Use Case C1: The effect of advection-dispersion on sewage effluent discharged daily in Pinios tributaries (NTUA)

1. Short description of the case

Use Case A analyzes the impact of human activities on the water quality of the Pinios river. The Pinios watershed belongs to the 8th Thessalia Water District (Greece) and was selected as a pilot basin for the WFD directive. The whole Pinios basin (including Lake Karla) drains an area of approximately 10,500 km^2. Eight significant tributaries contribute their flows to the main channel. However, the present study focuses on the upper part of Pinios and applies integrated modelling to simulate the hydrologic, hydraulic, and water quality processes of the upstream basin up to the junction with Enippeas tributary (~75klm). Important data sets used in the study are obtained from the records of Public Power Corporation, the Ministry of Environment, field surveys and discussion with local population.

Agriculture is the main source of income of the Thessaly Water District. Pinios basin is intensively cultivated with water demanding crops. The increased irrigation of the basin has seriously decreased ground water levels and river flow. Additionally, the fertilizers and pesticides used for the agricultural activities resulted to water quality degradation. Furthermore, untreated industrial waste and municipal wastewater directed into Pinios add to the local water pollution issues. Water quality may significantly vary in space and time depending on seasonal hydrometeorological conditions and water allocation/use. Climate change, land use change, deforestation, channel development, and groundwater overexploitation have increased the appearance of extreme (flood/ drought) events. The interrelated water quantity and quality concerns of the Pinios basin demand an integrated modelling approach. The OpenMI interface has been chosen to facilitate the linking of the most suitable available models representing the various processes in the area. In that manner, the present study has the following objectives:

a. Migrate in-house models in OpenMI
b. Set up, calibrate and validate the selected commercial and in-house models in the study area
c. Run the models separately and linked in OpenMI and evaluate the results (accuracy, time)

d. Identify critical locations along Pinios river related to water quantity and quality

2. Identification of the management / policy issue

The sustainability of the Thessaly natural and built environment depends entirely on Pinios water quantity and quality. Available surface water and groundwater has to satisfy the needs of farmers, industry, and local municipalities and furthermore, support the local environmental ecosystems. Appropriate water management programs should be developed to include mechanisms that ensure effective, economically achievable pollution reduction and secure water that meets the desired standards. The present study models the impact of point source pollution coming from different kind of industries (food processing, dairy industries, vegetable and fruit canning industries, weaving mills, slaughter houses, and tanneries) on Pinios water quality. Estimations of non-point pollution from agriculture will be also taken into account in the analysis as spatially averaged contributions to the study nodes. The simulation results are expected to seasonally vary depending on rainfall and industry discharge rates. The model output values at selected cross sections will be compared to legal standards taking into account the local specific water uses and the sensitivity of the local ecosystems. Different scenarios will be evaluated to test the linked models during extreme events and suggest solutions to the Competent Authorities.

3. Solution to these management / policy issues

WFD Directive, among other requirements, demands comprehensive modelling approaches that evaluate water quality at river basin scales. In order to evaluate the water quality along Pinios river, a hydrologic, a hydraulic, and a water quality model should be set up and exchange information. The use of the OpenMI standard allows those models to exchange information at run time, thus accurately simulate real life interactions. If the models are already OpenMI compliant, then, the linking process requires the end user to set up the case studies and link the populated models. If the models involved in a study are not OpenMI compliant, then model migration should precede any real time linking efforts. The study aims to identify critical locations and specific management actions tat will improve the water quality conditions along Pinios.

4. Setting the objectives

The present study objectives are divided into 2 categories: specific use case and wider perspective objectives.

Specific use case objectives

Use the OpenMI standard to achieve the following:

- Evaluate the water quality of Pinios at the upper section that accepts some significant point pollution sources and non point agricultural runoff
- Examine water quality during extreme events conditions (flood, drought)
- Identify and evaluate variables that characterize the contribution of specific industries to the river pollution
- Investigate in which areas any further pollution will be critical for the inhabitants and the environment
- Improve the data available to make regional and national decisions on existing policy implementations and optimise the cost-benefit analysis for any expenses made to improve water quality

Wider perspective objectives

Take advantage of the OpenMI standard ability to link models at runtime and achieve the following:

- Connect models created from different developers, in different languages, with different control specifications.
- Acquire better understanding and improve the representation and the way different processes interact in the basin
- Evaluate whether the real-time linked model simulation results are improved or not and under which scenarios
- Check which processes modelling would improve with the use of bi-directional links

5. Defining the actions

5.1 Preconditions for linking models

In order to start linking the models, the following actions should be completed:

First, the modeller should decide on the selection of the necessary models to perform the analysis:

- As mentioned above, the present study requires the use of a hydrologic, a hydraulic, and a quality model. The hydrologic could be conceptual or physics

based, lumped or (semi) distributed. At some earlier point, the use of MIKE-SHE was examined. However, the complete migration of MIKE-SHE in OpenMI was delayed, so the use of the NAM Rainfall-Runoff Module of the MIKE-11 model was considered the next best choice. An in-house hydraulic model, Rish-1D was selected to simulate the change of stages and velocity along Pinios. Rish-1D is coded in Fortran and solves the full Saint Venant equations. Finally, a lumped in-house water quality model, R-Qual, was selected to evaluate the advection/dispersion effects along Pinios. Mike11 is already OpenMI compliant. Rish-1D and R-Qual have to get migrated in OpenMI.

- Next, OpenMI, Visual C#, NUnit, and language compilers should be installed on the computer. Several water related models are written in Fortran. Often, Fortran code modellers are not very comfortable with Object Oriented Programming (OOP) structure. To overcome this issue in the present Use Case, the code developers will work together with an OOP programmer to have their models migrated.
- Finally, the selected models must be set up, calibrated and validated at selected locations in their study area.

5.2 Actions for the definition phase

5.2.1 Define the hardware environment

The present study will use personal PCs for modelling purposes.

5.2.2 Define the interactions to be modelled

For starting, all interactions will be considered uni-directional. The three models will exchange information at twenty-five nodes. At nine nodes, all three models will be linked. At seven nodes, only the hydraulic and quality model will exchange data (point sources). The other nine nodes are either locations for comparison with observed data (provide stage or concentration as output) or points of local interest (river geometry change, proximity to municipalities).

5.2.3 Define the links

The case study focuses on the upstream part of Pinios river, where several point pollution sources are released. The hydrologic model accepts the time dependent input

of rainfall and provides flow rate (m^3/sec) at specific locations along Pinios. In the case of one-direction links, the hydraulic model accepts flow rates and solves the Saint Venant equations providing time dependent stage (m) and velocity (m/sec) to the quality model. Finally, the quality model evaluates the time dependent concentration (mg/m^3) at the different nodes. The hydrologic and hydraulic model will share the same time step, selected according to data availability (one-day step). R-Qual model has a much smaller time step (for stability reasons). The time step difference should be carefully modelled during model linking.

5.2.4 Define and correct the gaps

It is not sufficient to relate inputs to outputs to have a proper model but to represent adequately the spatial variability of parameters and the physical meaning of the processes within the catchments. Depending on the assumptions made and the models finally chosen for the case study, the scenarios may require additional nodes or fewer nodes exchanging the necessary information. As a result, the homogeneity assumptions, the boundary and initial conditions will be re-examined during the study

5.3 Actions for the iterative phase

- Perform the model migration steps as described in the training
    - Convert engine to .dll
    - Create two .Net assemblies, one for the Wrapper and one for the Testing classes
    - Test the migration using the NUnit Framework
    - Load the component into the OpenMI GUI and test with trigger and with Simple River

To perform runs with the models not yet linked

- Collect all required data and set up models
- Run a few simulations and compare the simulated to the available observed values to verify that the models are correctly set up and the data are of good quality. For Use Case A, three years of data (1993-1996**)** are selected to calibrate the models
- Test the models separately to extreme conditions and examine their behavior using as an input the output from the relevant model

To link models and to perform tests of linked runs

- Link the models and compute similar runs to the ones mentioned above
- Evaluate the differences between the results of the respective scenarios

To solve the problems, encountered during the tests

- Re-examine the quality of the input data
- Check whether the shared variables are correctly linked in time and space
- Check the units
- Repeat the tests to see whether the issues are resolved

5.4 Actions for the demonstration phase

- Run a representative scenario for the area, where observed values are available to compare results
- Run a couple of scenarios that will provide input to decision makers, forecast, or suggest solutions to the pollution issues

5.5 Actions for the evaluation phase

- Examine whether using the OpenMI interface provides an added value to the analysis or which scenarios may benefit more from using OpenMI
- Evaluate the effort needed from potential End-Users to employ the OpenMI technology and simulate their case studies
- Check whether some bi-directional links may improve the model output at selected locations especially where there is backwater effect.

6. Milestones, deliverables, success scenarios

The first results of successful model linking in this case study are expected by Fall 2007. The milestones are divided, as suggested, into two categories:

6.1 Technical Milestones

- All three models become successively OpenMI compliant
    - Test new model migration using the NUnit Framework
    - Check whether the models can communicate in OpenMI
    - Evaluate the physical meaning of the linked modelling results and the use of bi-directional links
- Models are successfully linked
    - Run scenarios with and without the OpenMI linking and produce reasonable (and comparable) results

- Input is provided to the OpenMI technical group related to the learning process and the implementation process of the OpenMI interface

6.2 Use Case Specific Milestones

- Water quality at specific Pinios cross sections is examined
    - Different indicators are used and their values are compared to the acceptable limits
    - Scenarios of reducing specific pollution sources are re-evaluated
    - The impact of different rainfall scenarios (and flow conditions) is examined
    - Conclusions are drawn and input is given to the Competent Authorities
- The Competent Authorities get trained as OpenMI End Users and employ the OpenMI compliant models of the present study to create and evaluate their own scenarios