

# LAKE WATER QUALITY MODELLING: GETTING STARTED WITH GLM

First, download a precompiled version of GLM ([aed.see.uwa.edu.au/research/models/GLM](http://aed.see.uwa.edu.au/research/models/GLM)), and unzip. You will also need the example files. Save them to the drive where you have read & write access and preferably not a network drive. The examples zip file has two example simulations (“*warmlake*” and “*coldlake*”) and you can run these with the appropriate model executables (either 32 and 64-bit for Windows or Linux operating systems).

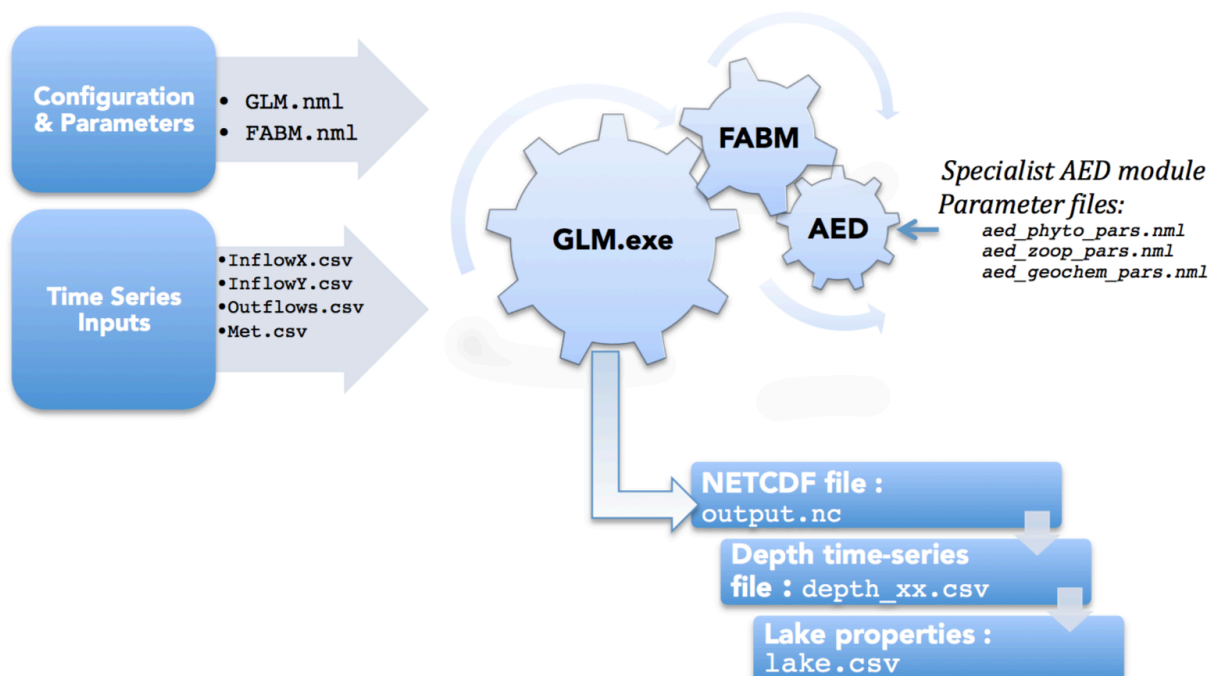
The simulations both include FABM water quality simulations, and we will first look at the hydrodynamic model and then explore in more detail the water quality modules of the simulation.

## A: Lake Stratification with the General Lake Model (GLM)

The simulation in the “\warmlake” directory is an example 40 m deep, monomictic lake that is used to supply drinking water and supports an active fishery.

Before running the model, open the file `glm.nml` in a text editor of choice and inspect the model setup etc.. This file is the main configuration file that drives the model. For editing text files we recommend jEdit or Notepad++, but Wordpad will suffice (don’t use MS Word). The file `glm.nml` has several key sections in it related to the model domain and parameters, the sources of boundary condition data, and details of outputs.

Also, open the boundary condition input files - these are csv files containing time-series of meteorological information, and inflow and outflow volumes. These files can be opened in Excel or a text-editor.



On Windows, the model can be run via the *command prompt* by calling `glm.exe` (either the 32 or 64 bit version depending on your operating system). In the simulation a batch-file “`glm.bat`” is provided that is used to automate running the model. You can right-click and edit this file to make sure it is setup correctly and points to the appropriate “`bin`” folder where the `glm.exe` file is located for your system.

From the command prompt, it will contain a command such as:

```
..\bin\glm32.exe  
or  
..\bin\glm32.exe --xdisp
```

This may need to be customized on your machine depending on your directory names. Once correct, double-click on “glm.bat” to run the model. Note that if you include the `--xdisp` option, then you must make sure the in-built GLM plotting configuration file, **plots.nml**, is available in the same directory as **glm.nml**. Three preconfigured plot files of different complexity are provided in this example that can be used. If the plotting option is selected a plot window will open and update as the model is running.

Users can inspect the results of the model in three ways:

1. via the time-depth contour plots that appear during the run (configured via **plots.nml**);
2. further information on the daily water and energy balance is in the output file **lake.csv**; and
3. time series values of state variables at any requested specific depth can be found in the WQ files (eg. **WQ\_17.csv**).

*Exercises:*

- Plot the lake water balance - volume and fluxes including inflows, outflows, rainfall and evaporation (refer to columns in **lake.csv**).
- Plot the surface heat fluxes such as shortwave, longwave, sensible heat latent heat (refer to columns in **lake.csv**).
- Calculate the mean average error in the simulation using the provided temperature data (assume provided temperature data is from the surface layer).
- Calculate the sensitivity of the modelled temperature to changes in water clarity (the light extinction coefficient,  $K_w$ ) and wind speed (*wind\_factor*). These can be found in **glm.nml**.
- Assess how the degree of stratification changes as the initial water level of the lake is reduced by 20m. To do this change the initial starting profile depth in **glm.nml**.

## B: The NPZD ecosystem model

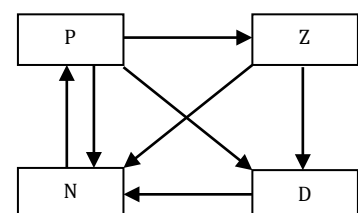
The “warmlake” model simulation ran above has the ecological model FABM enabled. It has been pre-configured to run two different ecological model setups: the default NPZD (nutrient-phytoplankton-zooplankton-detritus) module and the customisable AED modules. These are separate models, but have been setup to run side-by-side. They are configured using the text file **fabm.nml**.

Open the file **fabm.nml** in a text editor (not MS Word) and inspect the model setup in the `&models` section at the top. This lists the models to be run. For now ignore the aed modules that are listed.

Change the plots being produced to include the NPZD variables by renaming **plots\_npzd.nml** to **plots.nml**. This is a pre-configured plot file to summarise the simulation. Note the four variables of this FABM model (*nut*, *phy*, *zoo*, *det*) are named with a “gotm\_npzd\_” prefix, so the variable names to plot from the output file are written as: “gotm\_npzd\_nut”.

Before running the model, lets also add a new specific depth output file by editing the output section of the **glm.nml** file. Add the variable **gotm\_npzd\_phy** as a 4<sup>th</sup> column to the csv file that will be produced.

Now run the model as above by double clicking the **glm.bat**.



*Exercise:*

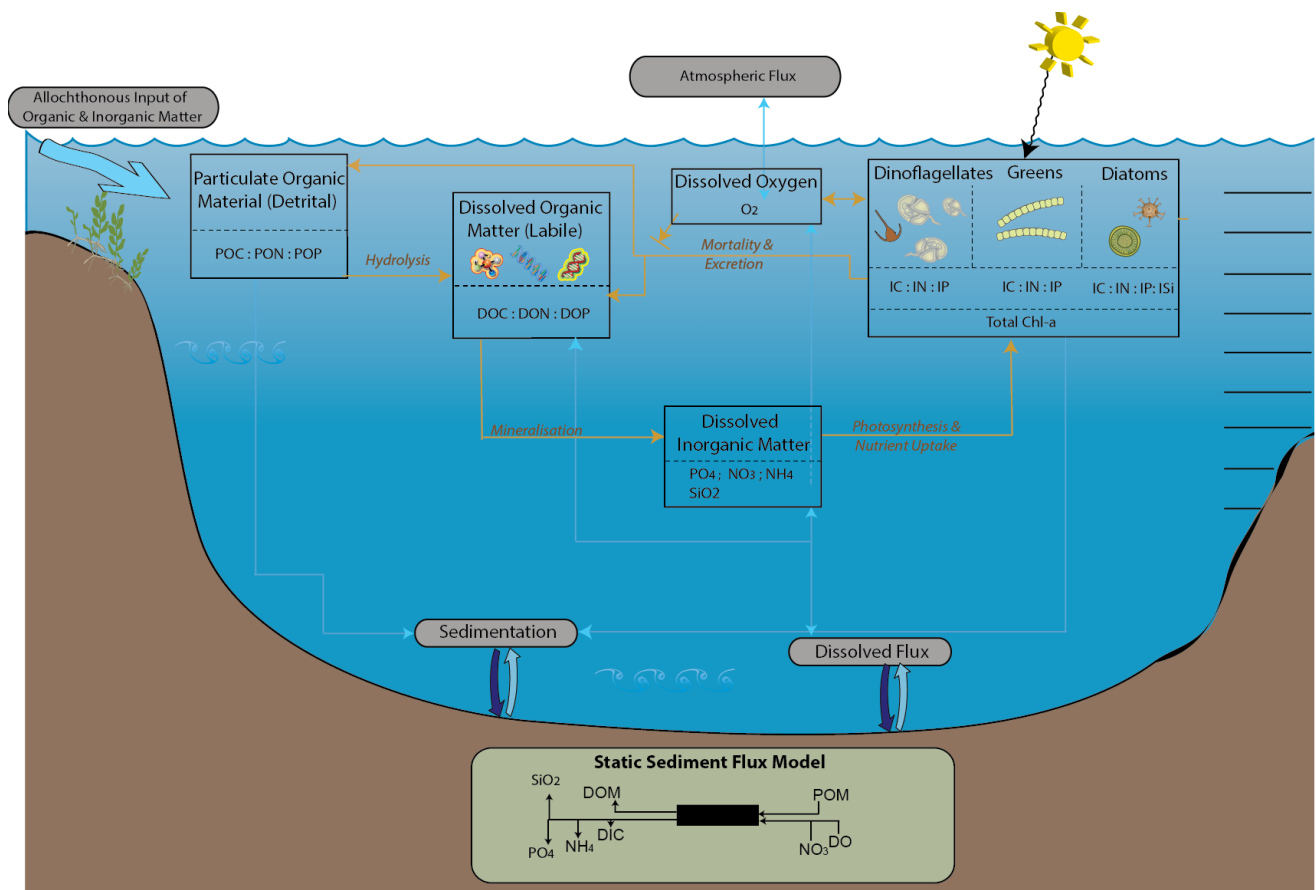
- Review and describe the change in N, P, Z and D over the depth of the lake and seasonally.
- Assess how sensitive the phytoplankton biomass is to water clarity?

**C: The AED water quality model**

Re-run the model, but this time use `plots_aed.nml` as your `plots.nml` file. This one is preconfigured to plot AED specific variables. Refer to the AED manual for more details on the individual models parameter names.

*Questions to explore:*

- How would reducing the sediment oxygen demand ( $F_{sedoxy}$ ) improve the degree of bottom water anoxia/hypoxia? Did this change the nutrient concentrations in the bottom layers?
- What if the “green” algae had a growth rate of 1.5 /day instead of 1.1 /day?
- How would the algae concentrations change if the air temperature increased by 3 °C? (HINT: you will need to edit the `met_hourly.csv` file).



**NOTE:** Remember to watch out the date format when you save a `met` or `inflow.csv` file from Excel. Excel changes the date format to be its preferred style instead of the style GLM requires (YYYY-MM-DD) so you must be sure to set that manually in the cell format properties section of excel before saving `csv` files.

## D: Ice-cover simulation with coldlake

The provided “coldlake” setup is an example lake ~30m deep lake created by mining activities that is being restored. It experiences seasonal ice-cover and you will see how the volume of the water reduces in winter as the surface freezes.

Open the file `glm.nml` in a text editor and inspect the model setup etc. Open the file `fabm.nml` in a text editor and inspect the AED model setup. A conceptual model of the AED setup is shown below.

Run the model as before – customize the plots being produced in `plots.nml`.

*Questions to explore:*

- How would the nutrient concentrations compare if the inflowing nutrients were halved?
- How would the algae concentrations change if the air temperature increased 4°C?

## E: Model validation with LakeAnalyzer and MCMC calibration

There are numerous ways that model users may wish to assess model performance and to optimise their calibration with observed data. As part of a GLEON ([gleon.org](http://gleon.org)) lake modelling working group, a specific workflow for model assessment and calibration has been trialled. The approach a) uses the GLEON “LakeAnalyzer” (LA) analysis scripts to assess model comparisons across a range of metrics, and b) combines these assessment scripts with a Markov Chain Monte Carlo (MCMC) procedure.

The combined GLM-LA-MCMC approach has been pre-compiled into an executable termed “`runMCMC.exe`”. Users must prepare several extra files and directories for providing the observed field data and also files associated with the MCMC routine:

- `Field/model.bth`
- `Field/model fld_temp.wtr`
- `InputFiles/glm_init.nml`
- `InputFiles/mcmc_config.nml`

The field files are based on LA formats. The model will run and output a log of model RMSE and other information about the performance of different parameter combinations. These will be written to files in the `Results/` folder.

To run the analysis download the zip file from <http://aed.see.uwa.edu.au/research/models/GLM>, and refer to the user manual for details of the file specification. Relevant field data needs to be formatted into the appropriate format before the model comparison can take place.

The MCMC procedure will run the GLM model many times depending on the `Nsim` parameter settings in the `mcmc_config.nml` file. The models simulations can be directed to an external server via ssh, or run locally. If the model runs correctly it will display the parameter distributions sampled, and prepare plots demonstrating the model calibration