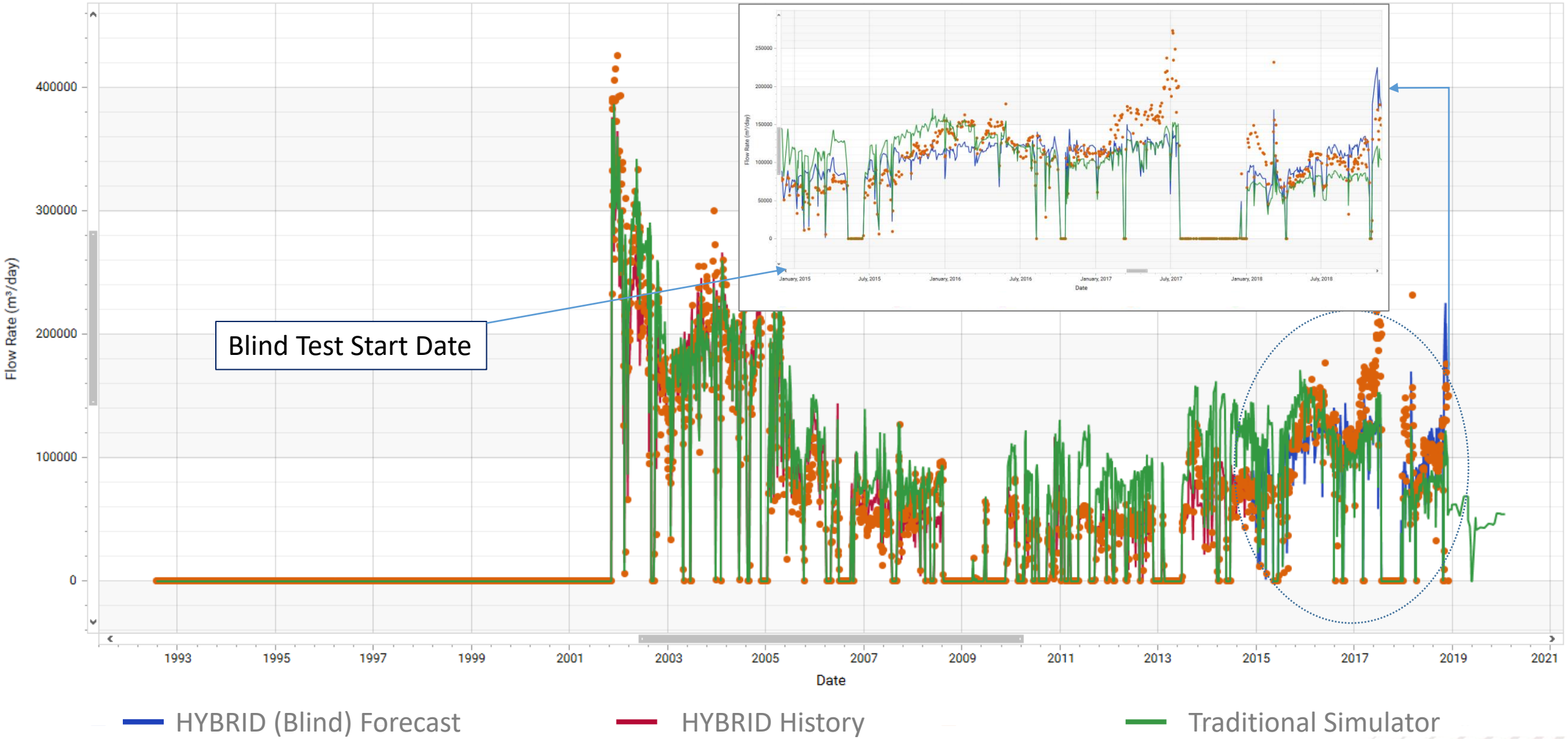
Blind Test Start Date

HYBRID (Blind) Forecast

HYBRID History

Traditional Simulator

Well 1 Gas Production Profile m³/day (Historical Blind Test)



Case 2:
Comparison of HYBIRD vs Traditional Simulator in Forecast mode.

Forecast comparison: Definitions

Traditional Simulation (with the provided history matched model)

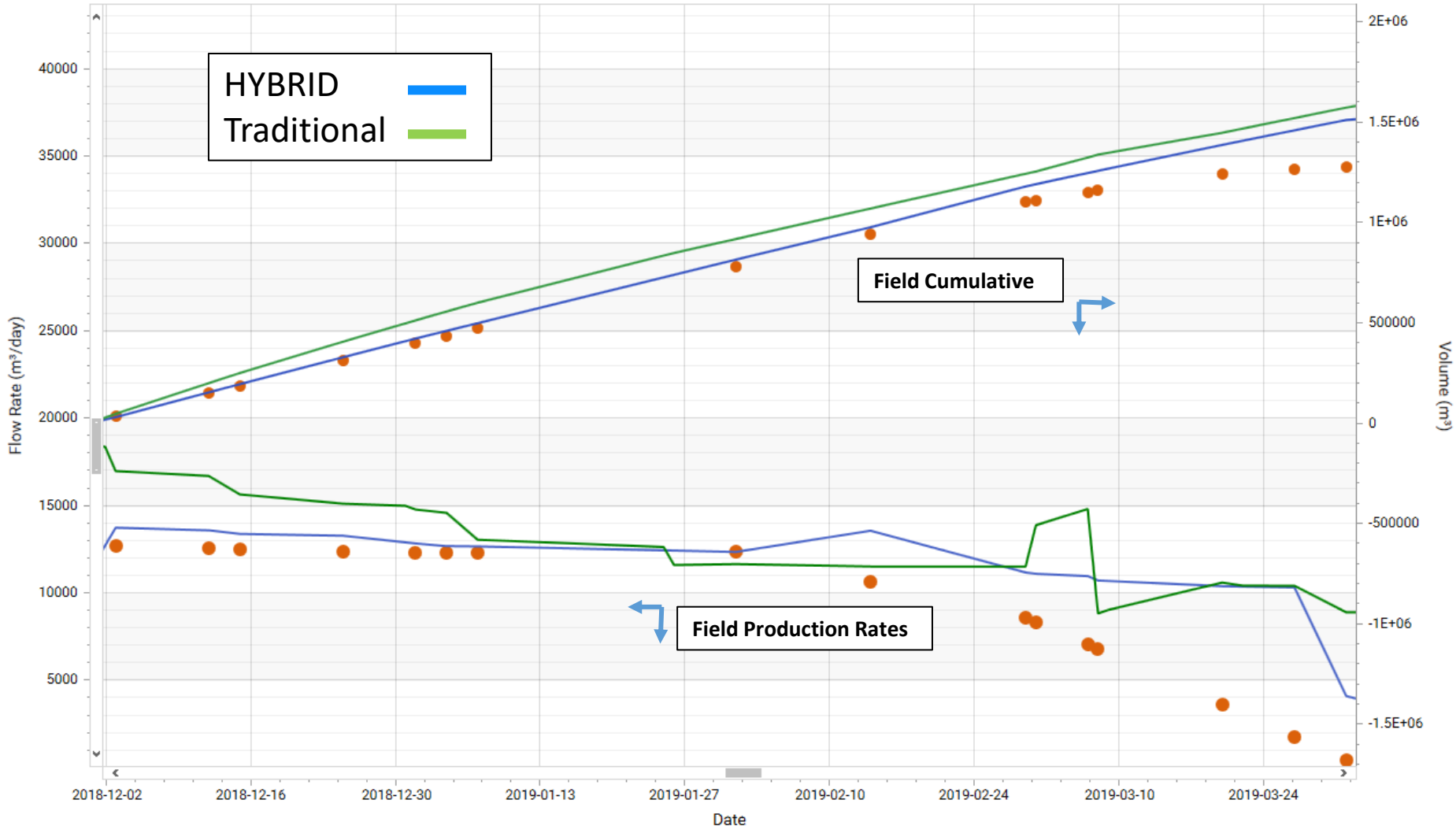
- Historical rates with reservoir rate constraints: Aug 1992 – Nov 2018
- Well production constraints: Dec 2018 – Apr 2019

HYBRID Simulation

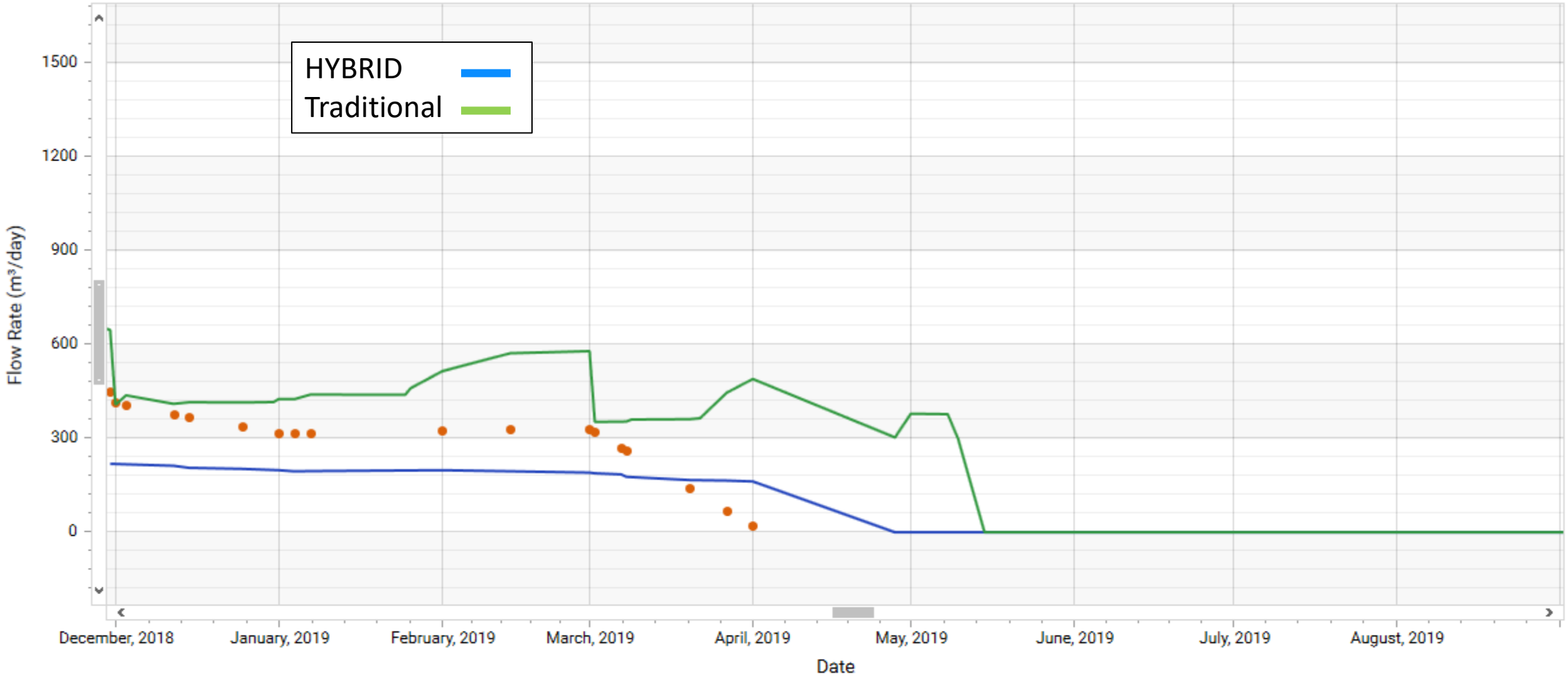
- History simulation: Aug 1992 – Nov 2018
  - Upscaled model: Historical reservoir rate constraints
  - AI/ML model: Training with historical rates
- Blind test prediction: Dec 2018 – Apr 2019
  - Upscaled model: Well production constraints
  - AI/ML model: Production rates forecast

Observed Production Rates: Aug 1992 – Apr 2019

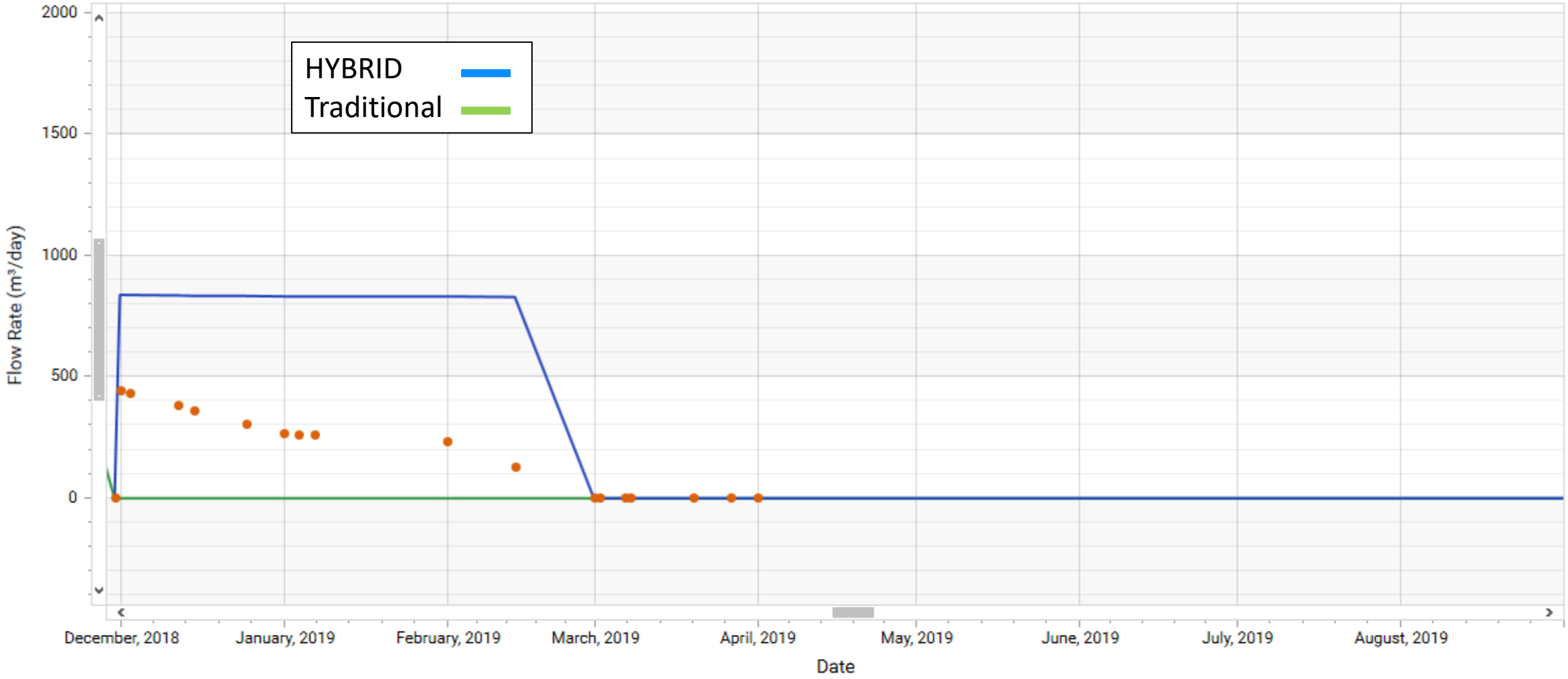
Field Oil Production Rates & Cumulative Production



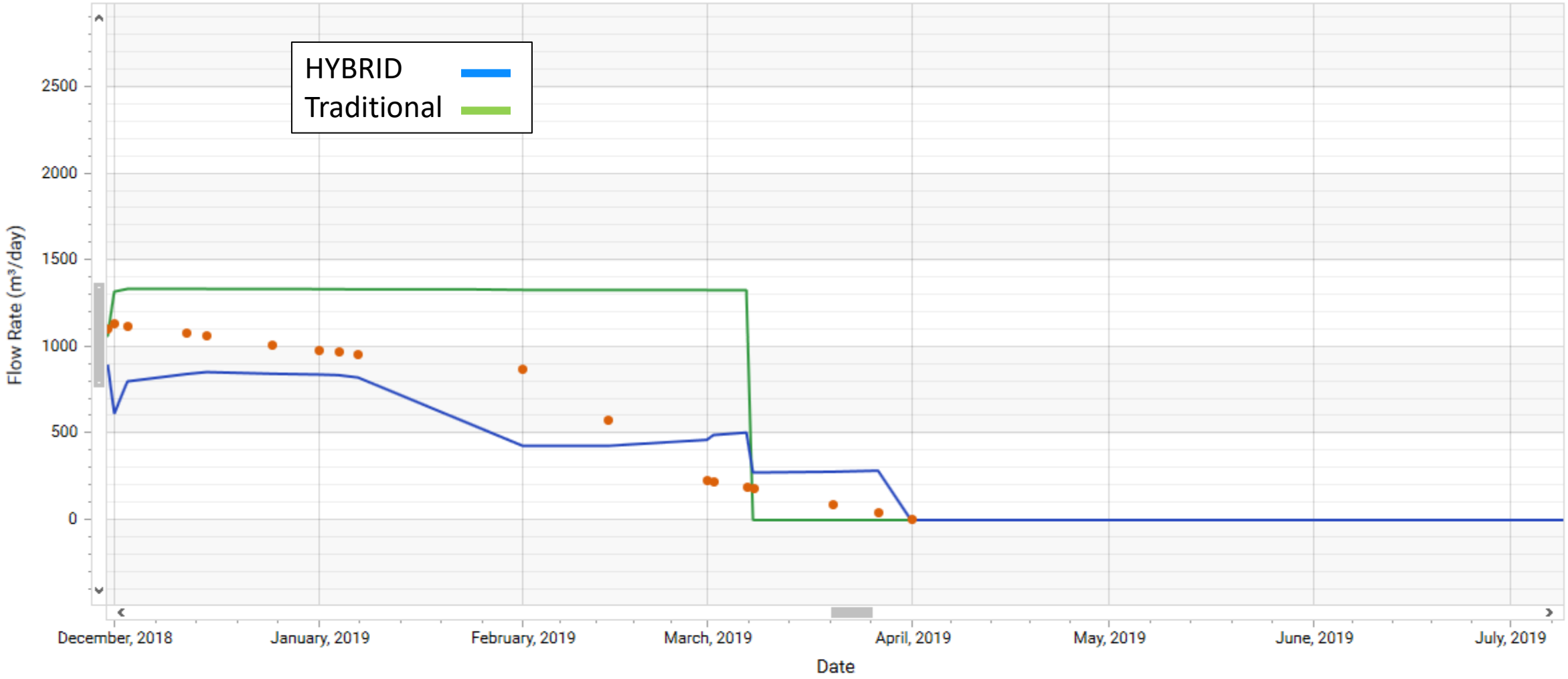
Well 1 Oil Production Profile m³/day



Well 2 Oil Production Profile m³/day



Well 3 Oil Production Profile m³/day



MEERA Simulation Achievements in Projects

No.	Project Description	KPI for Bench-Marking	Added Value
1	Brown field, 80 Wells, Natural depletion / Water flooding	1) HM/Blind Test Forecast/Forecast comparison with Trad model 2) STOIP verification in 2 newly drilled wells 3) Model updates and live remaining oil tracking	1) Saving 1.5 years for a full model update 2) Avoiding inappropriate drilling locations 3) Easy model updates and better expert utilization
2	Brown field with an old and poor static model, 130 Wells, Complex structure, Water/Gas Injection	HM/Blind Test Forecast comparison with Trad model based on a poor static model	✓ More reliable HM/Blind Test Forecast ✓ Saving a new model update cost
3	Brown field with limited and missing data, Complex structure	HM/Blind Test Forecast comparison with Trad models for a field with limited data	Overcoming data limitations and achieving more reliable HM/Blind Test Forecast
4	Brown field, 10 wells	HM time and accuracy comparison with Trad model	Saving time and resource by achieved HM in 2 days with higher accuracy
5	Brown field with highly faulted structure, 200 wells, complicated history matching (Case Study 2)	HM/Blind Test Forecast/Forecast comparison with Trad model … extremely complicated model	✓ Significant time and resource saving by achieving HM in 1 month (more than 3 years required for the conventional model) ✓ Better use of SMEs by removing HM process burden ✓ More accurate forecasts on a well level

KEY ADVANTAGES - Technical

Significant RE time saving due to fast computational run times (more scenarios tested in same time frame)

More accurate results in:

- ✓ History: due to better alignment with historical data
- ✓ Prediction: due to lower dependency to uncertainty / unavailability of physical reservoir data

Simple & quickly achieved model updates (High end simulation expertise not required)

Suitable guide for more detailed field development studies (or additional data gathering) through identification of the most critical parameters in the “digital twin” model

KEY ADVANTAGES OF HYBRID

Evergreen Production Forecasting & Reserves Tracking: Staff time saving and better alignment between further development and operations plans derived from simulation

Very fast Field History Matching & Production Forecasting process: By combining AI with numerical reservoir simulation. Significant RE/PE staff time saving

Live Infill Drilling Optimization: Efficient generation of infill drilling targets via fast and robust generation of bypassed oil maps

Valuable tool to aid in Well and Reservoir Management, giving staff the time to think creatively, to maximise the value of producing assets.

MEERA SIMULATION

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TARGET