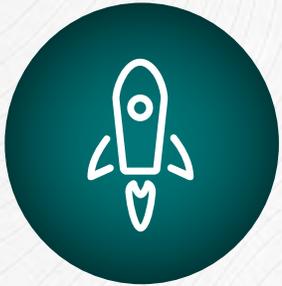


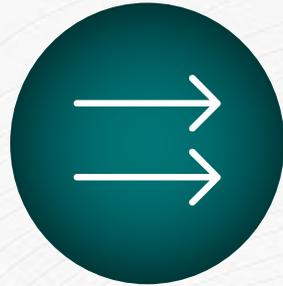
2025 Fourth Quarter General Highlights

2025.40 Release

CMG's 2025 Development Themes



Speed &
Performance



Out-of-the-Box
Optimization



Quick Screening &
Detailed Physics



Market-Driven
Enhancements



Extensibility &
Openness

- > Energy Transition
- > EOR and Advanced Processes
- > Accelerating Decisions
- > Production Engineering and Integrated Systems

Energy Transition Modelling Updates



Impacts of pH (Acid/Base) on Geochemical Reactions

Background

- Geochemical reactions in GEM – used in mineral dissolution/precipitation modelling – have historically assumed a neutral pH mechanism in the calculation of reaction rates
- Neutral pH may not always provide adequate accuracy/matches to lab and field reaction rates where acidity is impacting

New Implementation

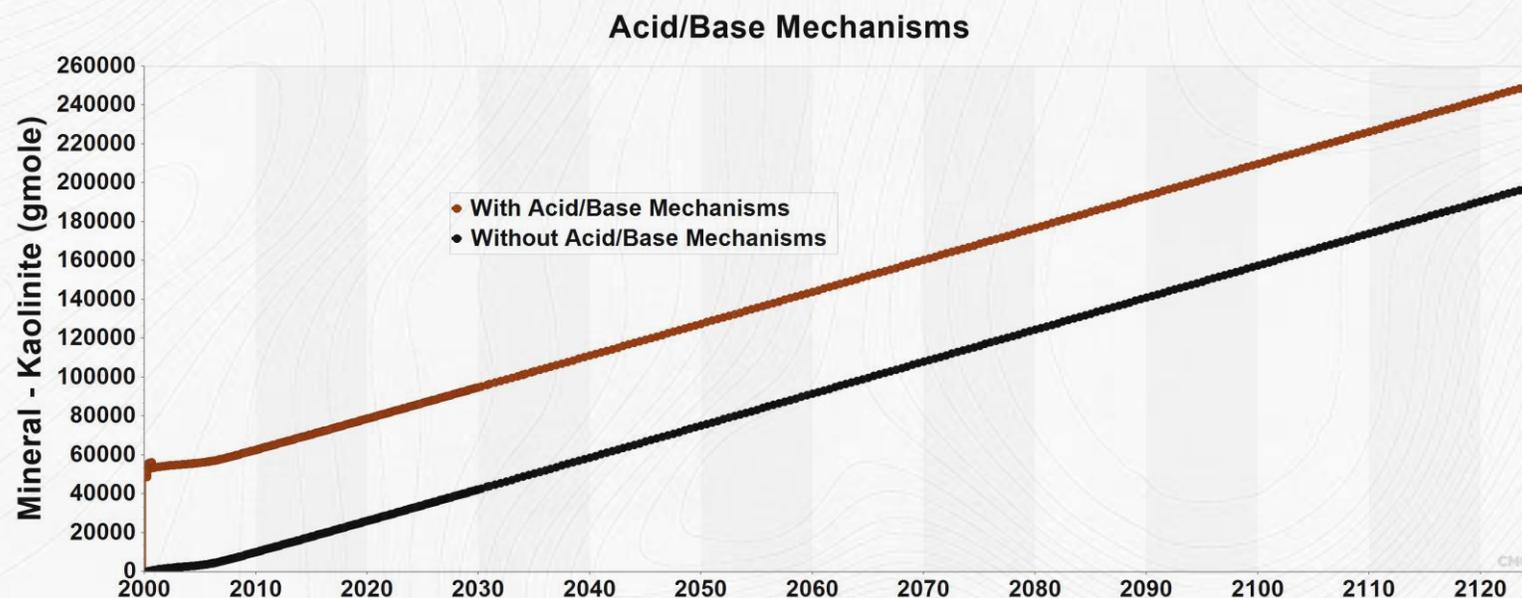
Dynamic updating of pH (acid-base balance) provides additional key physics for matching lab and field behavior

Acid/Base

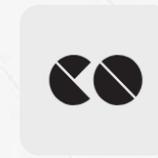
- Defined via user-specified activation energy, TST constants, and exponents for the H⁺ ion activity

pH-Dependence

- Modifies reaction rate constants under acidic/basic conditions as a function of user-specified thresholds and slopes



CO2LINK – Dynamic Multi-Component CCUS



Transient Wellbore - Impure CO₂ Injection Facilitation

LedaFlow™ Dynamic Multi-Component Setup and Impacts
(Inputs feed into CO2LINK™ and GEM™)

Challenge

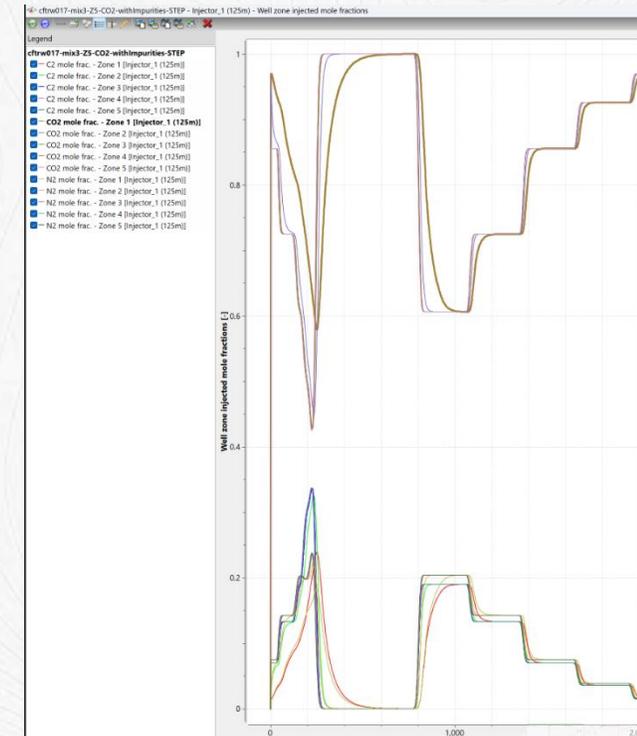
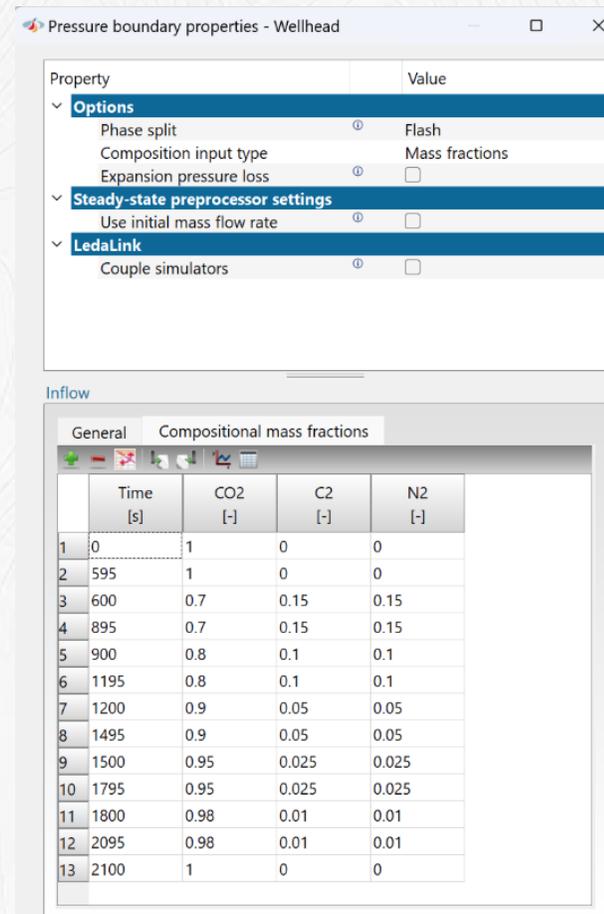
In CCUS processes, injection streams (potentially from multiple suppliers/emitters), may contain impurities which can impact the phase behavior and system dynamics

Solution

CO2LINK™ now facilitates dynamic injection updates of a multi-component hydrocarbon stream

Key Benefits

Ensures that the impacts on **pressures/temperatures and injectivity potential** are captured as the purity of the injection stream changes



Analytical Aquifers Extension for Top Connections



Challenge

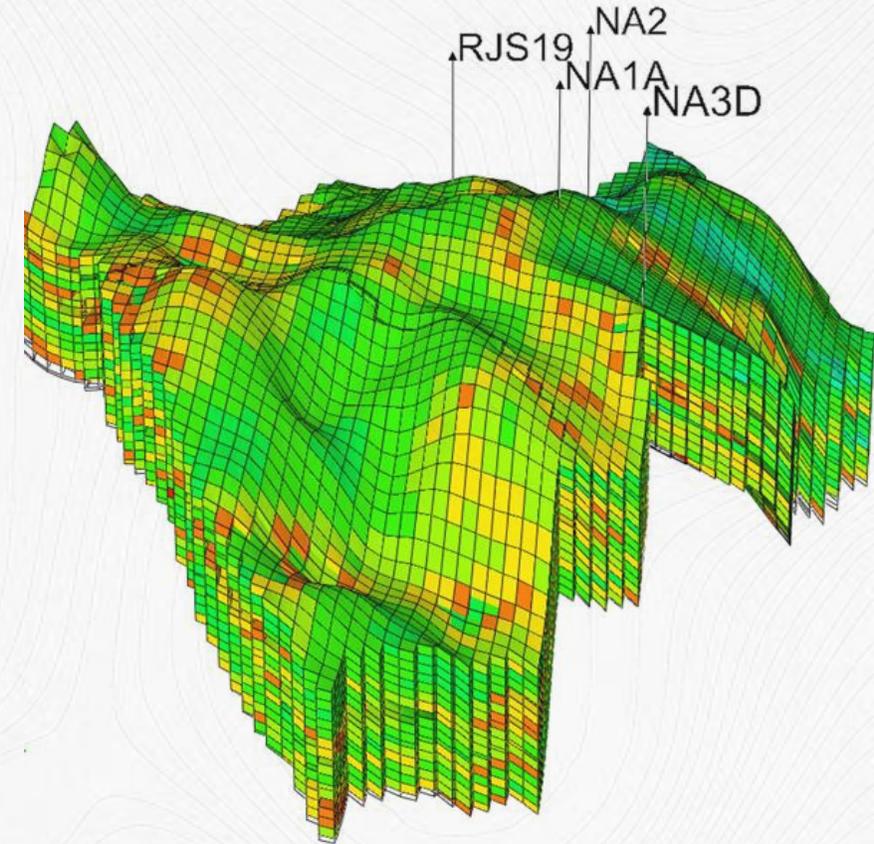
- In Geothermal, Solution Mining (REMs), and Carbon Storage (CCS) processes there may be overlying aquifer or fluid boundary movements for consideration
- Different from typical oil and gas systems (aquifers generally found at the bottom or edge of a reservoir zone)

Considering such systems was complex:

- Explicit modelling of overlying zones
- Use of wells to mimic the influx/outflux conditions

Solution

- Extension of the Analytical aquifer model for connection to the Top of a model
- Consider Energy and Aqueous-phase inflow/outflow easily
- **Efficient, Quick to setup and tune**



EOR and Advanced Process Enhancements

Leak-off Boundaries for Hydrocarbons

Multi-Component Aquifer (Boundary)

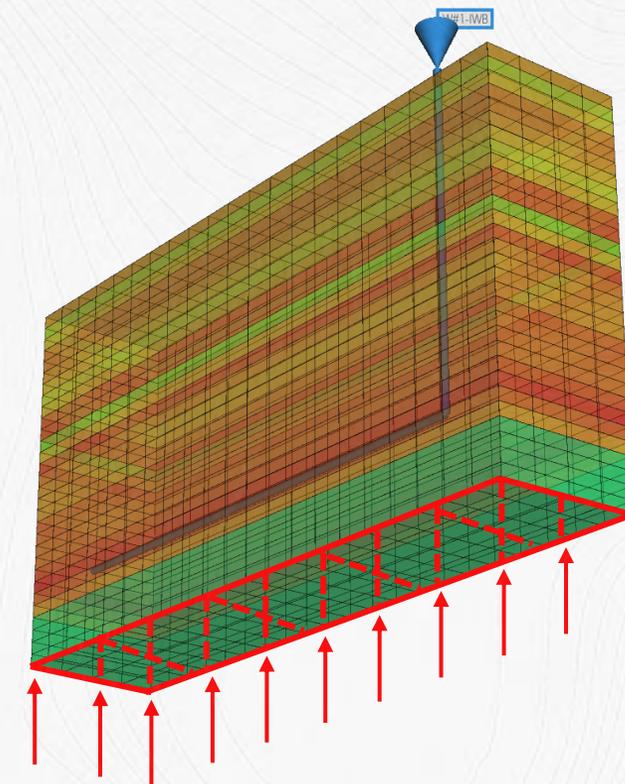
Challenge

In some higher-mobility hydrocarbon systems or fit-for-purpose studies where it is not feasible to model the entire asset (e.g. oilsands in Canada or expansive carbonate fields), submodels may be considered from which one or more sides of the model are open to flow

- For water-filled zones, analytical or numerical aquifers are preferred (easy to define)
- For hydrocarbon zones, aquifers could not be used. Instead, many wells are needed to control the inflow/outflow of fluids and energy.

Solution

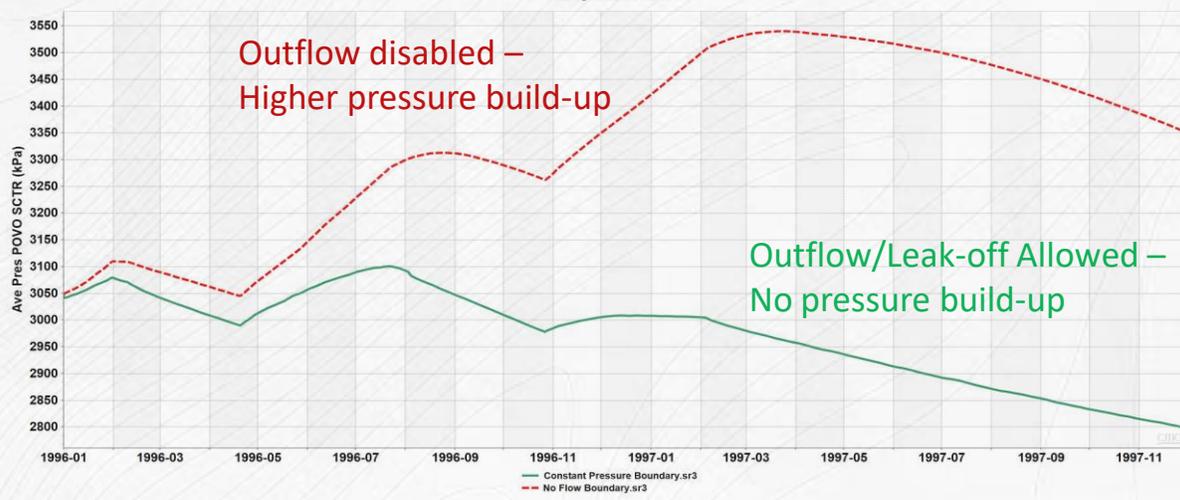
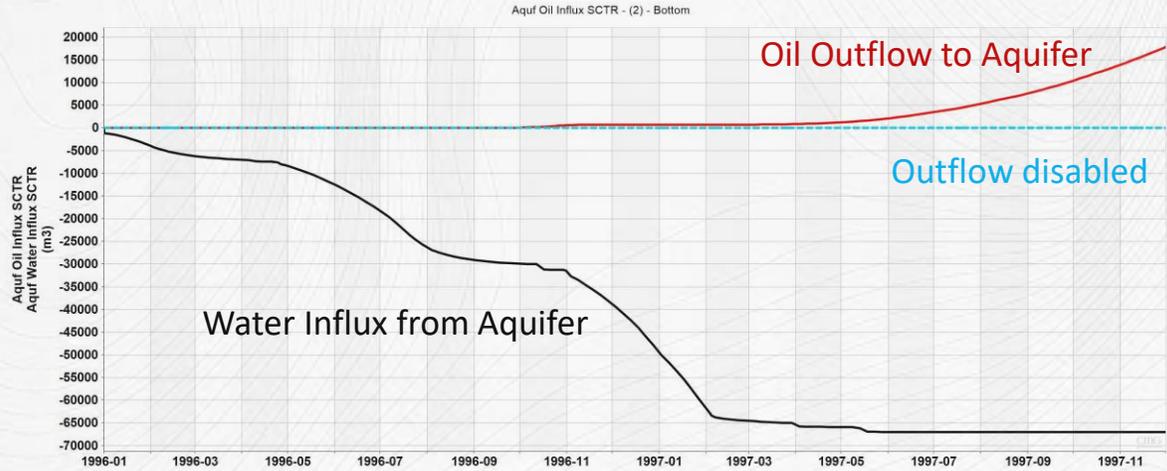
- Extension to Analytical Capabilities
- User-defined Pressure and Time-dependent boundary conditions
- Ability for any phase to inflow/outflow
- **Effectively handles multi-phase/component fluid exchange, easily**



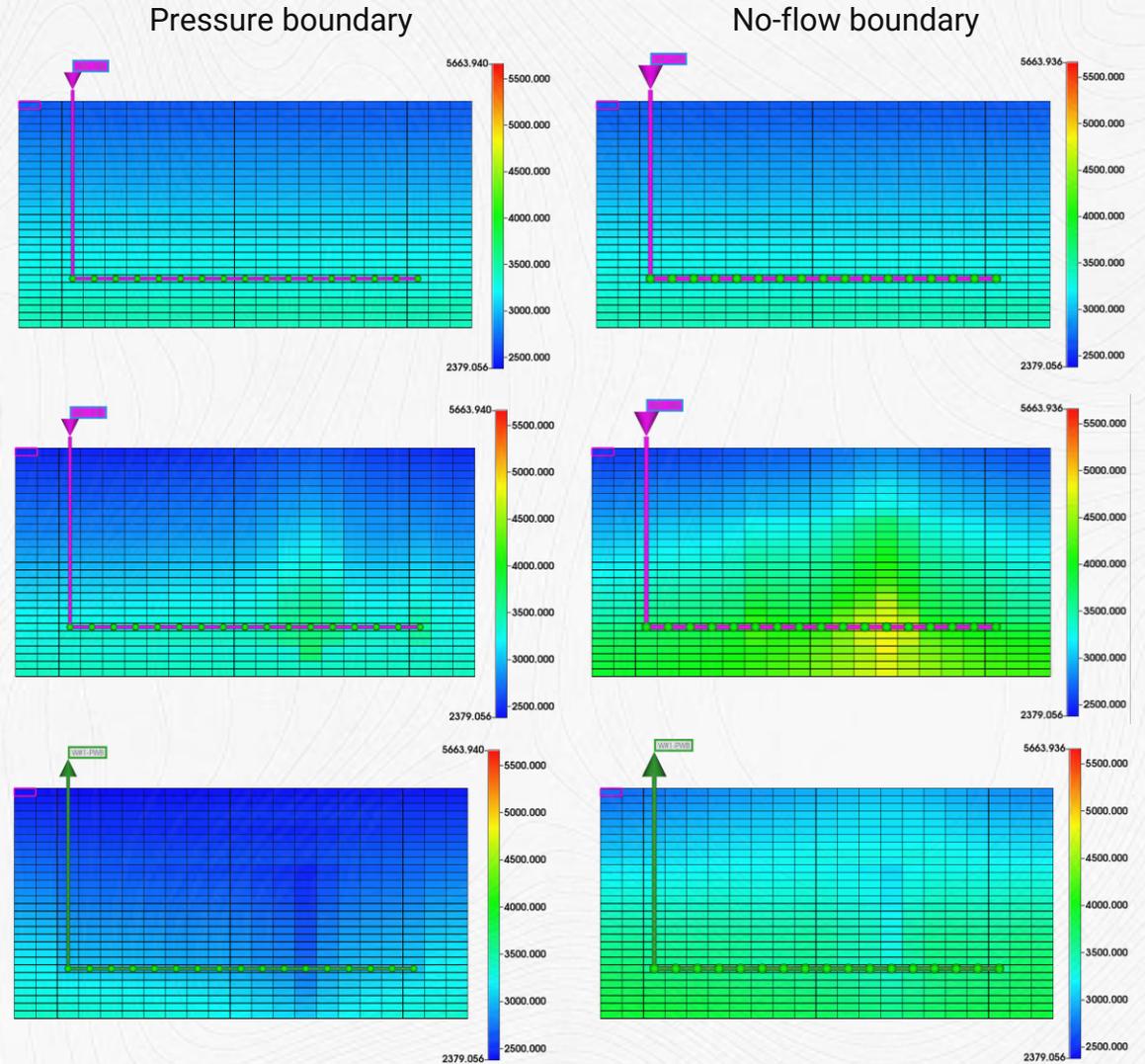
Constant Pressure Boundary (K-dir)



Leak-off Boundaries for Hydrocarbons



Pressure Distribution





v2025.40

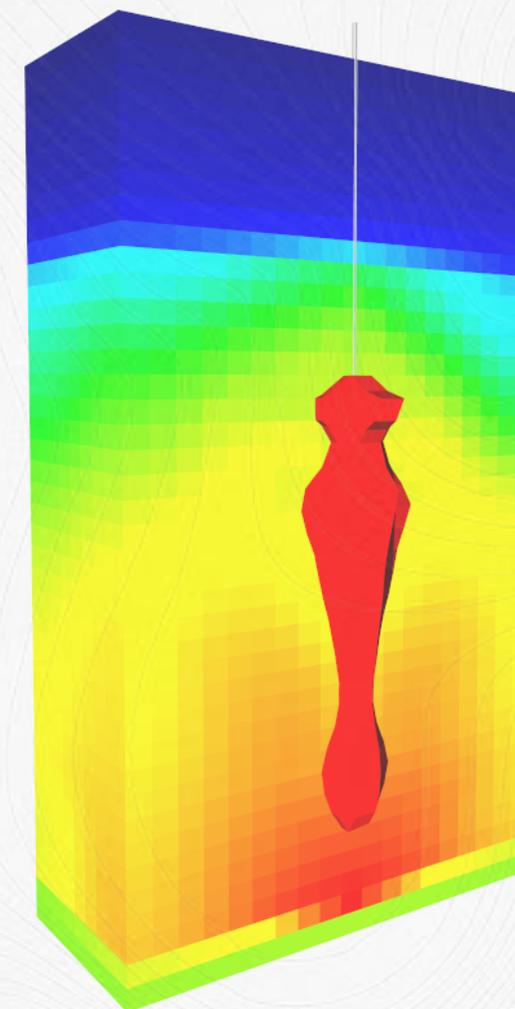
More Accurate CO₂ Modelling – NIST Properties

NIST Library – CO₂ Enthalpy Update

CO₂ property values from the NIST Database – Continued...

- **Enthalpy** of CO₂ for single or multi-component scenarios
- Expands previous developments – NIST library properties for CO₂ **Density** and **Viscosity**
- Important for dynamic pressure/temperature environments – **Such as Closed-Loop Geothermal or Solvent EOR**

*Additional component libraries based on the NIST-database are *in development*





Effects of Water Quality on Well Injectivity

Challenge

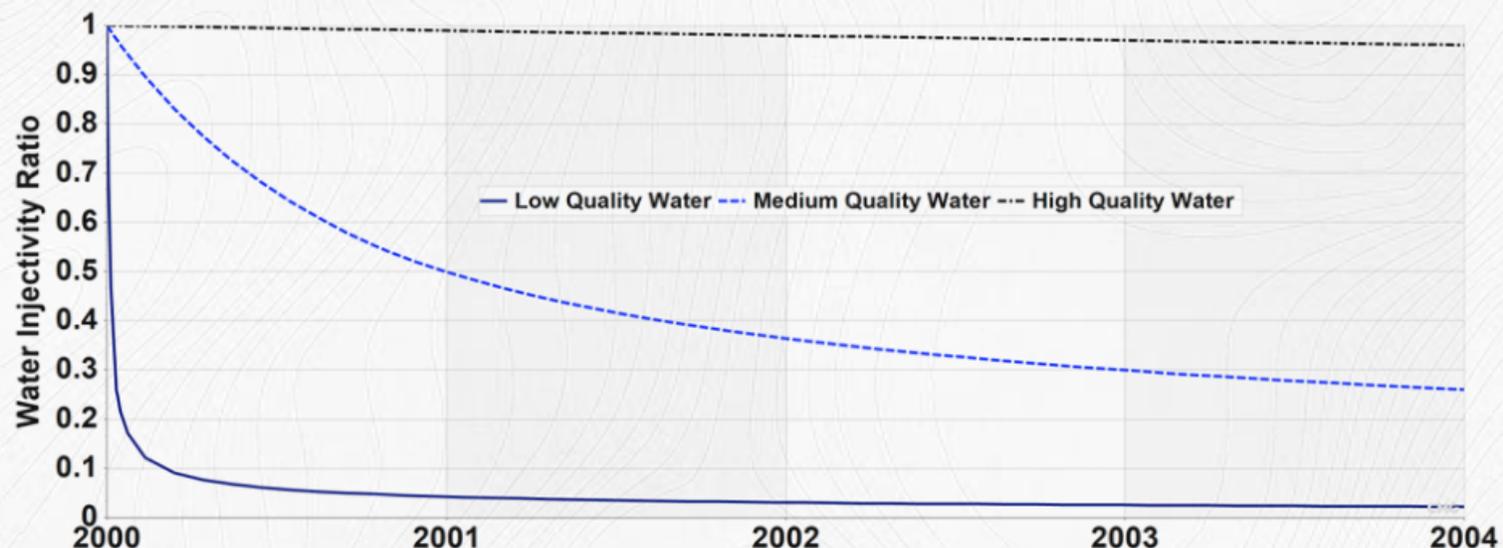
Lower-quality injection water (i.e. higher total dissolved solids – TDS – or other content) has higher potential for near-well impacts to mobility and reduced injectivity

- Effectively a dynamic increase in the skin factor of an injection well
- Reduction in the Well Index

Solution

Perkins and Gonzalez Correlation

- User-Defined Water Quality
- Correlates the Injectivity changes to the specified quality (per well)
- Gain insight on the potential impact to operations (sweep efficiencies, well spacing, potential max injection/disposal rates, etc.)
- **Reduces investment risks and provides more effective, reliable development plans**



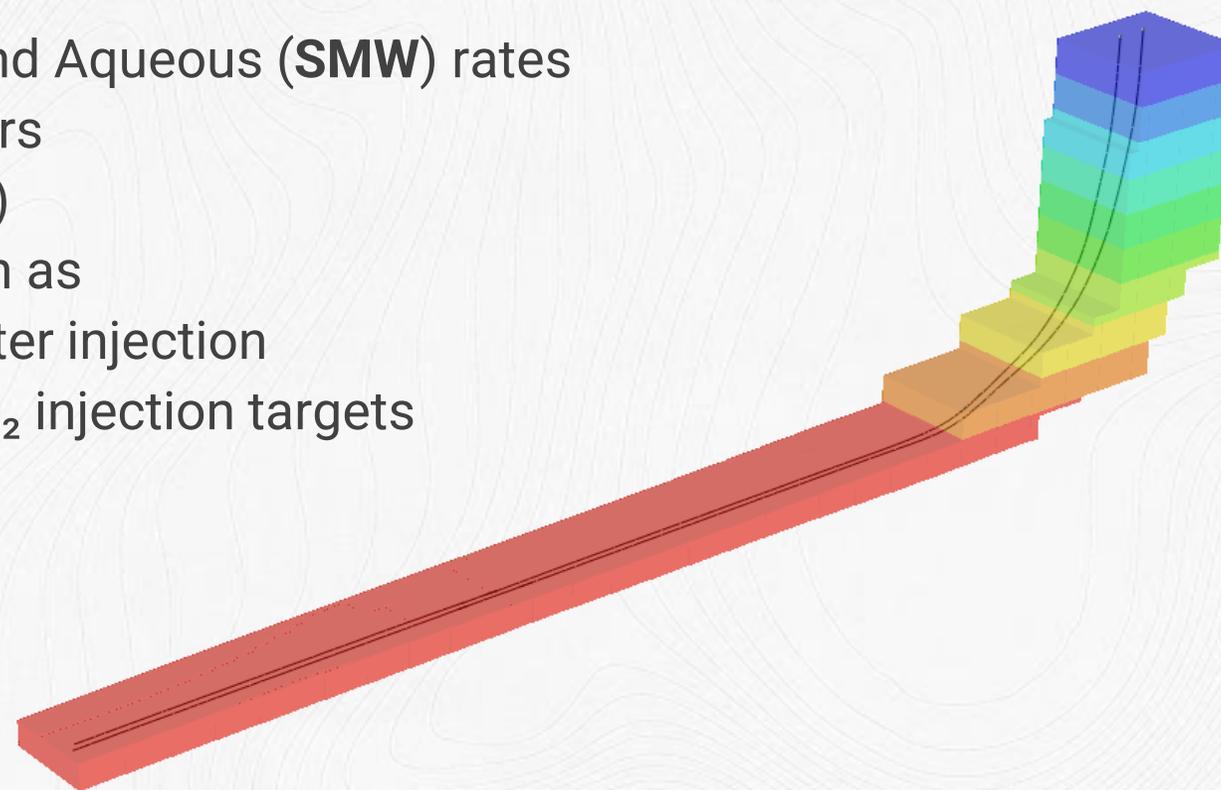


Mass-Based Operating Constraints

No more struggles managing conversions between volume and mass

STARS now supports mass-based operating constraints

- Surface oleic (**SMO**), Gaseous (**SMG**), and Aqueous (**SMW**) rates
- Available for both producers and injectors
- Metric and imperial (ton/tonnes per day)
- Improved flexibility for applications such as
 - Geothermal - requiring mass-rate water injection
 - CCUS projects using mass-based CO₂ injection targets
 - Solvent injection processes

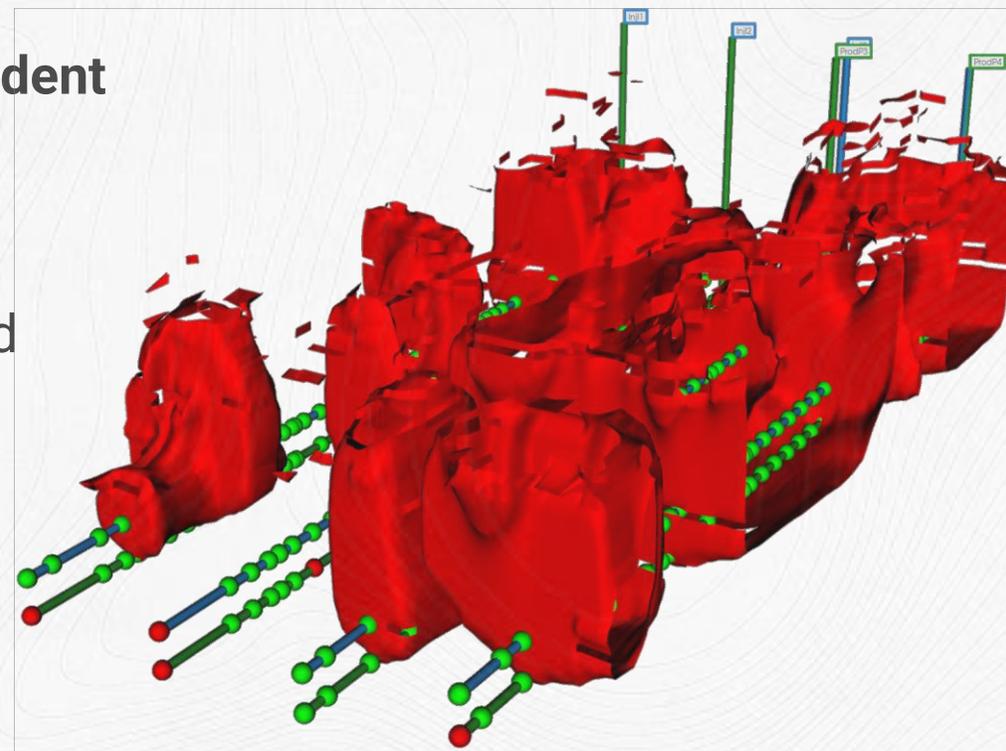


New Options for Defining Potential Thresholds

Potential Gradient Threshold Updated with Temperature and Viscosity Dependency

The PGT option enables flow-connections between cells after a defined threshold value is met

- Historic threshold → Pressure-dependent
- **New Thresholds → Temperature and Viscosity-dependent**
- Enhances the previous fixed value approach, offering greater flexibility
- Important in Thermal Processes, Tight Formations, and systems with Bingham plastic characteristics



CMG's Path to 4-Phase Modelling – Solvent EOR and Future Processes



Current Accomplishments

- 2025.30 Cubic Plus Association (CPA) EOS – WP Flash and Regression
- 2025.40 Generation of 4-phase PVT WP
- 2025.40 4-phase isothermal flash (k-value) OT
- 2025.40 Enhanced smoothing in k-value tables OT
- 2025.40 Adaptive k-value tables for 3 & 4-phase conditions OT

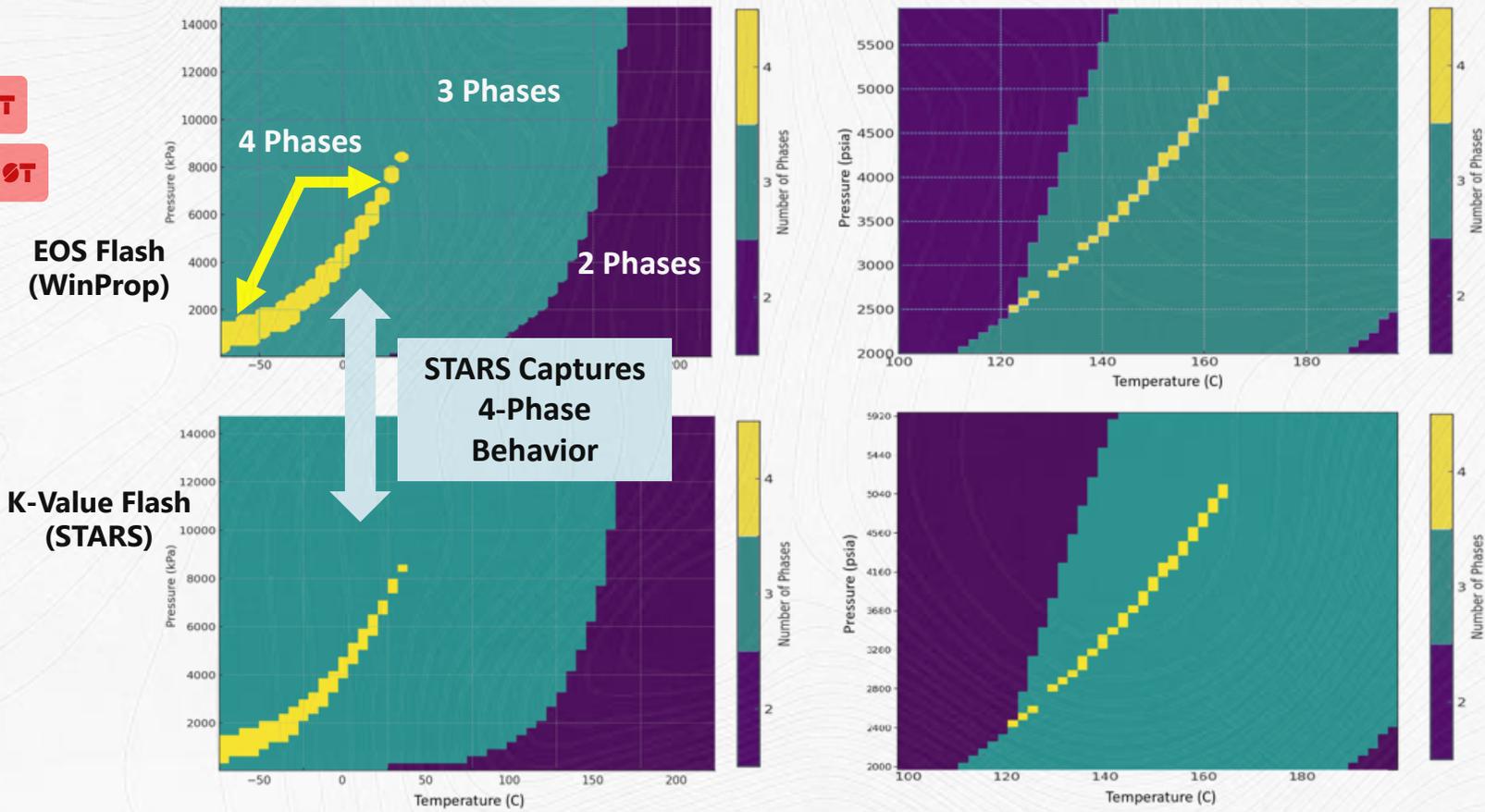
Ongoing Developments OT

- 4-phase isenthalpic flash
- Rock-fluid considerations for the solvent-rich liquid phase
- Coupling of 4-phase flash module with flow equations

Phase Map (WinProp vs STARS) Solvent + Oil + Aqueous

Sample 1: CO₂ Injection

Sample 2: NC₄ Injection



Enhanced General Stability and Support for 3 & 4-Phase Conditions

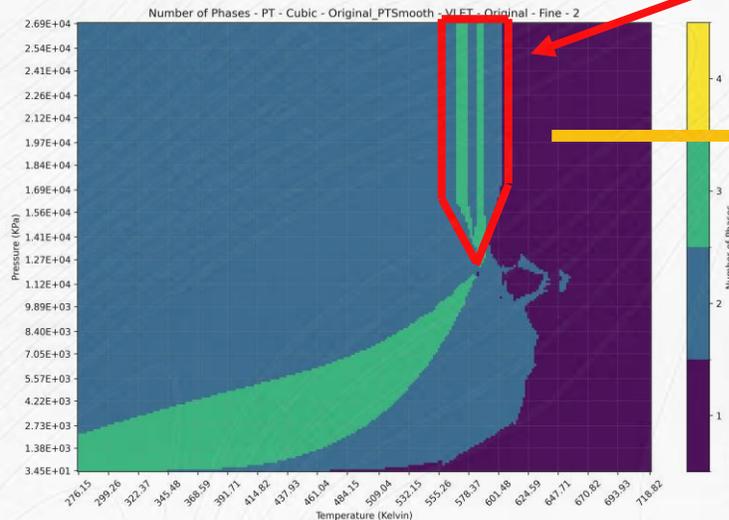


Adaptive K-Value Tables for Multi-Phase Flash

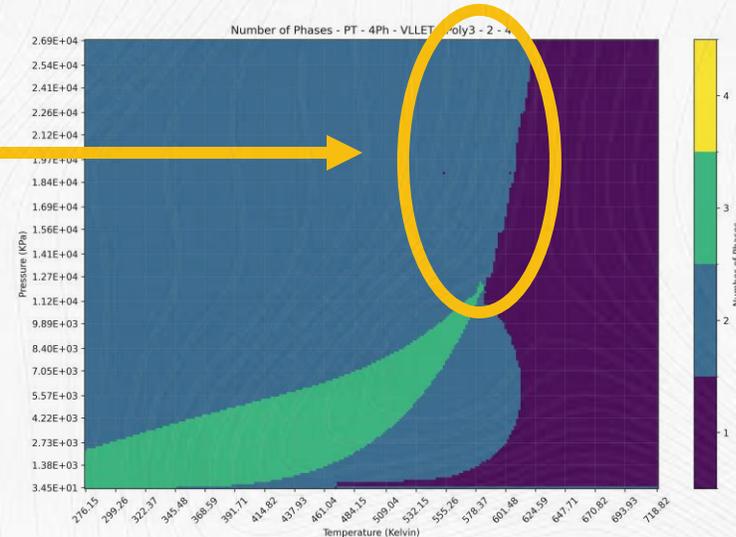
WinProp can now generate an adaptive multi-phase K-value table set for STARS

- Traditional Gas-Oil and Water-Oil Tables + New Gas-Water Table for oleic components
- Beneficial when an oleic-referenced component partitions to gas or water phases (e.g. supercritical region where gas/water coexist in equilibrium and oleic phase disappears)
- **Improved robustness and accuracy** in regions of phase equilibrium changes

Extrapolation of GLK and LLK
(Previous Approach)



Switch on WGK Table
(Adaptive Approach)



Multi-Stream Injection Option Enhancements – A Game-Changer for EOR Processes



Challenge

- With Enhanced Oil Recovery (EOR) processes, we combine multiple phases or components (sometimes at different conditions) on surface prior to the stream entering an injection well
- Resolving the thermodynamics of the system (i.e. saturation temperatures/pressures and compositions of the mixture) is complex and generally a manual process

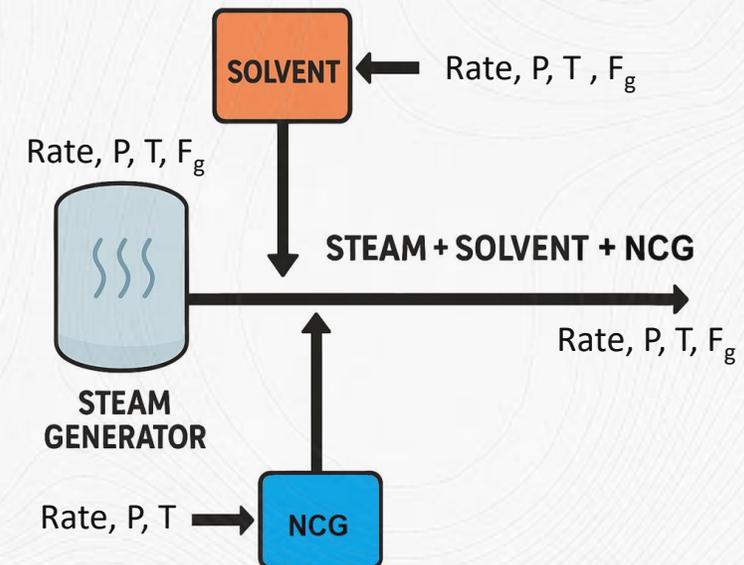
Solution

Automated Calculations of Injected Mixtures (2025.30)

- Dynamically assess the independent streams and determine associated downhole properties

2025.40 Enhancement

- Can now define an unlimited number of multi-stream sets
- Attach each set to one well or one set to multiple wells
- Builder interface support for easy setup



Multi-Stream Injection – Builder Setup Support [BETA]

The screenshot displays the 'Well Events' dialog box in the CMG Builder software. The dialog is titled 'Well Events' and shows a list of wells on the left and configuration options on the right. A yellow mouse cursor is pointing at the 'Water Stream (m3/day)' entry in the 'Stream Rate Configuration' table.

Well Events List:

Name / Date	Event
2012-01-01	WELL
	INJECTOR
	constraints
	injected fluid
	stream pressure
	stream temperature
	OPEN
injan	
2014-06-01	WELL
	PRODUCER
	constraints
	SHUTIN
2015-01-01	WELL
	PRODUCER
	constraints
	SHUTIN
prdan	
2014-06-01	WELL
	PRODUCER
	constraints
	SHUTIN
Prod	
2012-01-01	WELL
	PRODUCER
	constraints
	OPEN
2014-06-01	SHUTIN

Stream Rate Configuration:

MSR Type: 2

Note: Oil, gas, and water rates are at the conditions (Pressure, Temperature) specified in the Injection Streams section below.

Stream	Rate Type	Target Rate
<input checked="" type="checkbox"/> Oil Stream (m3/day)	Volume	0
<input checked="" type="checkbox"/> Gas Stream (gmol/day)	Molar	0
<input checked="" type="checkbox"/> Water Stream (m3/day)	Volume	0

At least one stream must be selected (Oil, Gas, or Water)

Stream Compositions & Injection Parameters:

Injection PVT Region: PVT Region 1

#	Component	Oil Stream	Gas Stream	Water Stream
1	WATER	0.000000	0.000000	0.000000
2	SOLVENT	0.000000	0.000000	0.000000
3	BITUMEN	0.000000	0.000000	0.000000
	Total Com...	0.000000	0.000000	0.000000

Injection Parameters:

Individual Injection Streams

Note: Individual stream parameters are only available when multiple streams are selected.

Parameter	Oil Stream	Gas Stream	Water Stream
Pressure (kPa)	0	0	0
Temperature (C)	0	0	0
Molar Gas Fraction	0	N/A	0

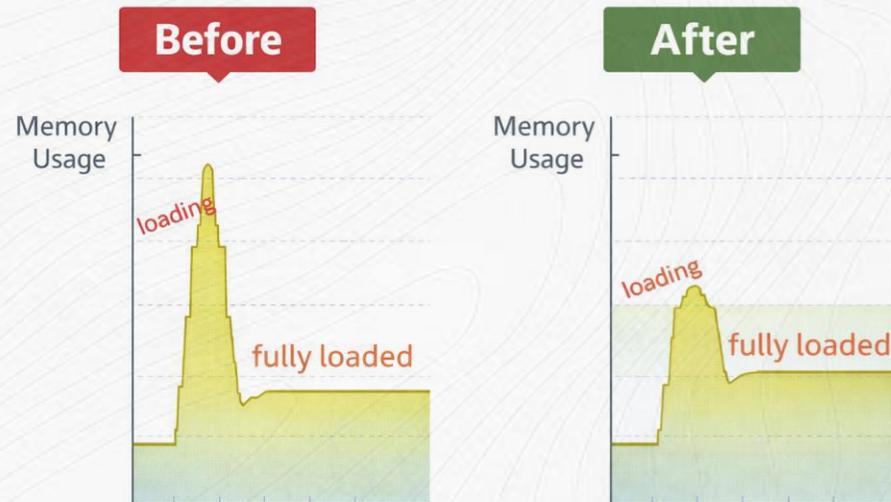
Accelerating Decisions

Speed & Stability Enhancements

Optimized Memory Usage: Faster & Stable Loading

Significant Reduction in Memory Consumption on File Load

- **Up to 50% lower RAM usage during model load:** memory remains stable throughout the session
- **Faster load times:** large models loading ~10% quicker on top of previous improvements
- **Improved stability on resource-constrained machines:** reducing slowdowns and risk of crashes



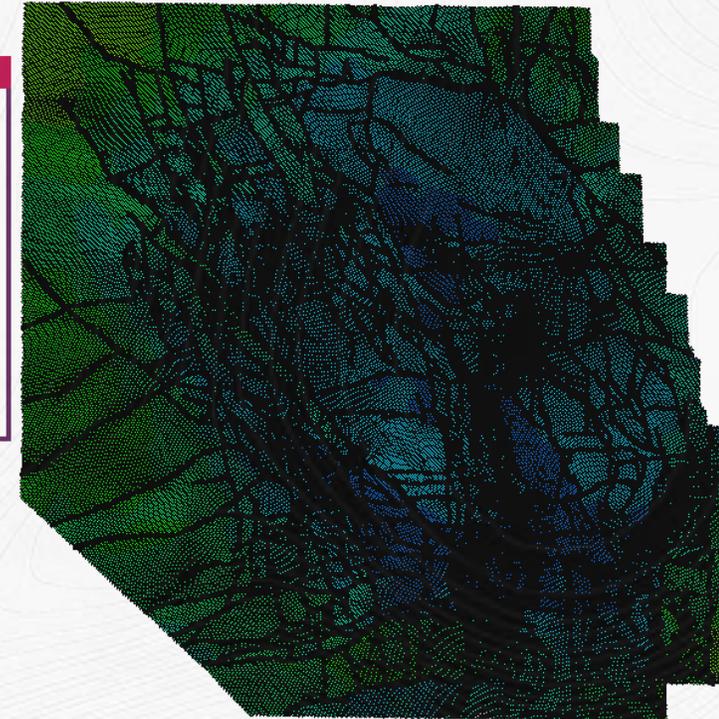
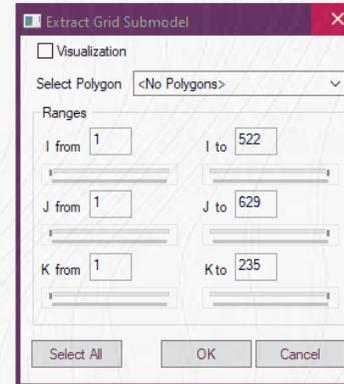
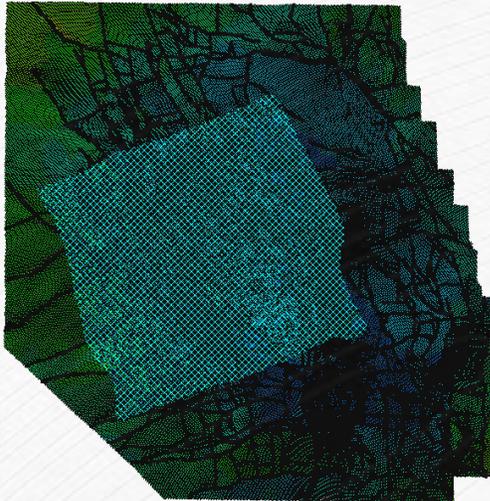
Run larger models more reliably, load cases faster, and get more value out of existing hardware.

Responsive Grid Highlighting

Smooth Grid Interactions at Any Scale

Grid selection and highlighting are significantly more responsive.

- **Noticeably quicker highlighting** when clicking or dragging across large grid regions
- **Faster range selections** with visualization enabled, improving responsiveness during visual workflows
- **Performance gains across selection tools**, including polygons, block selectors, and property edits



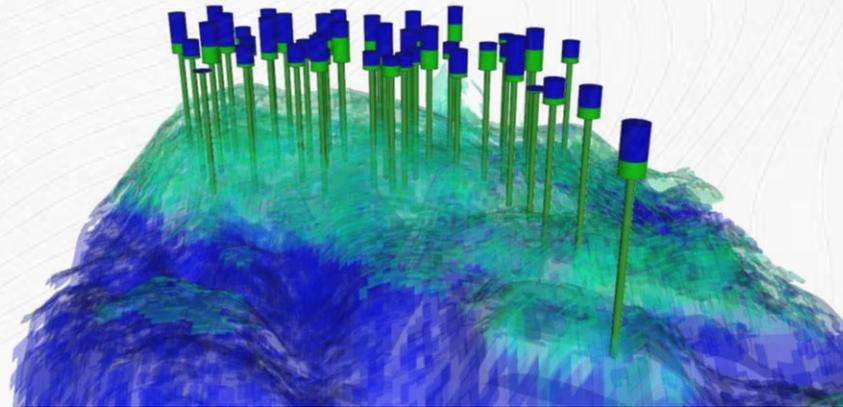
Selections respond in real time, enabling faster iteration, smoother grid manipulation, and a more fluid modeling experience

Faster Trajectory Workflows – From Import to Perforations

Trajectory-Related Workflows Accelerated

Move from raw trajectory data to simulation-ready perforations in a fraction of the time.

- **Import thousands of trajectories in minutes** using the improved Import Well Trajectory Wizard
- **End-to-end workflows significantly reduced** for trajectory-to-perforation setup
- **Instant access** to the Trajectory Perforation Intervals dialog
- **Faster perforation interval calculations** with a new progress bar providing clear feedback during processing



Set up complex well models faster, iterate more efficiently, and spend less time waiting.

Volume-Based Pinchout Tolerance – Enhancements to Logic

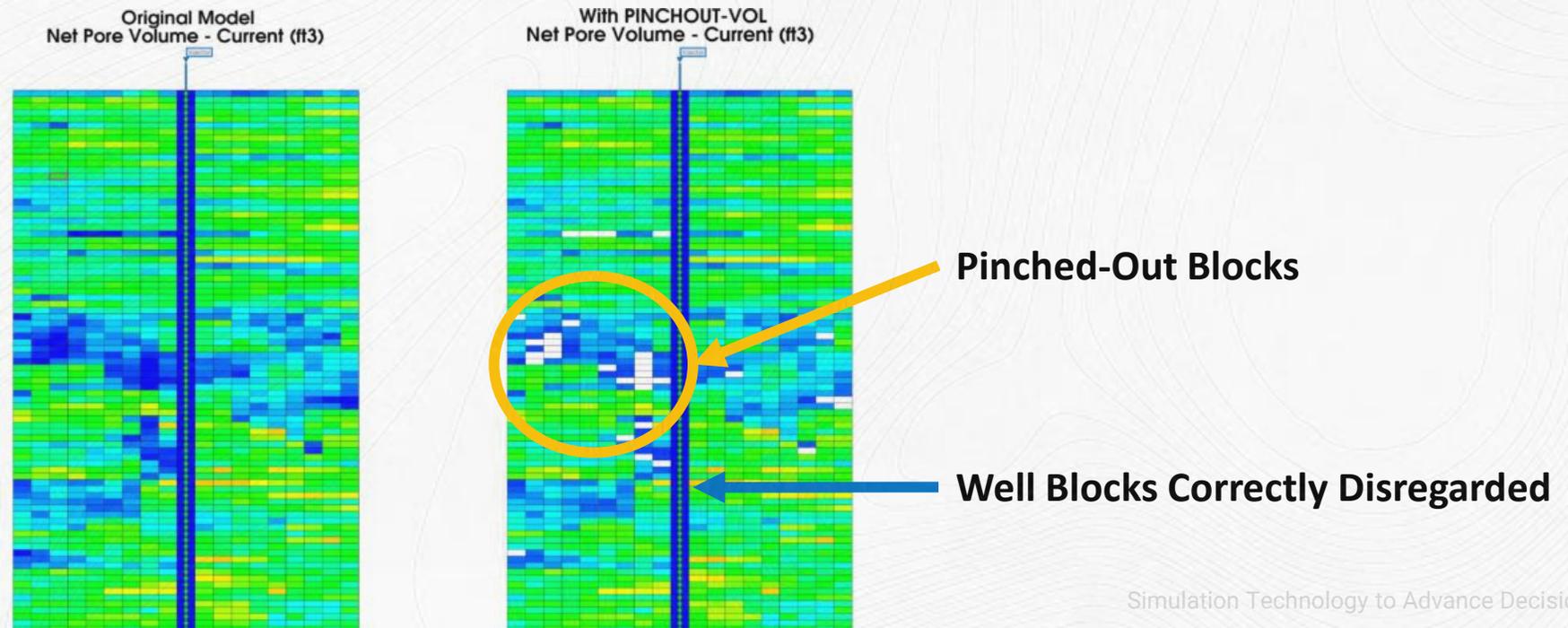


Volume-based pinchout logic (introduced in 2025.20) provides **Direct, Out-The-Box Performance Improvements** (particularly in highly heterogenous models)

Updates provided in the 2025.40 release:

Well blocks will now be automatically disregarded from being pinched-out

- Ensures well completions and behavior is not impacted



Volume-Based Pinchout Tolerance – Enhancements to Logic



Volume-based pinchout logic (introduced in 2025.20) provides **Direct, Out-The-Box Performance Improvements** (particularly in highly heterogenous models)

Updates provided in the 2025.40 release:

Check-Only Mode Option (STARS & IMEX, previously available in GEM)

- Analyze potential pinch-out tolerance outcomes before running
- Define a P-value and see resulting distribution of blocks that would be pinched-out

PINCHOUT THRESHOLD AND MOLAR AMOUNTS								
Percentile	Oil Moles (gmole)	Gas Moles (gmole)	Water Moles (gmole)	Diff Oil %	Diff Gas %	Diff Water %	Grid-blocks Eliminated	PINCHOUT-VOL (m3)
0.00E+00	5.3068E+09	2.3495E+04	4.0183E+10	0.000E+00	0.000E+00	0.000E+00	0	0.0000E+00
1.00E+00	5.2993E+09	2.3470E+04	4.0051E+10	1.426E-01	1.061E-01	3.302E-01	788	1.3946E+00
2.00E+00	5.2783E+09	2.3377E+04	3.9636E+10	5.382E-01	5.036E-01	1.361E+00	1577	4.4394E+00
3.00E+00	5.2484E+09	2.3176E+04	3.8796E+10	1.101E+00	1.358E+00	3.452E+00	2366	5.3434E+00
4.00E+00	5.2171E+09	2.2955E+04	3.7898E+10	1.691E+00	2.298E+00	5.687E+00	3155	5.7340E+00
5.00E+00	5.1854E+09	2.2724E+04	3.6983E+10	2.288E+00	3.283E+00	7.966E+00	3944	5.9848E+00
6.00E+00	5.1539E+09	2.2486E+04	3.6042E+10	2.883E+00	4.296E+00	1.031E+01	4732	6.1609E+00
7.00E+00	5.1221E+09	2.2252E+04	3.5113E+10	3.481E+00	5.289E+00	1.262E+01	5521	6.3333E+00
8.00E+00	5.0929E+09	2.2020E+04	3.4119E+10	4.031E+00	6.277E+00	1.509E+01	6310	6.5439E+00
9.00E+00	5.0620E+09	2.1790E+04	3.3168E+10	4.614E+00	7.257E+00	1.746E+01	7099	6.7467E+00
1.00E+01	5.0324E+09	2.1557E+04	3.2179E+10	5.172E+00	8.247E+00	1.992E+01	7888	6.9350E+00



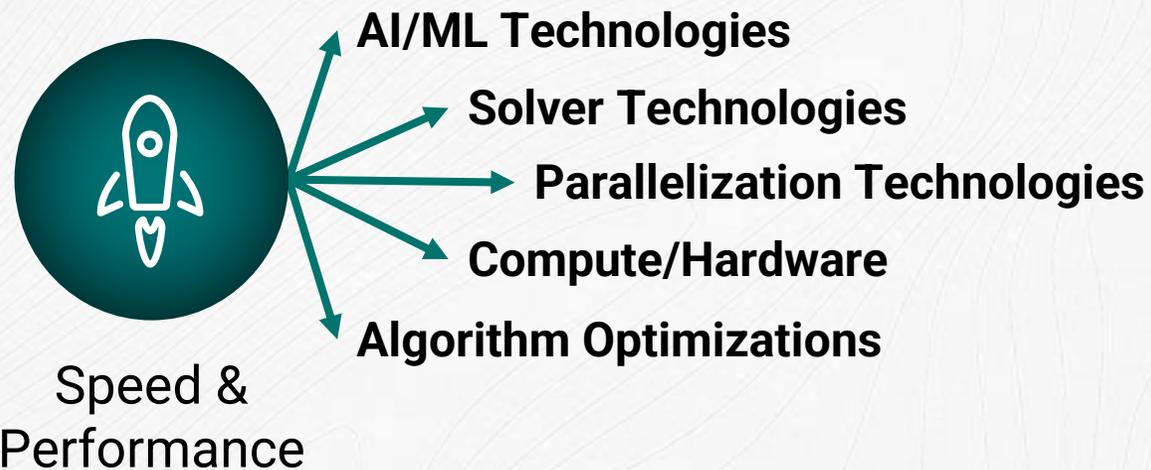
GEM – Faster Runs. No Trade-Offs

Average **1.6x Speedup**

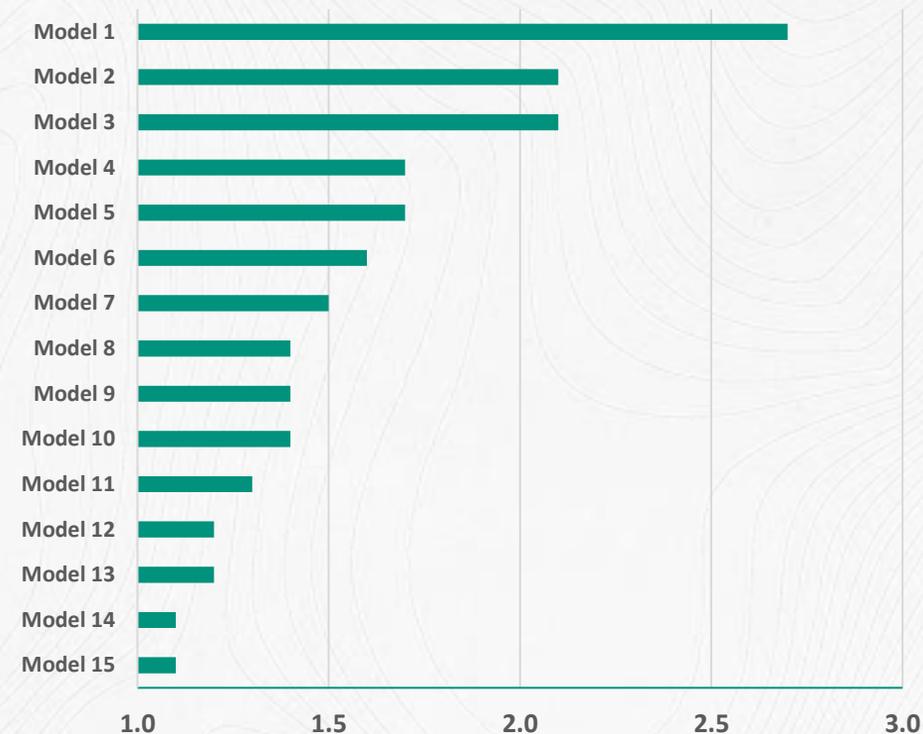
- Complex recovery and energy-transition processes
- **Without Compromising Accuracy**

Speedup achieved through updates in multiple initiatives:

- Algorithm Optimizations
- Partitioning Logic
- Solver Technologies



Benchmark Case Speedup Factors (Out-the-Box)



Production Engineering & Integrated Systems

CoFlow – Pure Component Modelling



v2025.40

Challenge:

Narrow boiling systems can't be solved with P-T approach, due to discontinuity in system enthalpy @ T_{sat}

Applications:

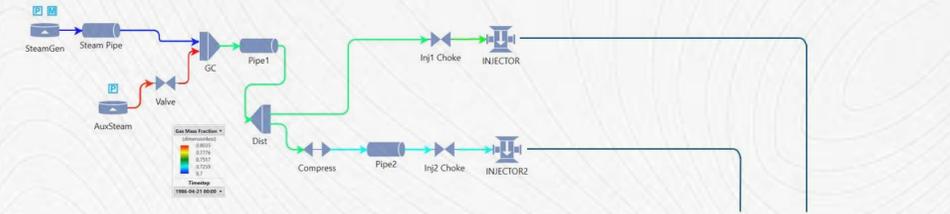
- **STEAM:** Heat loss in pipes and facility, arrival steam quality at well-heads, steam optimization, etc.
- **CO2:** P & T changes in surface pipeline network, correct CO2 arrival conditions @ BH need to be estimated

Available in 2025.40 (BETA):

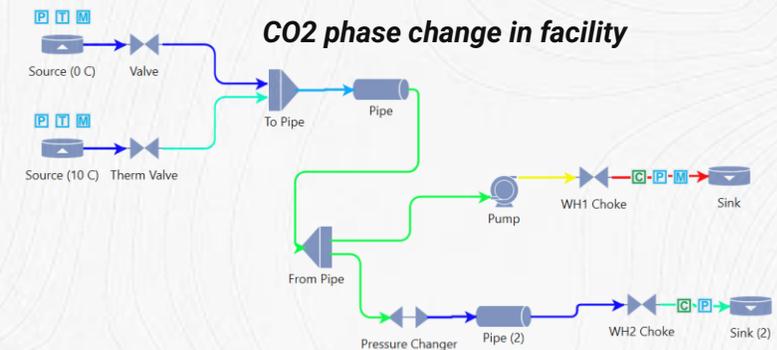
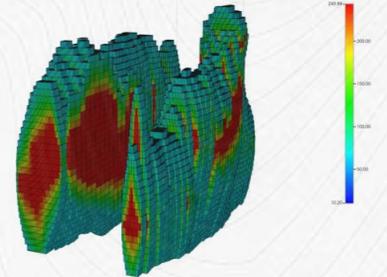
- P-H flash (enthalpy as primary variable) can be activated
- STARS steam injection models & GEM CO₂ injection models can be coupled
- Surface pipeline networks and most facility equipment can be solved for P & T changes

Next Steps:

P-H flash support for remaining facility equipment

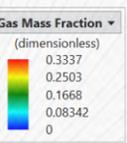


Steam quality change in facility



CO2 phase change in facility

- Experimental Features
- Use mass preservation explicit coupling
 - Use quasi-Newton solver
 - Use IMEX potentials for well group apportionment
 - Use variable update convergence criteria for wells and facilities
 - Use simplified model when there is well backflow
 - Use tight numerical derivative in pipe model
 - Use Z-Factor for gas density interpolation
 - Use enthalpy as a primary variable for wells and facilities



Wells, Facilities, & Network Solver Enhancements



Dataset Import Enhancements

- Support for many additional aspects of DAT files & their population into the CoFlow UI – e.g. WELSEP keyword, perforations using different UBA formats, historical constraints using RSV keywords, etc.
- More support for lift table imports – e.g. option to set lift table ref. depth to MD or TVD, better combination of two lift tables into one (PWELLBORE + TWELLBORE tables)
- Option to choose what DAT file features to import – historical constraints, lift tables, etc.

Nodal Analysis Usability – Improvements include Sonic ΔP availability in Visualization & Nodal Analysis

GAP Importer Enhancements – Such as gathering fluids collected from all separators into sinks

IPF Solver – Significant performance & feature enhancements achieved

- Robustly handle multiple complex scenarios with fluid distribution
- Updated numerical settings options
- Redesigning of some equipment equations

Architectural Updates



Multi-Node Job Submission Capabilities (Linux)

- **Parallel execution across multiple nodes**
 - Run simulations with node-spanning → **Faster Turnarounds**
- **User-specific execution credentials**
 - Better auditability of job ownership & activity
- **Support for custom SLURM scheduler parameters**
 - More control over job scheduling & resource allocation → maximize cluster utilization

PostgreSQL database upgraded to Version 17

Storage Metrics:

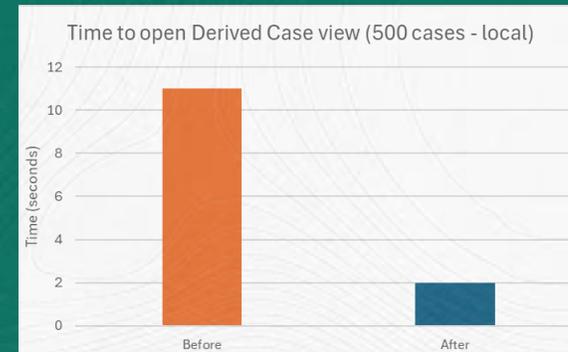
- Unprecedented visibility into how data is generated, stored, and consumed

Study Name	Total Size (MB)	DB Size (MB)	File Size (MB)	Output Size (MB)	Time Series Arrays (MB)	Simulation Files (MB)
test	99.31	52.35	38.88	7.51	0.57	0.00

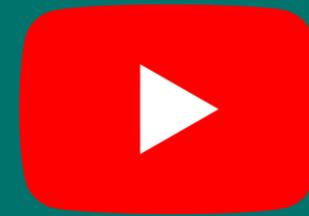
Case Name	Total Size (MB)	DB Size (MB)	File Size (MB)	Output Size (MB)	Time Series Arrays (MB)	Simulation Files (MB)	Refresh
1 Base Case	0.02	0.02	0.00	0.00	0.00	0.00	
2 Base Case (2)	5.41	3.81	0.90	0.69	0.01	0.00	
3 Scenario Analysis Manager	19.77	13.61	3.37	2.75	0.04	0.00	
4 Urchin With Time Interval STEs	74.10	34.90	34.60	4.07	0.52	0.00	

UI Performance

- Significant performance gains on many common operations – especially in big databases



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