

Make sure you have read the “*exercise_calibration_preparation.pdf*” before getting started here.

In this exercise you will learn how to run a calibration of a more **complex hydrologic model**. It is the Lake of the Woods reservoir with 21 subbasins (9 of which are explicit lakes) and 103 hydrologic response units (HRUs) over a 6 year calibration period. The example has **128 parameters** that need to be calibrated. We will use a multi-objective calibration to optimize the streamflow at one station (Vermillion) and the inflows to a lake (Lac La Croix). We will use the **OSTRICH toolbox** for calibration and the **hydrologic framework RAVEN** as our hydrologic model. The calibration algorithm will be the **Pareto Archived Dynamically Dimensioned Search (PA-DDS)**.

Task 1: Getting started

We will first make sure that all the settings are correct! This is similar steps as in exercise C₁.

1. Go to the exercise folder Demo_C2.
2. Depending on your operating system (Windows, Linux, or MacOS), you might have to make a few adjustments:
 - a. Identify the OSTRICH executable in the main folder Demo_C2 matching your operating system. Write it down:
Ostrich_____ .exe
 - b. Identify in the subfolder model the name of the Raven executable matching your operating system. Write it down:
Raven_____ .exe
 - c. Go to the subfolder model. You will find a script run_RAVEN.sh (Unix/MacOS) and run_RAVEN.bat (Windows). Open it and make sure that the correct Raven executable is used here (see 2b above).
 - d. You will find two files named ostIn_Windows.txt and ostIn_Unix.txt in the main folder. Take the one matching your operating system, copy it and save it under the new name ostIn.txt. The two files are basically the same, only some “/” and “\” conversions are necessary between the Unix (=Linux or MacOS) and Windows systems.

Task 2: Run Raven only

We will only run Raven- no calibration yet. This is to make sure that Raven is running without any problem. This is the same steps as in exercise C₁, except Step 5 which uses another basin name for running Raven.

3. Go to the model subfolder.
4. Make sure that you find a subfolder output there. If not, please create this folder. It will later contain all Raven specific output files such as discharge time series etc.
5. Execute the Raven executable matching your system (see 2b. above). This is done by opening a terminal/ command line.
Under Windows:
Open Command Prompt, navigate to the model subfolder, type and execute (use the right executable name):
Raven_____ .exe LOWRL -o output\
Under Linux/ MacOS:
Open terminal, type and execute (use the right executable name):
./Raven_____ .exe LOWRL -o output/
6. The simulation should finish with
Exiting Gracefully: Successful Simulation
Model results can be found in the output subfolder.

Task 3: Calibration

We will now start a calibration of the model we have just run with one parameter set in Task 2.

7. Go to the main folder Demo_C2.
8. Execute the Ostrich executable matching your operating system (see 2a. above) by running the following command in the terminal/ command line:
Under Windows:
 Ostrich_____ .exe
Under Linux/ MacOS:
 ./Ostrich_____ .exe
9. The calibration starts and will finish with some Algorithm Metrics.
10. The OSTRICH results and information will be stored in the main folder in several files.

Browse all of them and write down what they contain:

- a. OstErrors0.txt _____
- b. OstModel0.txt _____
- c. OstNonDomSolutions0.txt _____
- d. OstOutput0.txt _____
- e. OstPADDSPn.txt _____
- f. OstStatus0.txt _____

11. We calibrated NSE as you can see in the BeginResponseVars and BeginTiedRespVars block in the ostIn.txt file.

How many iterations were used?

- a. # iterations: _____

What is the final (best) calibration result?

- b. # non-dominated solutions found: _____

What is the best NSE found for streamflow at Vermillion station (first objective)?

- c. NSE of streamflow: _____

What is the NSE for the inflows to *Lac La Croix* for this parameter set (solution)?

- d. NSE of inflow: _____

12. Plot the non-dominated solutions in Excel/Matlab/Python etc.
13. Rename the subfolder processor_0 to results_nse_nse_budget_XXX (replace XXX by the budget under 11a) to save the results for later. Otherwise they get overwritten when you initiate the next calibration.
14. Repeat the calibration with higher budgets and add the non-dominated solutions to the plot you have created in the previous task! What do you observe?

Budget	Plotted	# non-dominated solutions	Takes about
50			~1.75m
200			~7.00m
500			~17.50m

Note: In MO calibration like this, when looking for best overall tradeoff across multiple trials, you can put all non-dominated solutions from multiple trials together and then do another non-dominated sort to retain the overall set of non-dominated solutions.

15. Something interesting to try:
 - a. Replace the objective for the lake inflows of maximizing the NSE value by minimizing the percent bias (DIAG_PCT_BIAS in model/output/ LOWRL_Diagnostics.csv).
 - b. Then redo the calibration with a reasonable budget.
 - c. Save the results under results_nse_pbias_budget_XXX.
 - d. Rerun the model in forward mode with the non-dominated solutions!
 - e. Does the simulated streamflow look better? Are the Nash-Sutcliffe efficiencies for the lake inflows very different from the results where we calibrated the NSE (task 11-14)?

Good luck!