# SAMG-Modflow for groundwater simulations: Efficient linear solution process as a black-box

In order to produce reliable results in minimal computational time, groundwater simulations have to employ robust and efficient linear solvers. SAMG-Modflow allows the exploitation the most efficient solver algorithms via a simple plug-in.

Hierarchical solver approaches like algebraic multigrid have proven to provide virtually optimal efficiency for numerical solution methods of diffusion problems such as pressure corrections without user interactions.
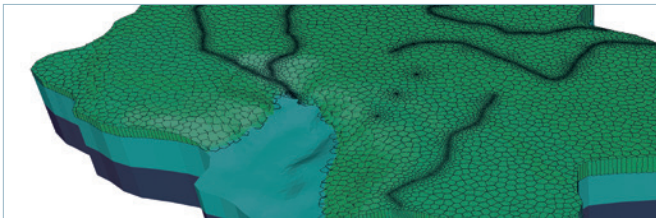


*Groundwater reservoir, to which SAMG-Modflow is applied*

SAMG-Modflow adapts itself to unstructured grids and high permeability contrasts, making it applicable in a black-box manner within Modflow.

Internally, SAMG-Modflow can exploit parallelism via multi-threading, utilizing available hardware features to accelerate the solution process.
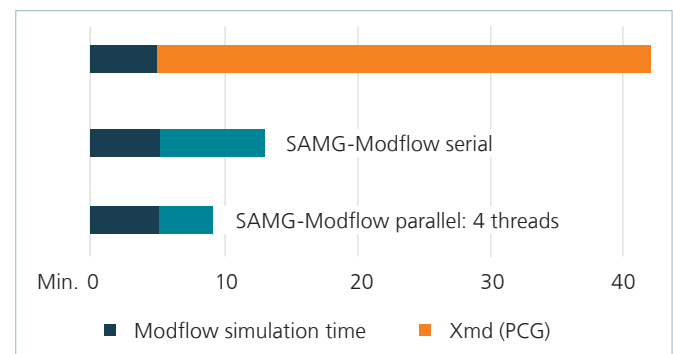


*Simulation runtime, Modflow6 case with 600,000 cells*

## Machine learning tools to control the solver

SAMG-Modflow uses machine learning tools to control the solution process, which adapts the solver autonomously to the individual simulation type for optimal performance and robustness.

SAMG-Modflow is available for
- Modflow 2000, 2005,
- Modflow USG,
- Modflow 6.

For Modflow USG and Modflow 6, the extension module SAMG-Modflow+ is available to handle more sophisticated simulations. This covers transport problems and inactive cells as well as connected linear networks and multi-aquifer wells.

"

**We have been including the SAMG-Modflow solver in Visual MODFLOW Flex for over a decade. In our experience, it is typically the fastest solver available for larger and more complex groundwater models. It can offer significant reductions in model run times and typically requires the least amount of user intervention. We are excited for the upcoming release of SAMG-Modflow+ which will cover a wider set of modeling scenarios and provide some additional performance improvements."**
Waterloo Hydrogeologic

**"In general, the SAMG solver is the fastest MODFLOW solver that we have used."**
Aquaveo LLC

## Based on the idea of algebraic multigrid

Being based on the idea of algebraic multigrid (AMG), SAMG-Modflow is a very efficient linear solver for diffusion-based problems. Internally, SAMG-Modflow is based on the SAMG solver kernel, which accelerates many different industrial simulations. The runtime grows only roughly linearly with the number of equations. Hence, it can be applied to small problems and provides efficient solutions for bigger models as well.

The purely algebraic setup adapts itself to individual grids and can easily cope with large material and permeability contrasts. An integrated control mechanism exploits machine-learning methods to control the selection of solver method and set-up to provide high efficiency and guarantee a robust solution.

In addition, SAMG-Modflow supports both serial and multi-core computations on single PCs, workstations, or compute nodes. The parallelization is completely encapsulated in the solver library. Just as with the solver parameters, no user interaction is needed.
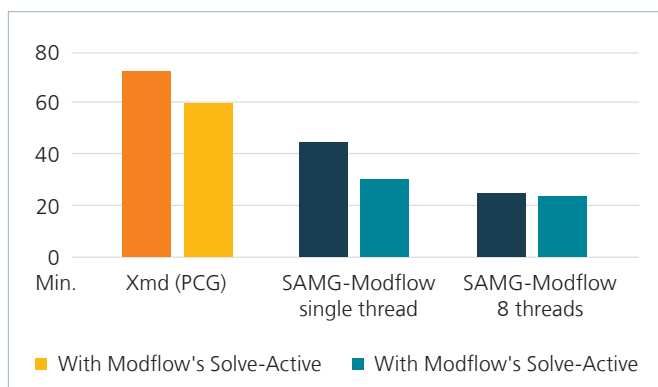


*Simulation runtime, Modflow USG case with 737,191 cells*

## Extension for more sophisticated cases

With the extension module SAMG-Modflow+, the plug-in solver is enabled for:

- transport problems, where individual strategies are applied for flow and transport problems
- inactive cells, where the solution process is limited to active cells in order to improve the performance
- connected linear networks (CLN; Modflow USG) and multi-aquifer wells (MAW; Modflow 6), where the respective equations are handled by SAMG with a more robust approach.

In all cases, the ML-based solver control adjusts the solver according to the more involved model characteristics. This does not require further user interaction but is handled automatically.
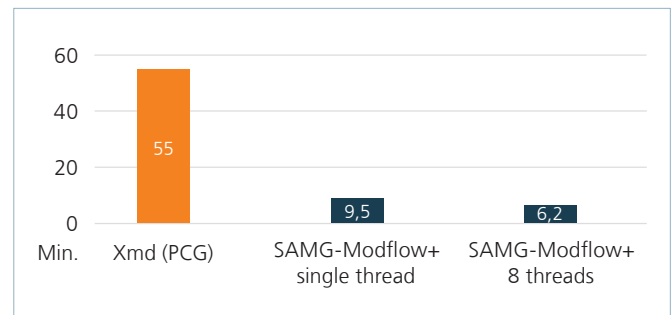
## Commercial reference

The following companies offer SAMG and SAMG-Modflow in their groundwater simulations software:

- Aquaveo LLC
- DHI-WASY GmbH
- Environmental Simulations Inc.
- ITASCA Denver Inc.
- Waterloo Hydrogeologic
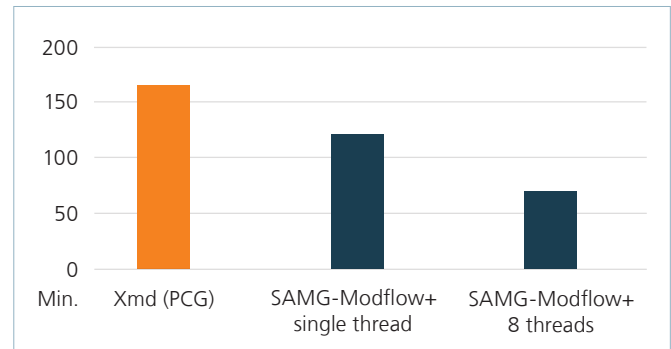


*Simulation runtime, SAMG-Modflow+ application for a transport problem with 552,800 cells*



*Simulation runtime, SAMG-Modflow+ application for a problem with 137,384 cells and 14,130 CLN cells*

### Contact

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