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Demonstration of Integrated Modelling using the OpenMI in the Scheldt River Basin

Neel Devroede^a, Yves Ronse^a, Johan Van Assel^b and Hans Vereecken^c

^a *Vlaamse Milieumaatschappij (VMM), A. Van de Maelestraat 96, 9320 Erembodegem,
Belgium (n.devroede@vmm.be, y.ronse@vmm.be)*

^b *Aquaflin, Dijkstraat 8, 2630 Aartselaar, Belgium (johan.vanassel@aquafin.be)*

^c *Flanders Hydraulics Research, Berchemlei 115, 2140 Antwerpen, Belgium
(hans.vereecken@mow.vlaanderen.be)*

Abstract: Water management in the transnational Scheldt River Basin (Belgium, France, the Netherlands) is scattered among many different authorities and operators. For several years, most of them have adopted modelling as a technology for optimising investment and operation strategies for the part of the water system that is under their responsibility. As the European Water Framework Directive imposes water management to be integrated across both authorities and water domains, there is a clear need to streamline and integrate the various modelling efforts. However, many of those models have been developed completely independently from each other, with inconsistent spatial boundaries, and using different approaches and objectives. Hence, integrating these models is far from straightforward. The development and release of the OpenMI (Open Modelling Interface) standard in 2005 offered a potential solution to linking models of various origins and concepts, and the challenge was taken up to try and apply this new standard at full scale on real operational models. In the frame of the demonstration project OpenMI-Life, four use cases were defined within the Scheldt basin, in which various aspects of model linking will be tested. By the end of the project, it is hoped that water managers will have better insights of how interactions between water systems may affect strategic decisions.

Keywords: OpenMI, model linking, integrated water management

1. INTRODUCTION

Due to its transnational character and its geographic location in the heart of one of the most densely populated areas in Europe, the Scheldt River Basin is a good example of how complex and challenging integrated water management is in practice.

From an institutional point of view, the International Scheldt Commission co-ordinates the policies of no less than six member states/regions (France, the federal state and three regions of Belgium, and the Netherlands). But even within these six entities, there is a variety of authorities and operators involved in the different water domains and water industry sectors.

From a water management point of view, there are important issues about flood protection and water quality. Furthermore, the economic role of the river basin, which contains the Antwerp, Ghent and Zeebrugge ports along with many heavily used canals, is not to be underestimated.

During the preparation of the OpenMI-Life project, four use cases were identified (Vits and Devroede [2007]), which were thought to give a good picture of the possible interactions between the main large scale modelling programs that have been running for the last ten years. These use cases are :

- linking a sewer model with a hydraulic river model
- linking two different hydraulic river models for navigable and non-navigable water courses
- linking a river quality model with two hydraulic river models
- linking a 1D-river model with a 2D-estuary and coast model.

Details of the four use cases are described further.

The aim of the OpenMI-Life project is to demonstrate that the OpenMI standard (Gregersen et al. [2007]) and its implementations can provide a technical solution for the different linking problems in the four use cases, and that the OpenMI Association as a support organisation can come up with solutions for those areas where further improvement and development to the Standard would still be required. Besides the use cases in the Scheldt River Basin, tests are conducted in the Greek Pinios River Basin.

The project is supported by the European Life Programme and is co-ordinated by the UK Centre for Ecology and Hydrology (CEH). It started in October 2006 and lasts until January 2010. More information on the project can be found at www.openmi-life.org.

2. DESCRIPTION OF THE USE CASES

2.1 Use case A : sewer-river interactions in the drainage area of Leuven

In the first use case a (hydraulic) sewer model is linked to a hydraulic river model. The models respectively describe the urban drainage area around the town of Leuven (appr. pop. 120000, appr. area 120 km²) and the river Dijle with its main tributaries between the Walloon/Flemish regional border and the confluence with the river Demer (appr. length 40 km, appr. area 300 km²) (Figure 1). Partners involved in this use case are Aquafin (the company responsible for building and operating the wastewater treatment plants and main trunk sewers in Flanders) and the Division Operational Water Management of VMM (Vlaamse Milieumaatschappij – Flemish Environmental Agency), responsible for the non-navigable watercourses in Flanders. The models have been built in InfoWorks CS (sewers) and InfoWorks RS (rivers) (Wallingford Software, UK).

Simulating the models in linked mode is expected to lead to an improved forecast of flooding, both in the sewer system and in the river, and will provide new insights and opportunities for optimising the investment schemes and operational management for both the sewer and the river system.

Under normal conditions two types of interactions can be defined. Firstly, the sewer system discharges into the river system at various locations, such as permanent outfalls, overflows and at the waste water treatment plant. Secondly, high water levels in the river system can prevent free discharging from the sewer system. Flows may occasionally revert in these cases where outfalls are not protected by a flap valve.

Under flood conditions additional exchange of water can occur between sewer and river system, as the river may flood certain sewer manholes, causing the river water to enter the sewer system, or flooded manholes may spill (diluted) sewage into river flood areas.

In OpenMI terminology this means that the quantities exchanged are flows (from sewer to river model) and water levels (from river to sewer model). Although this does not look particularly complicated, it is the high number of links (more than 100 in normal

conditions and probably an even higher number for flood conditions) and the fact that all links are bidirectional, which makes up the technical challenge for this use case. All these exchanges will lead to a continuous and dynamic flow redistribution between both models, which would never be achievable using predefined boundary conditions.

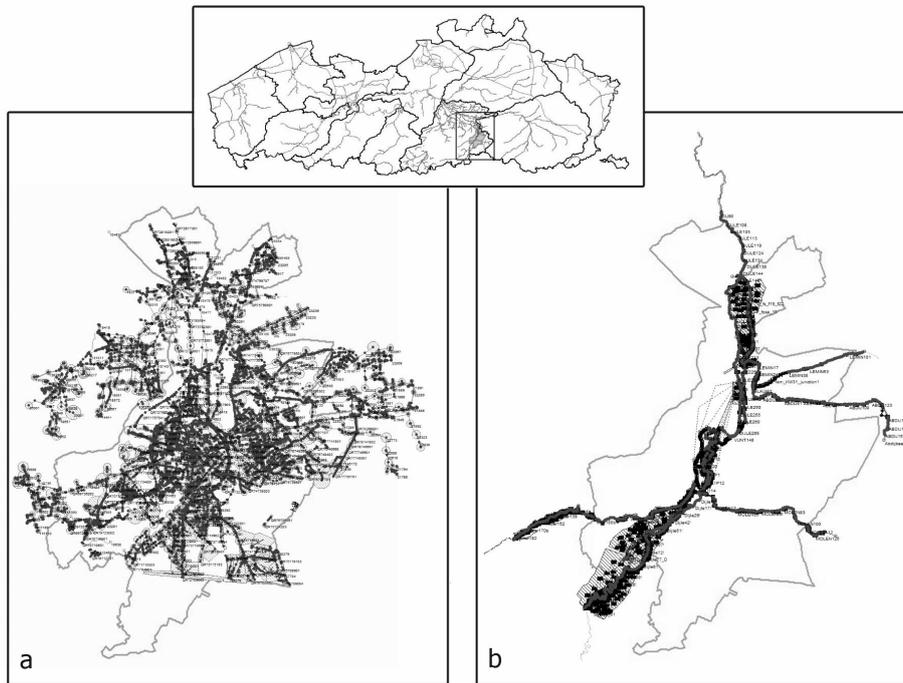


Figure 1. Geographic setting (top) and models for use case A : InfoWorks CS sewer model of Leuven (left, a) and InfoWorks RS Dijle river model (right, b)

2.2 Use case B : linking Scheldt and Dijle river sub-basins using two different hydraulic river models

The second use case comprises the linking of two independently built hydraulic river models. The first one describes the subbasin of the river Dijle and its tributaries, upstream from the confluence with the river Demer (the same model as used in use case A). The second one describes the tidal part of the Scheldt river and its tributaries, including the river Dijle downstream from the confluence with the river Demer (Figure 2).

The end of the tidal and navigable zone, which forms the split point between the two models, also delineates the competence area of both partners in this use case : on the one hand the Division Operational Water Management of VMM; on the other hand the Division Flanders Hydraulics Research of the Flemish Ministry of Mobility and Public Works. The models have been built in InfoWorks RS (Wallingford Software, UK) and Mikel 1 (Danish Hydraulic Institute, Denmark).

Simulating the models in linked mode, thus avoiding the need for setting up appropriate and reliable upstream and downstream boundary conditions, is expected to improve the accuracy of flood forecasting in both models. By linking the models both competent authorities can take into account the impact of operational flood management (such as the use of retention basins) in each other's parts of the river basin.

As for use case A, the quantities exchanged are flows (from Dijle model to Scheldt model) and levels (from Scheldt model to Dijle model), again defined as bidirectional links. The number of exchange points however is very limited, even with the occurrence of mazed tributaries in the boundary area between the two models. As both original models have an

overlapping zone (in order to dampen the immediate impact of boundary conditions), alternative scenarios for the definition of the links will be investigated (e.g. with the flow exchange not necessarily occurring at the same location as the water level exchange). When looking at the models in flood conditions, flow and level exchange will be applied not only on the main river channel, but also in the flood zones.

Finally, a clearly different technical challenge, as opposed to use case A is the fact that use case B deals with models from different suppliers.

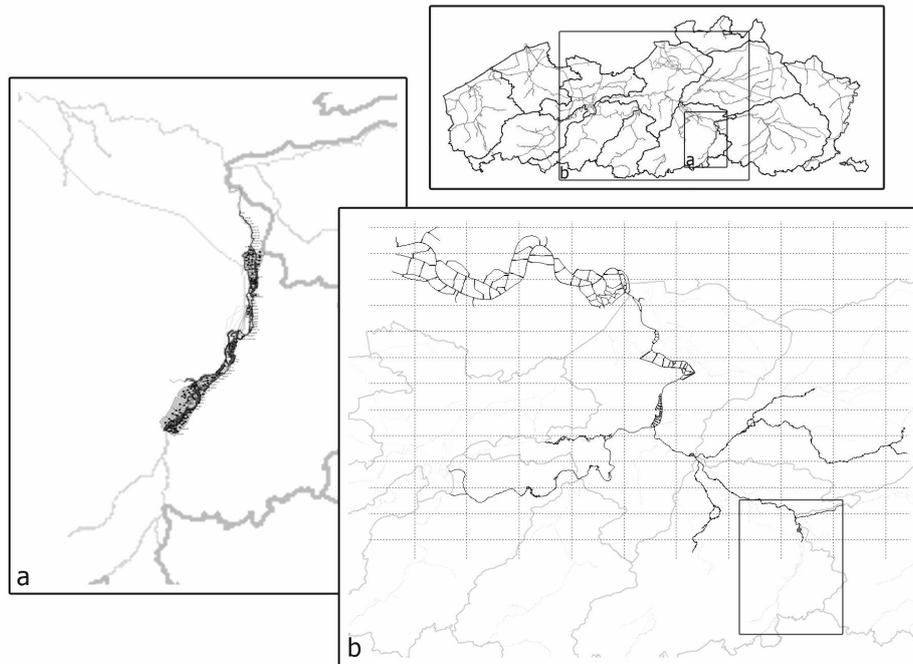


Figure 2. Geographic setting (top) and models for use case B : InfoWorks RS model of the river Dijle (left, a) and Mike11-HD model of the river Scheldt and tributaries (right, b)

2.3 Use case C : linking a river quality model with two different hydraulic river models in the Dijle and Demer sub-basins

In use case C parts of the two aforementioned hydraulic river models will be linked (one at a time) with a river quality model, which describes the whole of the river Dijle and river Demer basins (including the Walloon part of the river Dijle) (Figure 3).

The river quality model PEGASE was developed by the University of Liege, Belgium and is used by the Division Water Quality Management of VMM in view of developing its surface water quality management plans. It has a built-in hydrological module, which – based upon flow observations from river gauges- can produce flow patterns for the river branches. By linking the PEGASE model with the hydraulic river models InfoWorks RS and Mike11, it is expected that the flow calculations will become much more accurate compared to the ones produced by the built-in hydrological module. This in turn will improve the accuracy of the river quality calculations, as these are obviously very dependent from the velocities. In areas without a InfoWorks or Mike11 feed, PEGASE will continue to use its own flow calculations. Point inflows to the river (waste water treatment plants, industries) will continue to be taken from the PEGASE input database.

Besides the expected improvement of the water quality calculations, the linking of the models will enable water quality and river managers to account for the expected quality of the flood water in the decision process of the construction and operation of flood zones.

The technical aspect of the linking is different from the two aforementioned use cases in so far that the models are sharing the same geographical area. This means that the linking is to be seen as a global overlay rather than as a point-to-point link as in use cases A and B. Inconsistencies in the details of the river schematisations in both models form a specific point of attention when applying this.

Quantities exchanged are water depths, flows and velocities (all from the hydraulic river models to the river quality models).

Contrary to the other use cases, it is also to be mentioned that the PEGASE model was not yet OpenMI compliant before the start of the OpenMI-Life project. Hence, the process of migrating a model is another element in demonstrating the applicability of the OpenMI.

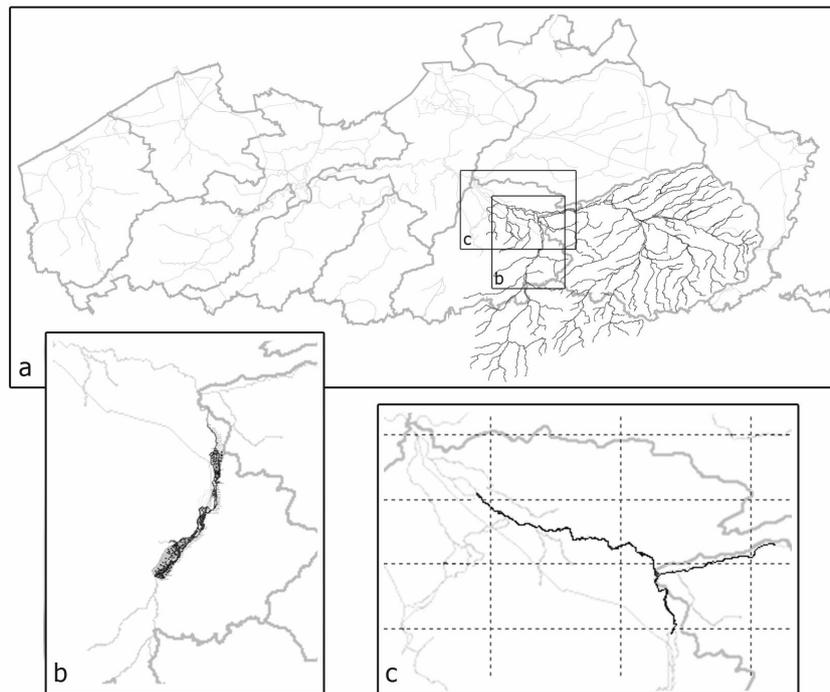


Figure 3. Geographic setting (top, a) and models used for use case C : PEGASE river quality model for Dijle and Demer (top, a), InfoWorks RS hydraulic river model for Dijle (left, b) and Mike11-HD hydraulic river model for Demer (right, c)

2.4 Use case D : linking 1D-river model to 2D-estuary models in the Dender sub-basin and main Scheldt basin.

The fourth and final use case describes the linking of a 1-dimensional hydraulic river model to a 2-dimensional estuary and coastal model. The first one is the model of the Flemish part of the river Dender basin (built by Flanders Hydraulics Research). In a later stage of the project it is hoped that this could be replaced by the full tidal Scheldt model. For the second one, two different options will be investigated: on the one hand the “Kustzuid” model, on the other hand the “Zeekennis” model (Figure 4).

“Kustzuid” is an operational model from the Dutch authority Rijkswaterstaat, built with the WAQUA software (currently maintained by Deltares). It covers the whole Scheldt estuary and a large part of the North Sea. For the purpose of the OpenMI-Life project it was extended to the confluence of the Dender and Scheldt rivers. “Zeekennis” is a morphology oriented model, built in Delft3D, covering a smaller area than “Kustzuid”.

Linking the 1- and 2-D models is expected to increase the accuracy of flood prediction (especially in a later phase when the Dender model would be replaced with the full 1D tidal Scheldt model), and to improve the forecasting of the accessibility for large vessels of the port of Antwerp.

As for use cases A and B, quantities exchanged are flow (from Dender model to estuary models) and water level (from estuary models to Dender model) in a bidirectional link. Special attention is required in this use case to the transformation of the quantities. Not only do the models have different dimensions (1D to 2D), but due to the different national altitude references, a linear conversion in the water level has to be applied as well.

Waqua and Delft3D were also not yet OpenMI-compliant at the start of the project. And as for use case B and C, this use case also deals with models from different suppliers.

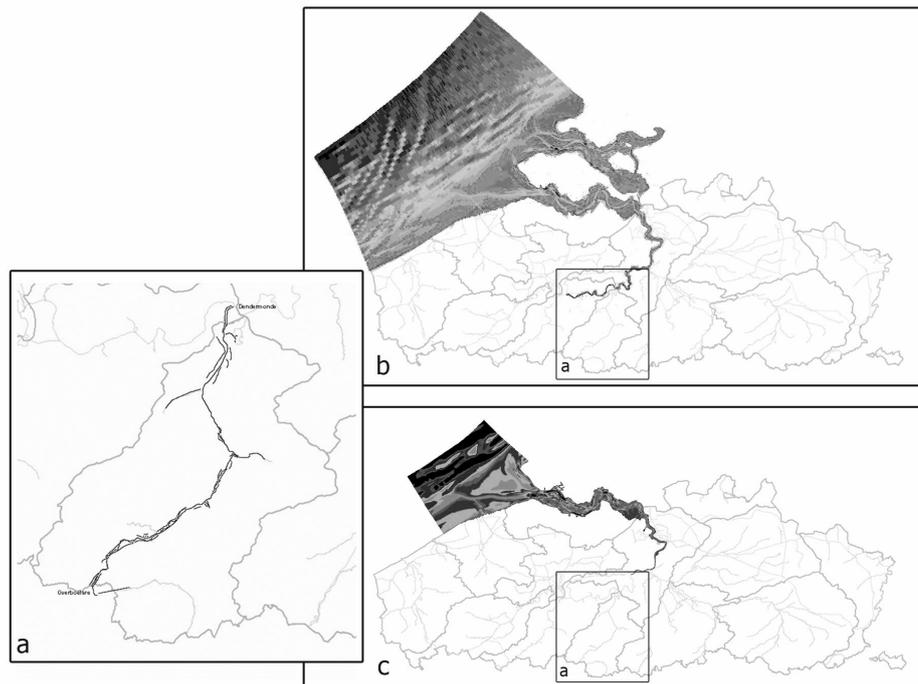


Figure 4. Geographic setting (top, b) and models used for use case D : Mike11-HD model for the Dender sub-basin (left, a), Waqua-model “Kustzuid” (top, b) and Delft3D model “Zeekennis” (right, c).

3. CURRENT PROGRESS

3.1 General

The timing of the OpenMI-Life project foresaw four major phases in the elaboration of the use cases :

- Definition phase describing the objectives, technical details and expected problems of each use case (October 2006 – March 2007)
- Trial phase, during which all aspects of the linking are being tested and problems identified and solved. This phase includes migration for those models that were not yet OpenMI-compliant (April 2007 – September 2008)
- Operational phase, during which the models will be run in linked mode on a full operational scale, i.e. performing all the types of simulations they would normally be used for in stand alone mode (October 2008 – March 2009)

- Evaluation phase. In this latest phase the use cases will evaluate the results of the operational phase (benefits compared to stand alone modelling, benefits in view of water management policy) (March 2009 – September 2009).

All use cases have produced a definition report, from which it appeared that the current version of the OpenMI standard was not a limiting factor with a view to the linking operations that were envisaged. In some cases however, there was a need for revising certain elements of the way OpenMI had been implemented in the then already compliant softwares.

3.2 Use case A

The linking of sewer and river model under normal conditions seems to work fine, even with many bidirectional links. The exchange of flows under flood conditions is currently still being tested. Other items that need resolving are the simulation of predefined series of events in linked mode, and further decisions need to be made about inconsistencies in rainfall used in both models.

None of these is expected to endanger the timing of the use case.

3.3 Use case B

Linking the upstream RS river model to the downstream Mike11 river model at a single exchange point proved to be very straightforward. In the near future it will be tested if linking at multiple exchange points is workable. Afterwards coupling at an overlapping set of exchange points will be tried out and it will be looked at how this can be applied to overlapping flooding areas.

3.4 Use case C

The main present technical achievement in this use case is the migration of the river quality model PEGASE from the UNIX environment into the Windows environment. The migration to make this model OpenMI compliant is ongoing. Several stand alone simulations have been performed with the river flow models InfoWorks RS and MIKE11 on the river Dijle in order to feed the PEGASE model after the links between the models have been defined. Appointments for defining the links have also been made.

3.5 Use case D

Waqua and Delft3D are now both OpenMI compliant. The river Dender model was coupled to the “Zeekennis” model and a correct data exchange between the two models was achieved. Due to the fact that the “Zeekennis” model was originally built for a smaller area not reaching Dendermonde, it would take too much time to extend and calibrate the “Zeekennis” model. But it was shown that the linking between the two models from a technical perspective worked correctly. The coupling between the river Dender model and “Kustzuid” is currently being tested.

The progress of the use case is in agreement with the foreseen planning.

4. FUTURE ISSUES

From the case studies, the largest concern about OpenMI is not its technical implementation, but its user-friendliness. If OpenMI based modelling is really to tear down the barriers for practical co-operation between authorities, then the use cases will

have to prove that it is possible to conceive, set up and run linked simulations with little more technical and organisational effort than what authorities are experiencing now in their normal modelling practice.

One of the key expectations that were raised by all partners involved in the use cases was the possibility of remote linking. Local linking means that all models have to run simultaneously on one machine and often requires additional licenses for software that would otherwise not be necessary. Creating links between models running at different locations and under each user's own licence, would improve the perception of complexity and practicability of integrated modelling. Although recent developments (Curn [2007]) seem promising, it cannot be guaranteed that all models will have implemented this option by the end of the operational phase.

Linked modelling will also introduce additional problems of quality assurance procedures. The risk of wrong sets of models being linked to one another is a real concern, and could lead to a deterioration of the quality of the calculations, which would be dramatic for the credibility of linked modelling.

All these issues will have to be carefully considered during the last phase of the project so as to produce a well funded evaluation of the use of OpenMI in integrated water management.

5. CONCLUSIONS

The first trials of the application of the OpenMI on real scale models in the Scheldt River Basin indicate that there is a clear potential for its use in integrated water management. So far there were no real technical obstacles that could not be handled with the current version of the OpenMI. Improved implementations for specific applications may be necessary however.

It is expected that the use cases will continue to make good progress and that operational simulations can be run at the time foreseen in the OpenMI-Life project schedule. At that time (end of 2009) it will become clear if the expected technical benefits of linked modelling and the improved way of co-operating between the different authorities will stimulate real integrated water management within Europe and beyond.

ACKNOWLEDGEMENTS

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