Migrating components to support integrated modelling in Pinios

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Three Use Cases

- Use Case A: Investigates water quality issues at Pinios river
- Use Case B: Analyzes the operation of a river-reservoir water management system
- Use Case C: Evaluates various possibilities for the restoration of Lake Karla

- Use Case A and Use Case B are developed and run by NTUA
- Use Case C is set up and evaluated by UTH

NTUA model components supporting Use Case A and Use Case B

- Use Case A
  - 1: **RiSH-1D**: hydraulic model and **RiSQ-1D**: water quality model (upgraded R-Qual to satisfy unsteady flow simulations)
  - 2: **OTIS** and **ASCII Total Reader** components

- Use Case B
  - 1: Reservoir Management Model (**RMM-NTUA**)
  - 2: **Rule** Component and **SUMComponent**

- Use Case C
  - **UTHBAL**: will be presented later today!

Issues encountered and addressed

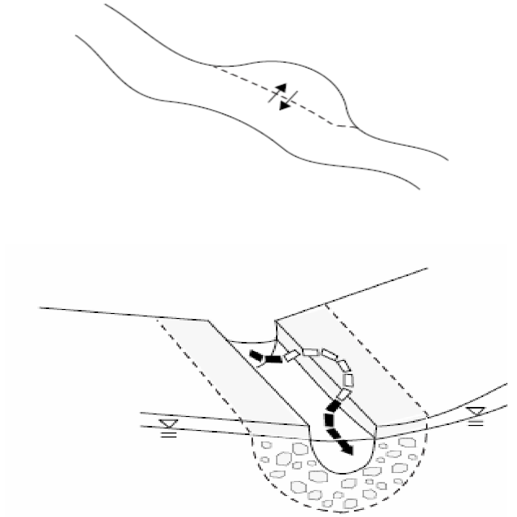
- Different kind of problems:
  - Related to conceptual issues for variable exchange
    - OpenMI may ensure that variables are exchanged properly but will not ensure that the exchange will be physically meaningful: this is a responsibility of the modeler!
    - Variable definition is different from model to model
  - Related to code structure and language

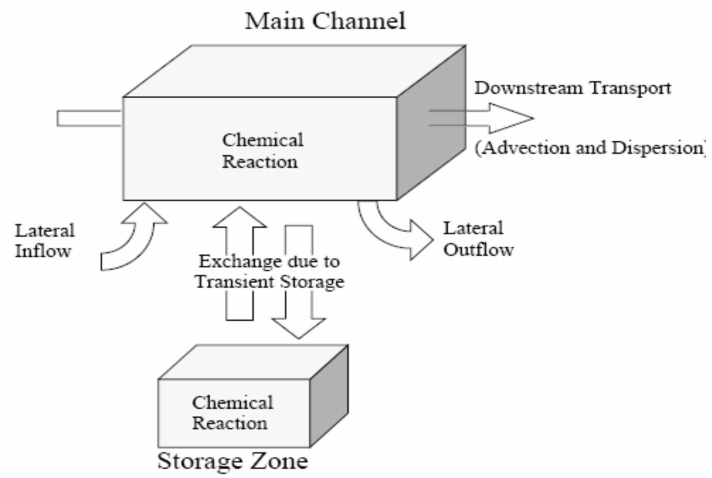
Ensuring successful (and useful) migration!

- Study migration material posted on the OpenMI Association Technical Committee WIKI pages and the OpenMI Associatior website (www.openmi.org)
- Participate in training courses
- Have an OO developer and the Source Code model developer work together: spares a lot of time and frustration
- Examine the exchange variables of potential model componer candidates for OpenMI linking before migrating the in-house developed model
  - .xml files under the section OpenMI compliant models at the OpenMI Association website
  - OpenMI Editor exchange variable properties

OTIS migration

- One-Dimensional Transport with Inflow and Storage (OTIS)
  - Developed by USGS
  - A Solute Transport Model for Streams and Rivers
  - Model is written in ANSI standard Fortran-77, has free source code and





OTIS Migration: steps

- Discuss with people understanding conceptually OTIS, have possibly used it or/and are interested in linking it with other OpenMI compliant models
- Decide on exchange variables and links
- Implement certain required functions:
  - Initialize()
  - PerformTImeStep()
  - Finish()
  - Dispose()
  - GetModelDescription()
  - GetModelID()
  - GetTimeStepLength()
  - GetNumberOfTImeSteps()
  - GetInputTime()
  - GetCurrentTime()
  - GetSimulationStartDate()
  - GetFlow()
  - AddInFlow()
  - GetMessage()

OTIS migration: specific difficulties identified by developers

- Tricky isolating the OTIS source code for implementing the performTimeStep() function because print step was generally different from the running timestep loop and generated adverse effects
- Problem passing strings from C# to Fortran77 over .NET with StringBuilder. Not able to find a functioning encoding. Solved by mapping integers to strings
- Some InputExchange variables didn't update correctly OTIS variables at first runs because of an internal update function in the beginning of the repeated timestep-loop. Solved by making some adjustments in the source code

OTIS MIGRATION limitations

- During the models linking we were restricted by other models in the format of the OTIS Input/OutputExchange variables. Sc we could not use some advantages of OpenMI we may liked:
  - i.e. the ability to connect multiple nodes to multiple nodes

  ****If the other model (=possible linkable component) is commercial (such as Mike11 in our case) we can't transform the source code
- Investigate whether linking models starting the simulation at the same time does not allow running one model for a short period ahead
  - To overcome the instabilities and then start interchange data with the other models

ASCII Reader migration

- ASCII OpenMI compliant model reads historical data/records
  - Releases and Industrial data in our case
- Model Functionality for the End User
  - A user denotes the delimiter in the omi file
  - ASCII file contains the name of the OutputExchange variable, the number of the different locations where the interchange takes place and finally the dates with the corresponding values
  - The timestep is allowed to be different between the ASCII Reader Component and the connected model because of the way the GetValues of the ASCII component is implemented
- Guideline Reference
  - OpenMI Association -> Technical Committee Wiki -> Getting Started with OpenMI -> How to turn an Ascii file reader into a Linkable Component

Technical issues related to RiSH-1D / RiSQ-1D Fortran migration

- Upgrade obsolete features/techniques of Fortran programming language (version 66 or 77) in RiSH-1D Model's Engine Core

- Ensure the stability and performance of RiSH-1D Model after the changes

- Ensure code compatibility with new technologies (e.g. Intel Visual Fortran Compiler v. 10.x)

- "Translate" these changes to Model Developers!!!

Technical issues related to Fortran migration

- Discard old technologies (e.g. Microsoft ForTran PowerStation and adopt new ones with useful debugging Tools
- Use of NUNIT Testing Framework as shown in the Documentation of OpenMI
- Use of SimpleRiverModel Engine Core example in OpenMI distribution
- Check the OpenMI Technical Committee Website for patterns and examples
- OO developers: get advice from Fortran experts!!!

Technical Issues related to Fortran migration

Future Perspectives :

- Build a Repository (perhaps in OpenMI Association Web Site) with detailed information related to Migration Technical Issues such as :

  → Mixed-language programming techniques

  → Known bugs

  → Known incompatibilities between conventions of different languages

  (e.g. Delphi, ForTran, C#)

  …………

  – Enhance Migration ease by eliminating the need of face-to-face cooperation between Model Developers and OO Programmers

- Convince Model Developers to adopt new programming technologies!!!

Reservoir and Rule Component

- RMM-NTUA Reservoir-Engine's code is in Delphi:
  - Simpler
  - Faster
  - Better integrated with .NET platform
- Rule Component
  - Engine code also in Delphi
  - Bidirectional links with both reservoirs
  - Main function:
    - In every timestep of the Reservoir's performTimeStep() adds all InputExchanged variables
    - GetValues returns the sum to all connected models
    - Its necessary to write in Rule's inputFile the number of the bidirectional linked models with it

SumComponent in C#

- The whole program is written in C#
  - Implemented LinkableEngine and the main class where engine-core takes place
- Functions
  - Sums numerous components
- Conclusion
  - Possibly replaces RuleComponent's funcitonality
  - Simpler in coding to make it OpenMI compliant
  - Avoiding to construct additional classes in order to connect with source engine written in a programming language other than C# (usually named DllAccess and DonNetAccess)

Get support

- Post questions on the OpenMI Source Forge, exchange opinions and read analyzed topics
- Contact directly the OpenMI compliant commercial software providers

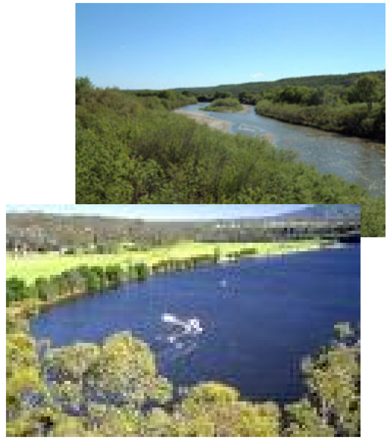
COMING SOON:

- Study the continuously updated material of the E-Learning platform

INFLUENCE FUTURE PROGRESS:

- Join the OpenMI Association and influence the development o OpenMI

Use Case A: integrated modelling for stream water quality management



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Layout

- Introduction
- Mathematical Model Presentation:

- Hydrodynamic sub-model: RISH-1D
- Water Quality sub-model: RISQ-1D

- The Area of the Study
- Available Data
- Application of the Integrated Model
- Conclusions - Proposals

Introduction

- Large number of existed water quality models are used for design /operational purposes.

- An integrated modelling system developed in the Laboratory of Applied Hydraulics of NTUA, is composed of two sub-models – coupled through Open MI platform:

- RISH -1D (River and Stream Hydraulics in 1Dimension).
- RISQ-1D (River and Stream water Quality in 1Dimension).

Introduction(2)

- Purpose: Development and application of an integrated, 1-D mathematical model for water quality management in rivers and streams.
- The sub-models of the integrated model linked through Open MI platform can be used for real time simulations of flood routing and water quality in rivers and streams.

- Target: Determination of water quality in a part of Pinios River, Thessaly, Greece.

MATHEMATICAL MODEL
General Features

- Hydrodynamic sub-model RISH-1:

- Equations Saint Venant in 1 Dimension.
- Spatial discretization: Preissman “box scheme”.
- Time discretization: Implicit solution scheme.
- Solution: Newton- Raphson
- Time steps: Long (10 – 102 s)
- Program language: FORTRAN

MATHEMATICAL MODEL
General Features

RISQ-1D

- Water quality sub-model:
- Mass balance equations for water quality variables of concentration C.
- Space and Time discritization: 2nd order accurate for both space and time implicit Crank –Nicolson method.
- Solution: Thomas Algorithm.

General characteristics

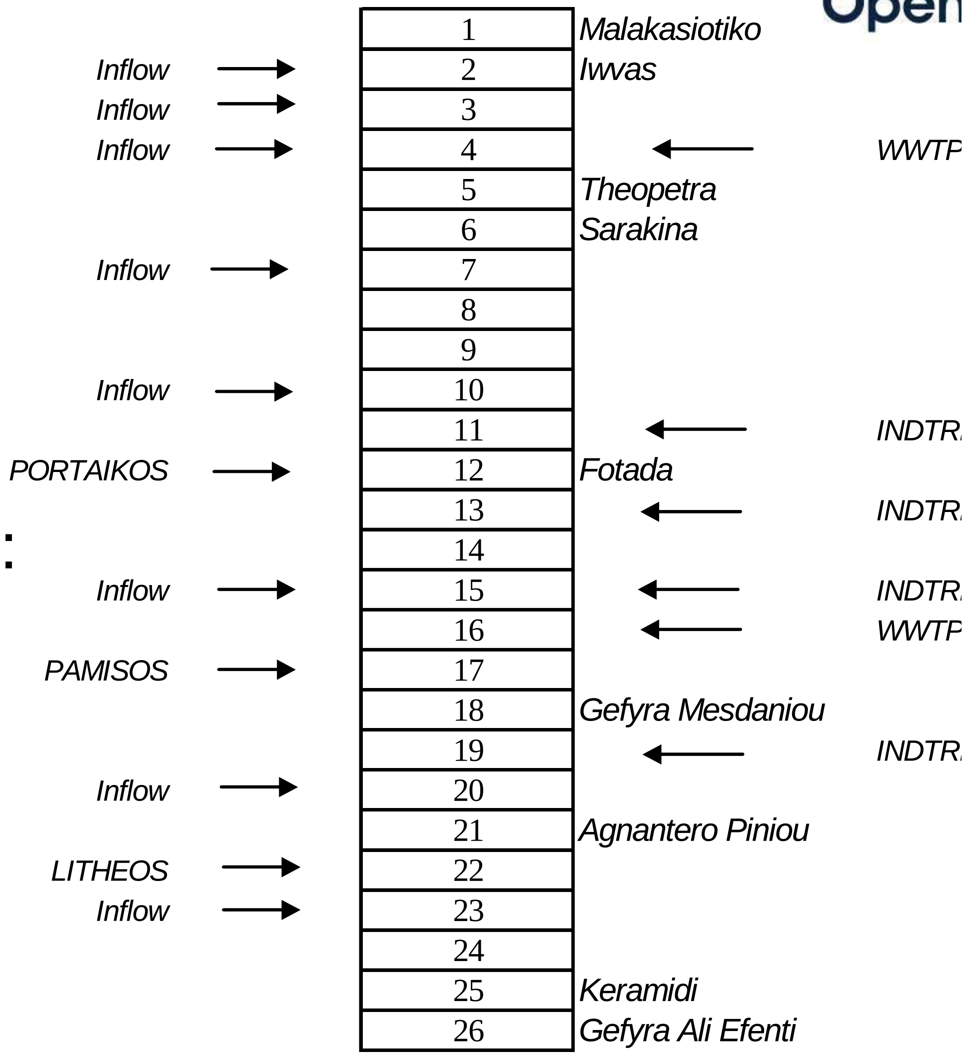
Lateral flows from MIKE-11

- Pinios River: a part of total length 78 km².
- Location: Trikala, Thessaly, Greece.

The area of the study

General characteristics

- Number of segments: 25.
- Number of WWTP & industry discharges: 6.
- Number of tributary inflows: 12



Schematic presentation of the river system

General characteristics

- Segments' characteristics:
- trapezoid main cross sections
- two sub – sections /main section
- Uniform flow velocity (U): calculation using Manning's Equation, for each main section

$$U = \frac{Q}{A} = \frac{Q}{w \cdot y} = \frac{1}{n \cdot w \cdot y} R^{2/3} \cdot S$$

4. AVAILABLE DATA

- Geometric and morphologic characteristics of the segments: variable section width and bed slope along the river.

- Inflow hydrographs calculated by MIKE 11, DHI, for hydrological: data selected= October 1993.

- Characteristics of pollution sources: position, loads (kg/day), from relative references.

- Average monthly water quality field data for 1993 (Ministry of Environment and Public Works)

  » water temperature
  » COD

Sources of pollution

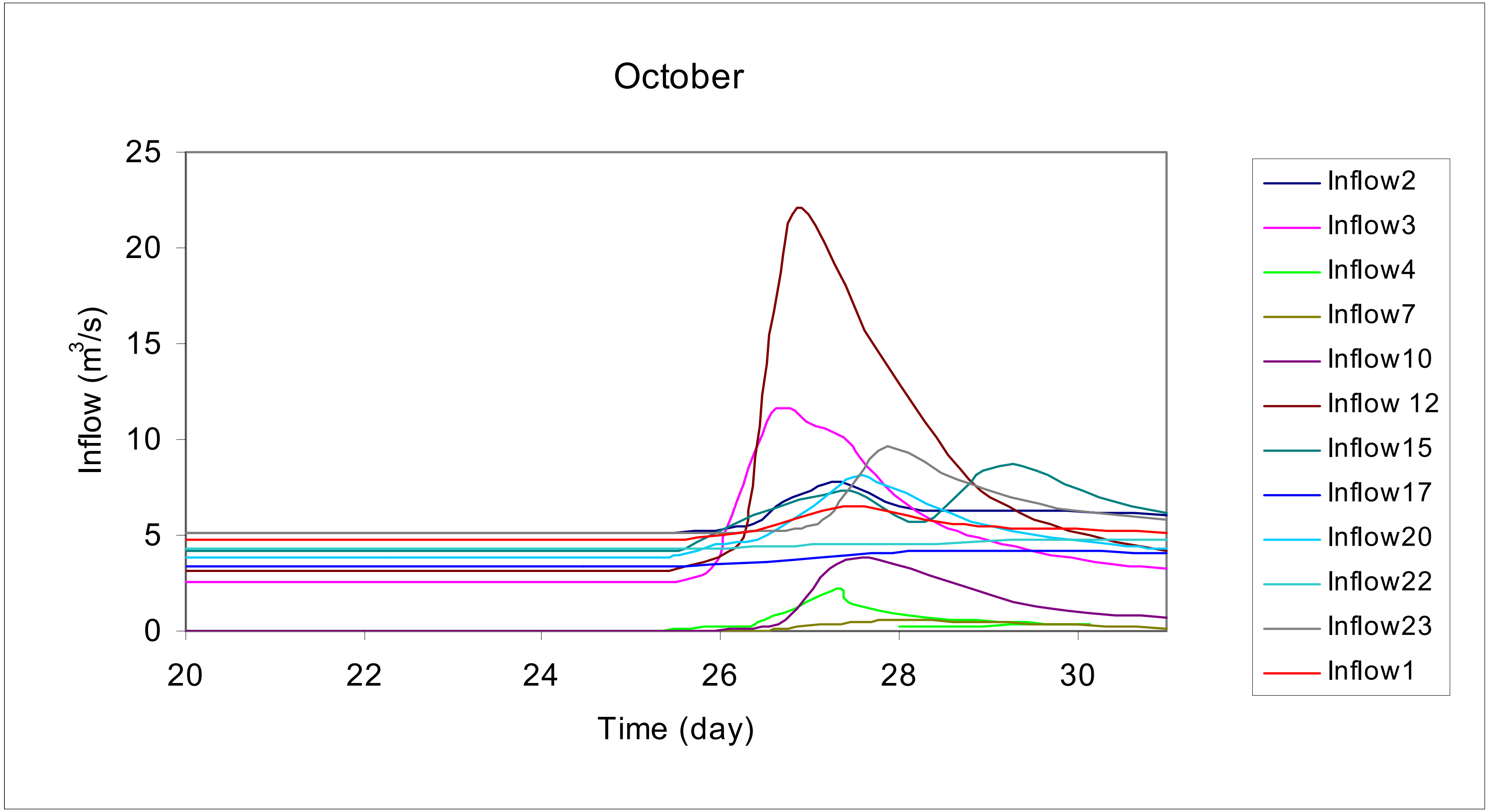
- Main sources of BOD5:
- Industrial plants (INDTRIs).
- Waste Water Treatment Plants (WWTPs).
- Tributaries.
- 1,2,3: estimated from relative references.

Sources of pollution

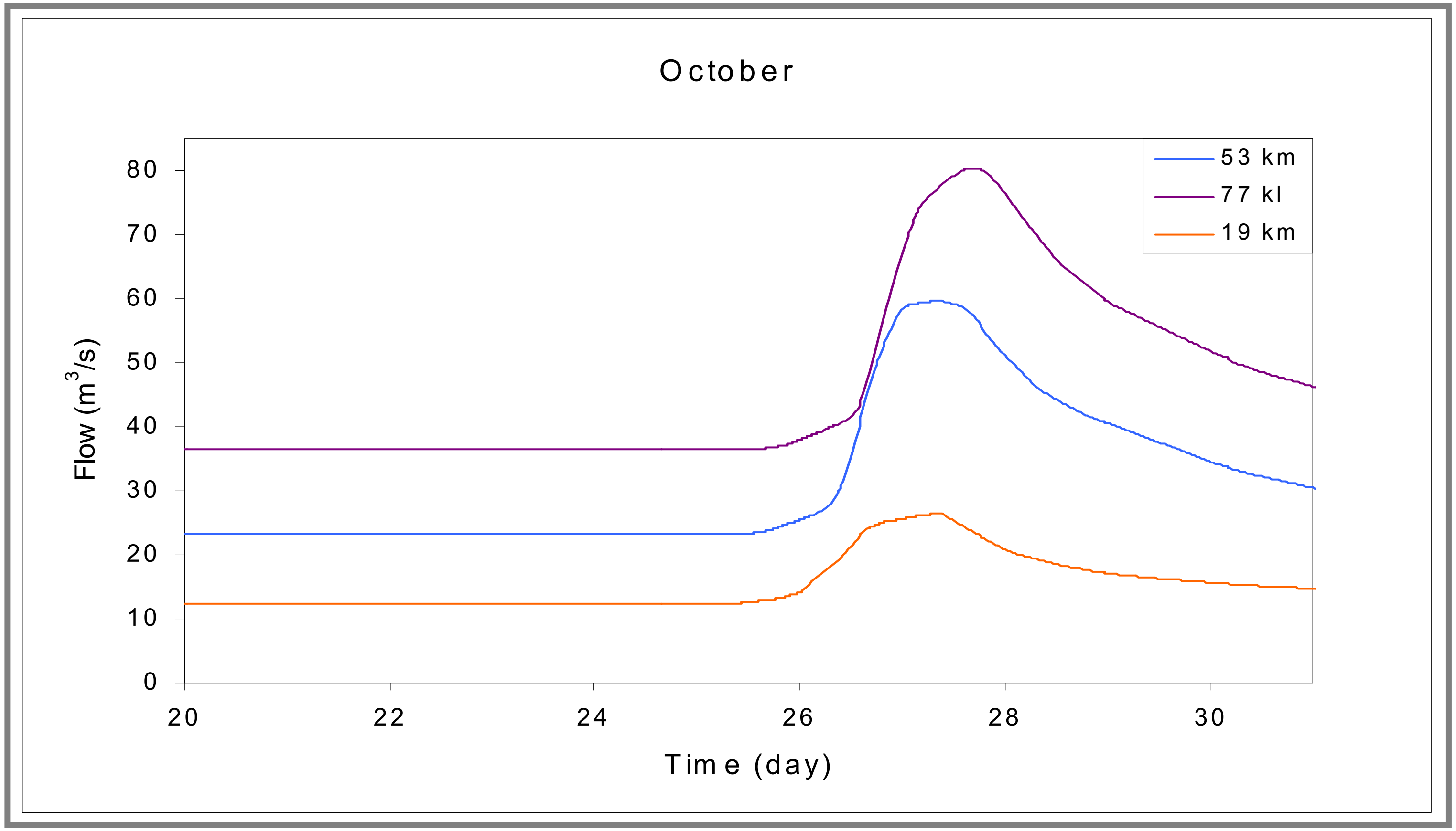
Section	Distance (km)	Point source	Symbol	Load (kg/d)
4	11.56	WWTP- City of Kalambaka	WWTPTRI03	143.0
11	37.35	TYRAS SA - Dairy	INDTRI008	64.2
13	40.79	BATAGIANNIS - Tannery	INDTRI006	4.8
15	46.52	TRIKKI - Dairy	INDTRI005	9.0
16	49.21	WWTP- City of Trikala	WWTPTR01	260.0
19	55.70	AGRIC.CO-OP.UNION OF TRIKALA - Textile	INDTRI004	248.0

Daily BOD_5 pollution loads from WWTPs and INDTRIs

MIKE-11 subcatchment flows



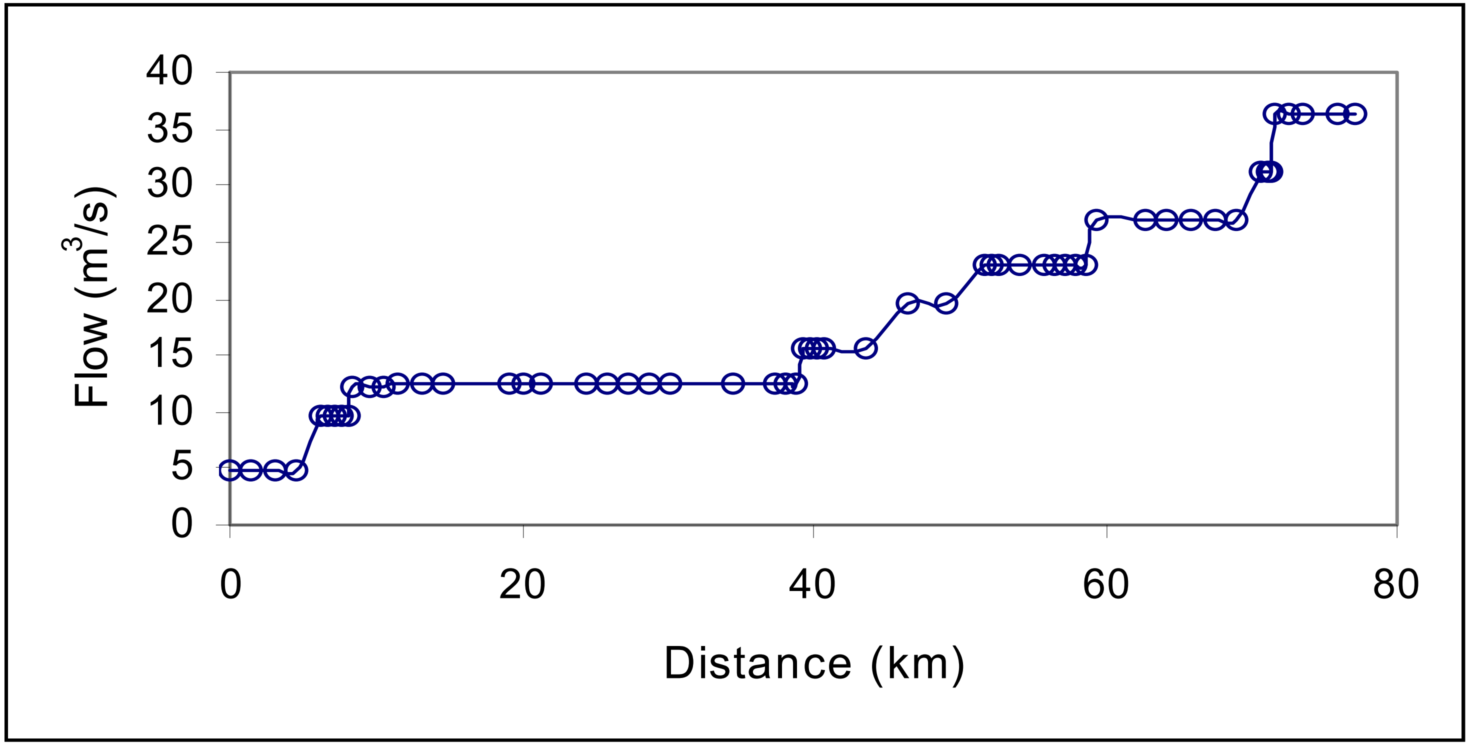
MIKE-11/RISH-1D: Hydraulic calculations



Calculated hydrographs at 19 km (monitoring section 6), 53km (monitoring section18) and 77 km (monitoring section 26)

5. APPLICATION OF THE INTEGRATED MODEL -17
5.1 Hydraulic calculations

For the base flows of hydrographs, for steady flow conditions



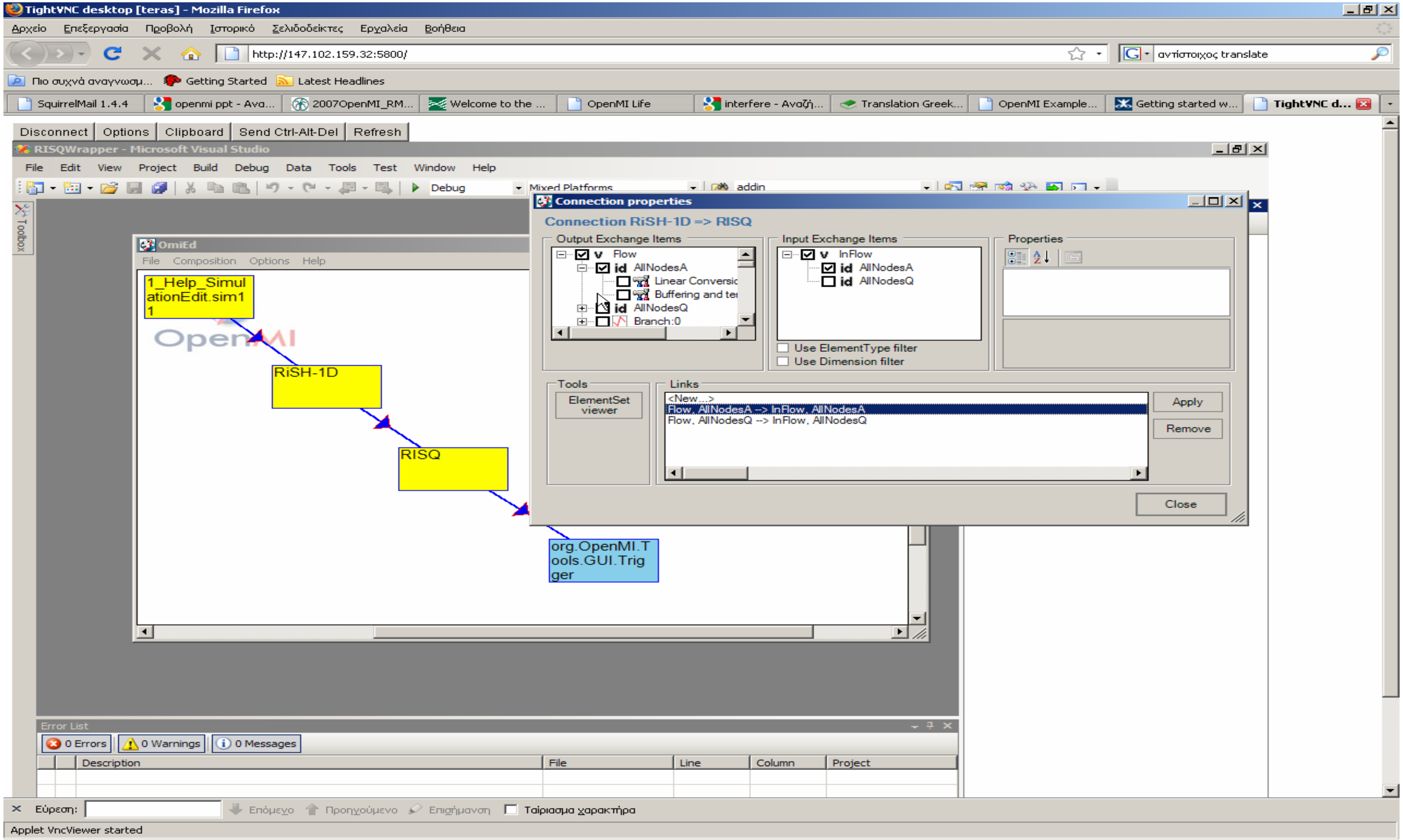
Calculated longitudinal distribution of flow, input to RISQ-1.

INTEGRATED MODELLING
Water quality calculations

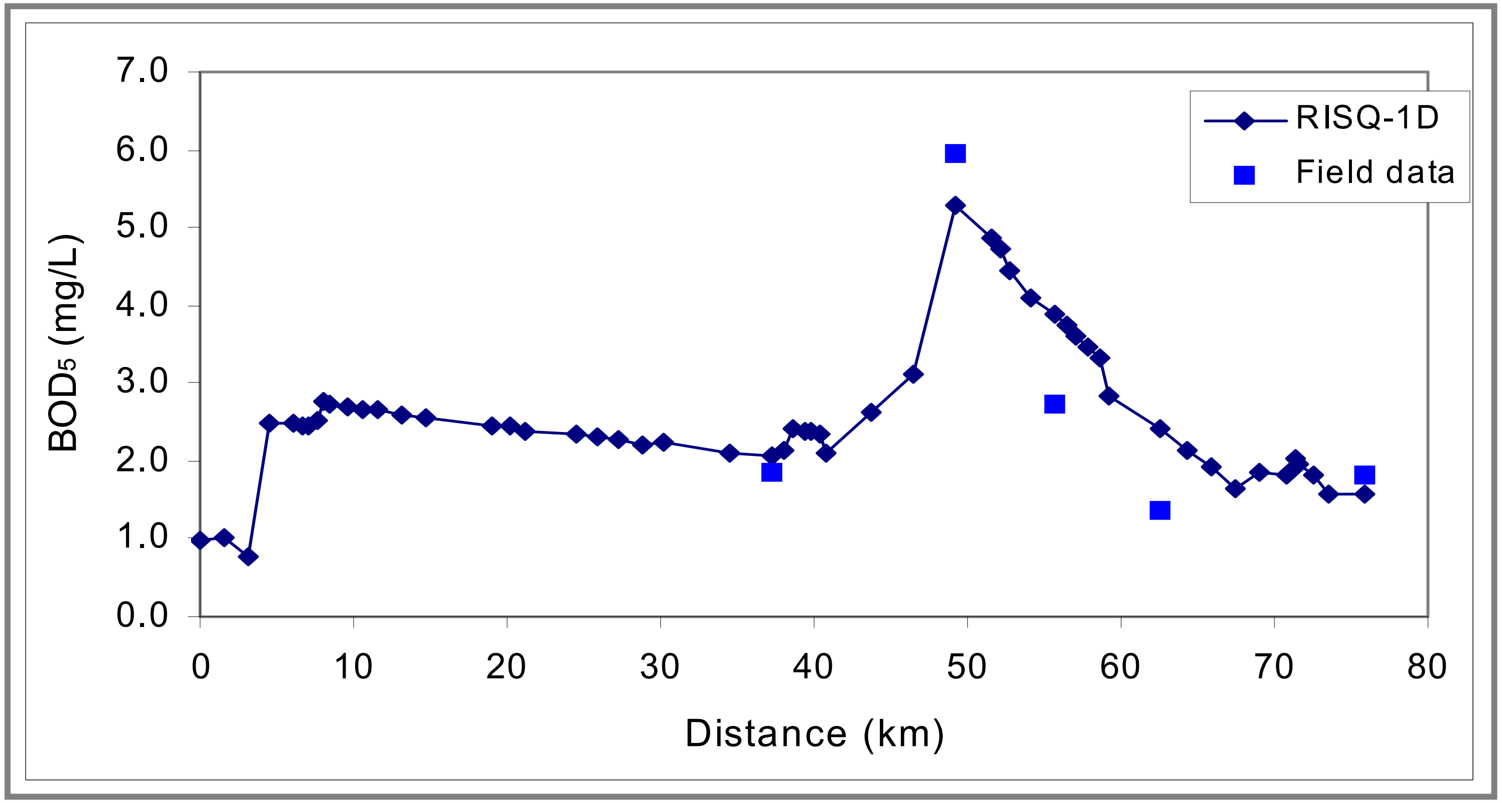
FIRST SEPARATE MODEL RUNS – THEN LINKED RUNS IN OPENMI

- RiSH-1D: Input to RiSQ-1D
- Hydraulic profile of the river (Q, A) by RISH-1D.
- Lateral inflows and solute concentration of lateral inflow (QL ,CL)
- Field data - average daily values for BOD5, calculated from respective COD concentration values using the assumption: COD/ BOD5 =3.5.

Hydraulic and Quality models linked with Mike11



INTEGRATED SYSTEM
Water quality calculations



Calculated BOD_5 concentrations vs. field data

Discussion - Conclusions

- Selected models by developers became OpenMI compliant
- Use Case are defined and set up to explain all different loads in the area
- OpenMI may save a lot of time if input data/ data conversion when several sources exchange data
- Linked models show reasonable results at simple cases and observed flows but:
  - Have some instabilities that need re-definition to be overcome
  - Will be compared with the following scenario to see whether different assumptions/variables but same data produce reasonable/comparable results

Discussion - Conclusions

Meaningful model: Not only meaningful linking but also aqequat data

- Determination of anthropogenic pressures: loads from WWTPs, industries, tributaries, temporal variations
- Systematic & regular field measurements:
  - **Water quality variables**
  - **Hydrological characteristics**
  - **Hydraulic characteristics**

2. MATHEMATICAL MODEL RISH-1D -7

2.2 Hydrodynamic equations

- Conservation form of Saint Venant equation for Flow (Q) and Water Surface Elevation (h)

Continuity

$$\frac{\partial Q}{\partial x} + \frac{\partial (A + A_0)}{\partial t} - q = 0$$

Momentum

$$\frac{\partial Q}{\partial t} + \frac{\partial(\beta Q^2 / A)}{\partial x} + gA\left(\frac{\partial h}{\partial x} + S_f + S_e\right) - \beta q v_x + W_f B = 0$$