TRACING FLOWS ALONG THE RHINE

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Snow and glaciermelt: relevance for NL

Discharge at Lobith is during summer period already an issue for watermanagement in the Netherlands.

Due to climate change lower discharges can be expected (during a longer period).

Reduced summer discharge is causing problems for navigation, agriculture and energy production (limitation cooling water).

Basic questions:

- What is the actual contribution of snow and glacier melt in the (summer) discharge of the Rhine at Lobith?
- What reduction can be expected in the future?

Relevance for the Netherlands

We are concerned about the low flows.

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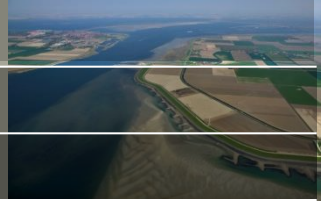
OpenTracers



To analyse the contribution of various sources to the discharge, Deltares developed “OpenTracers”.

OpenTracers is:

- a post-processing tool for hydrological / hydraulic models
- (previously known as “fractions”, used as pre-processing tool in water quality studies)
- (a water quality model for transport of conservative tracers)
- a tool to analyse the mixing of flows from various sources

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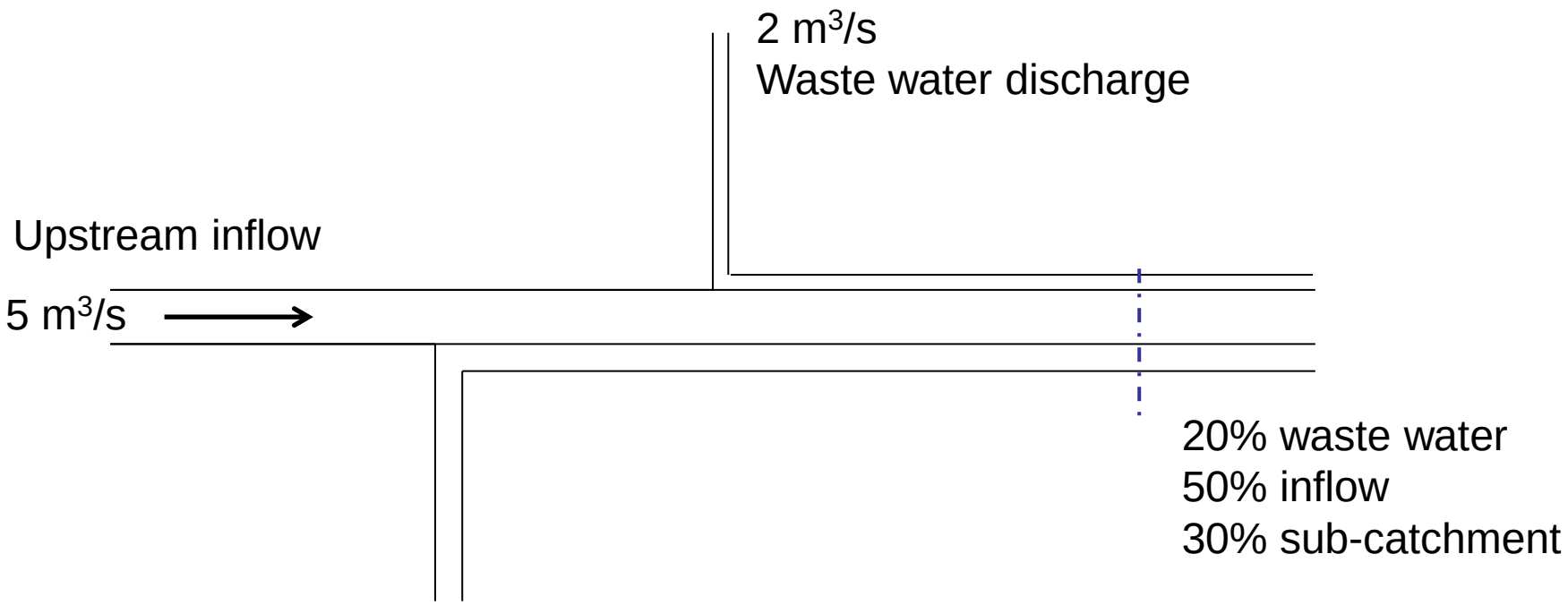
Concept of OpenTracers



In reality:

- time variation
- more boundaries / sources
- analysis along the entire river
- storage
- mixing

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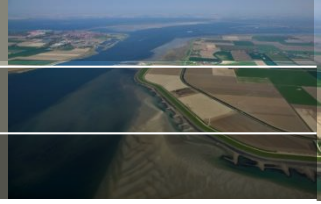
How does OpenTracers work?



A hydraulic model simulates flows, water levels in a study area.

An adapter reads the native output file of the hydrological model and transfers it into a ‘hyd-file’.

OpenTracers reads the hyd-file and creates an overview of the boundaries (sources) of the model.

At each boundary, a substance is introduced.

- the name of the substance = the name of the boundary
- the concentration of the substance = 1

OpenTracers (the water quality model) calculates transport, mixing and age of the various sources (substances).

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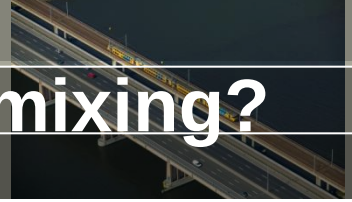
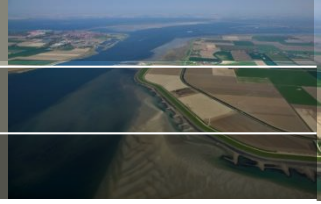
How deals OpenTracers with mixing?





Mixing and storage of sources is calculated using a water quality model.

OpenTracers provides various numerical integration schemes to handle (numerical) dispersion.

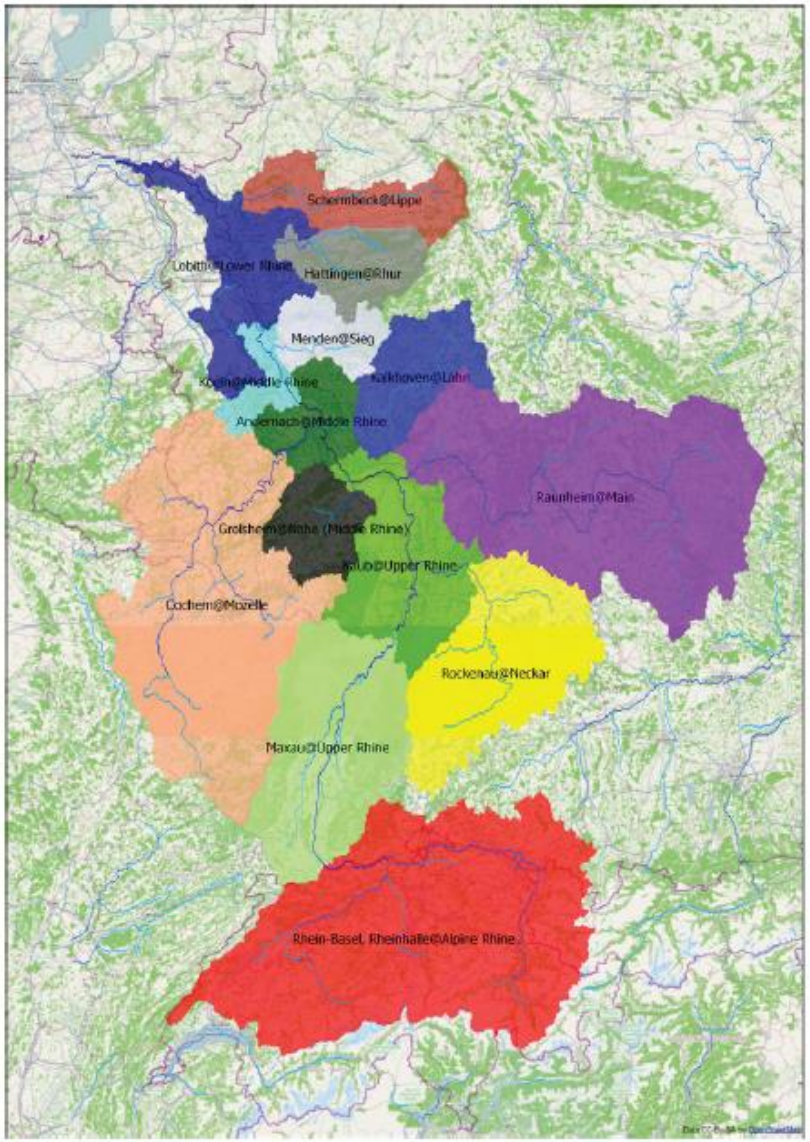
These 15 different integration schemes have been developed over the last 30 years in water quality modeling.

Storage in reservoirs (either lakes or groundwater or glaciers) is included.

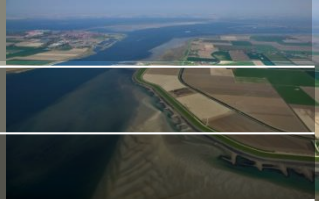
Example Rhine basin

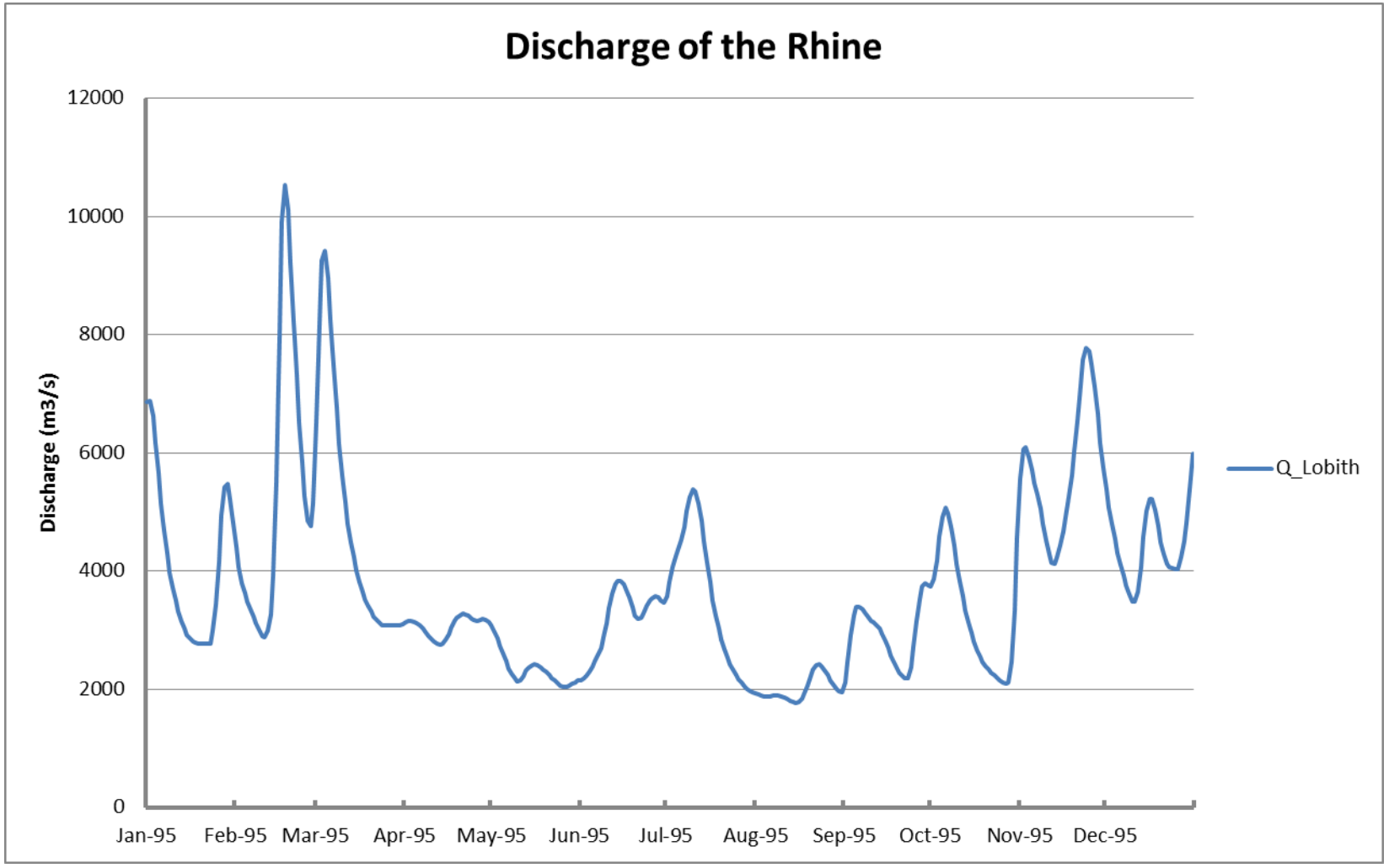
We used a WFLOW-model
“off the shelf” for the Rhine basin.

Only 1995 data were available
in this example.



Discharge at Lobith (1995)





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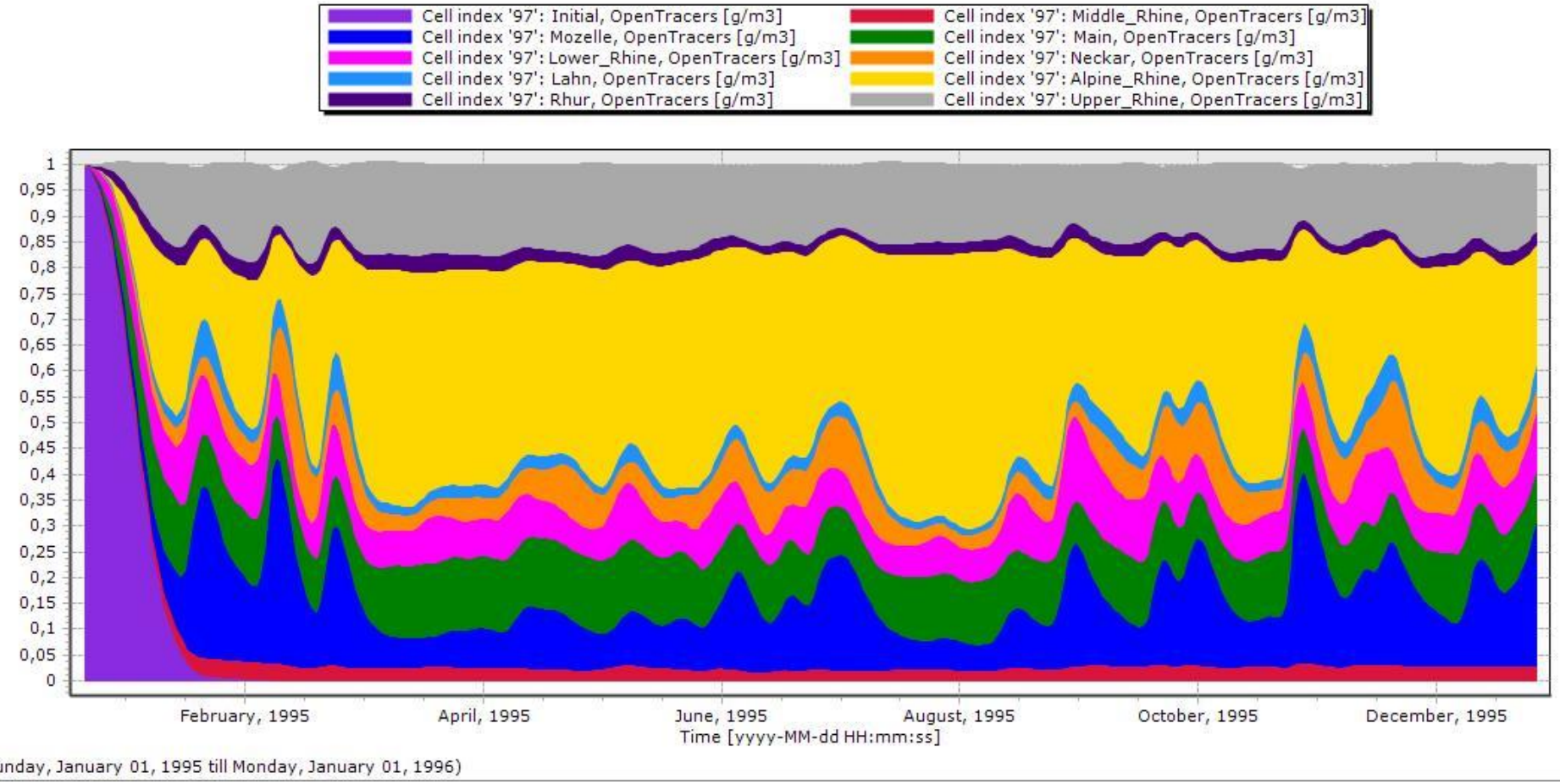
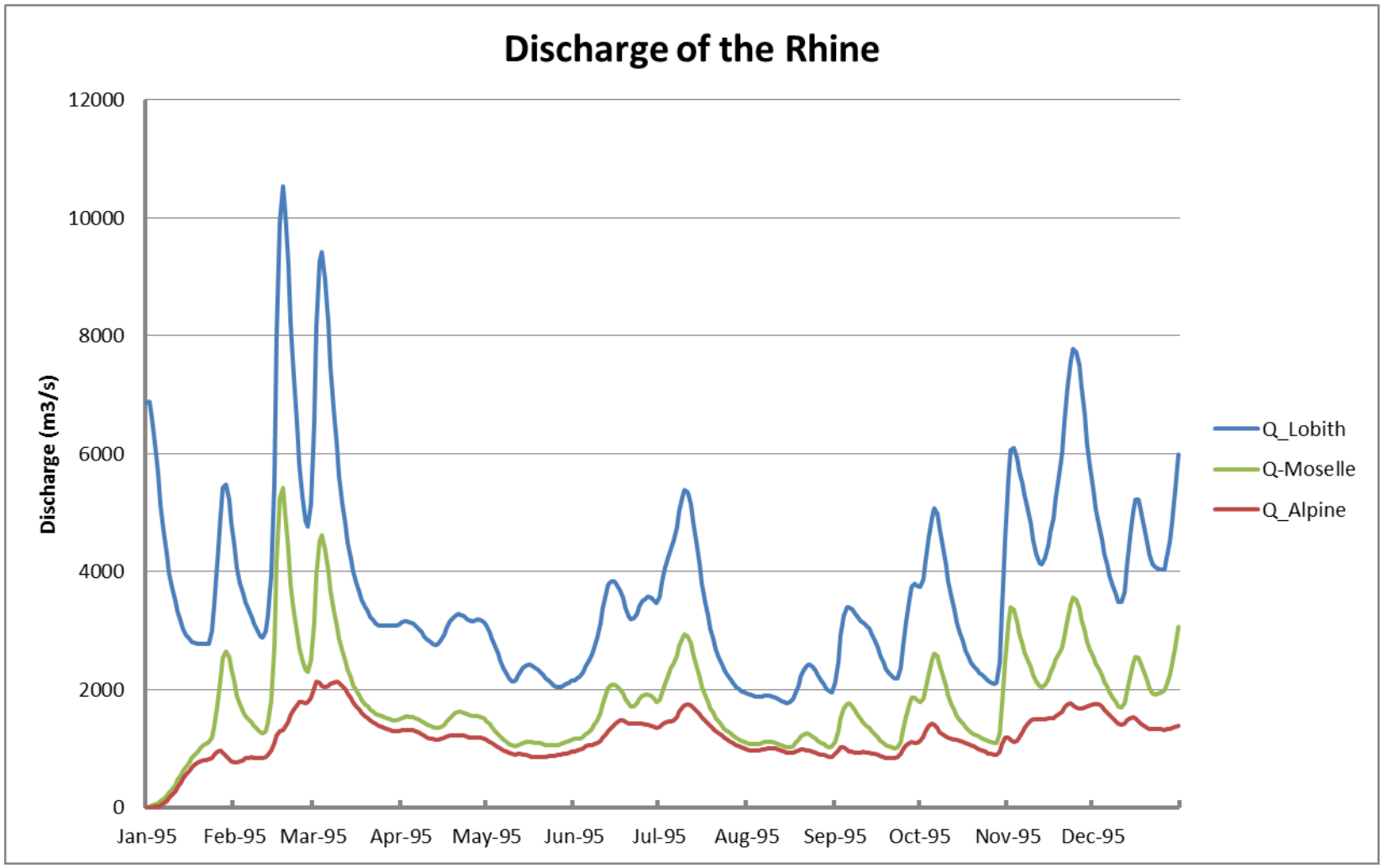
Contribution of various sources at Lobith



Contribution to discharge at Lobith



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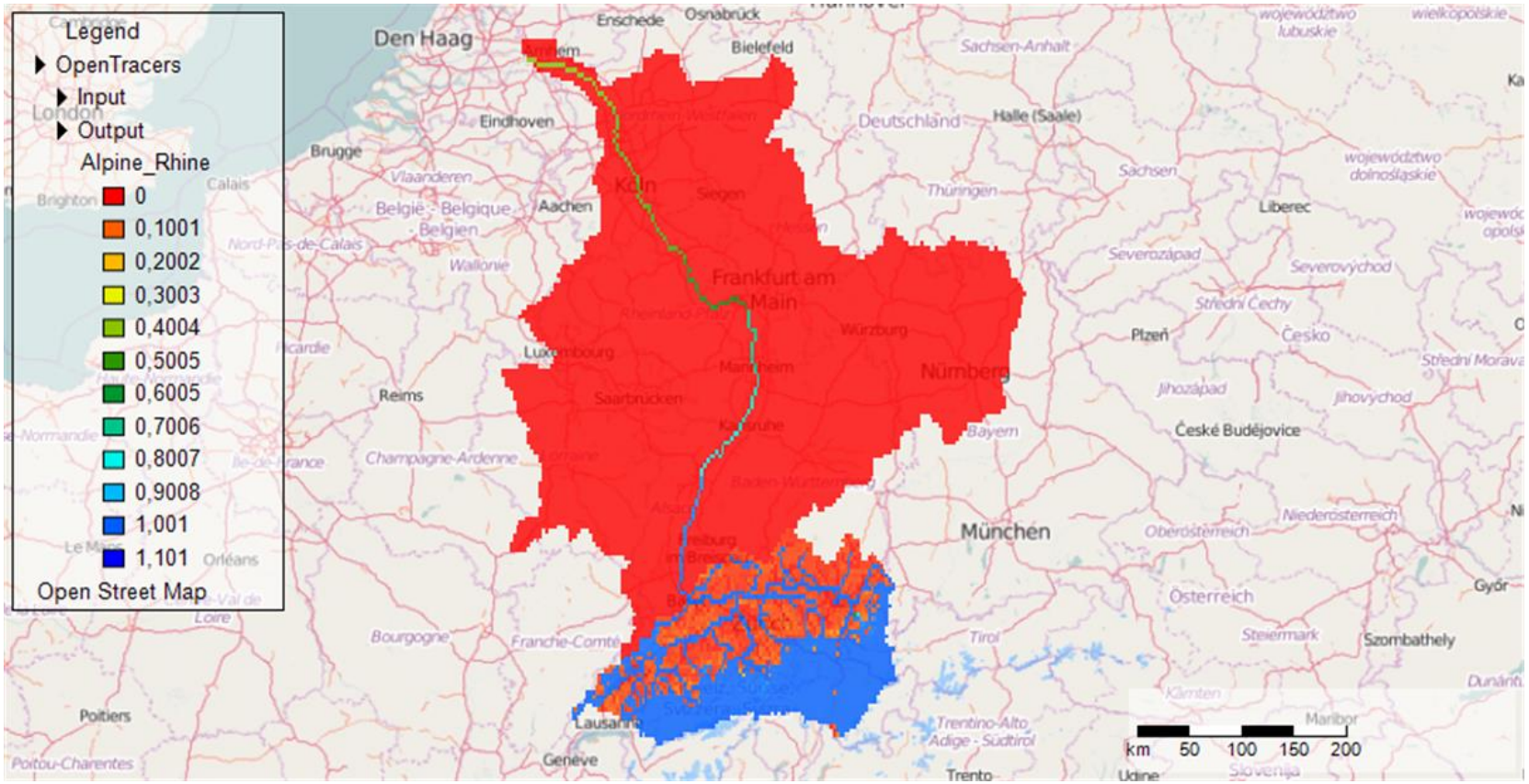
Example of source “Alpine_Rhine” in WFLOW



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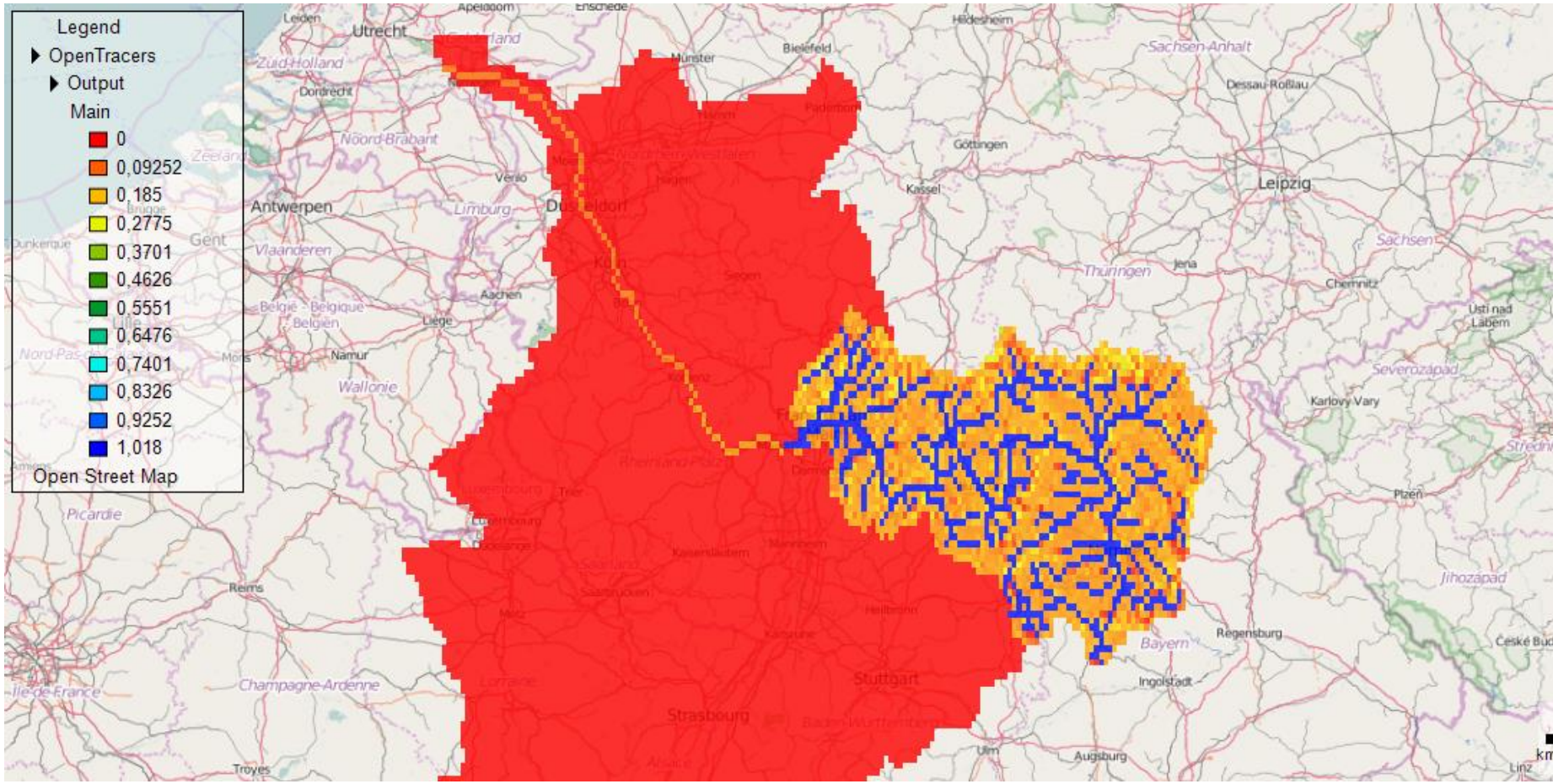
Example of source “Main” in WFLOW



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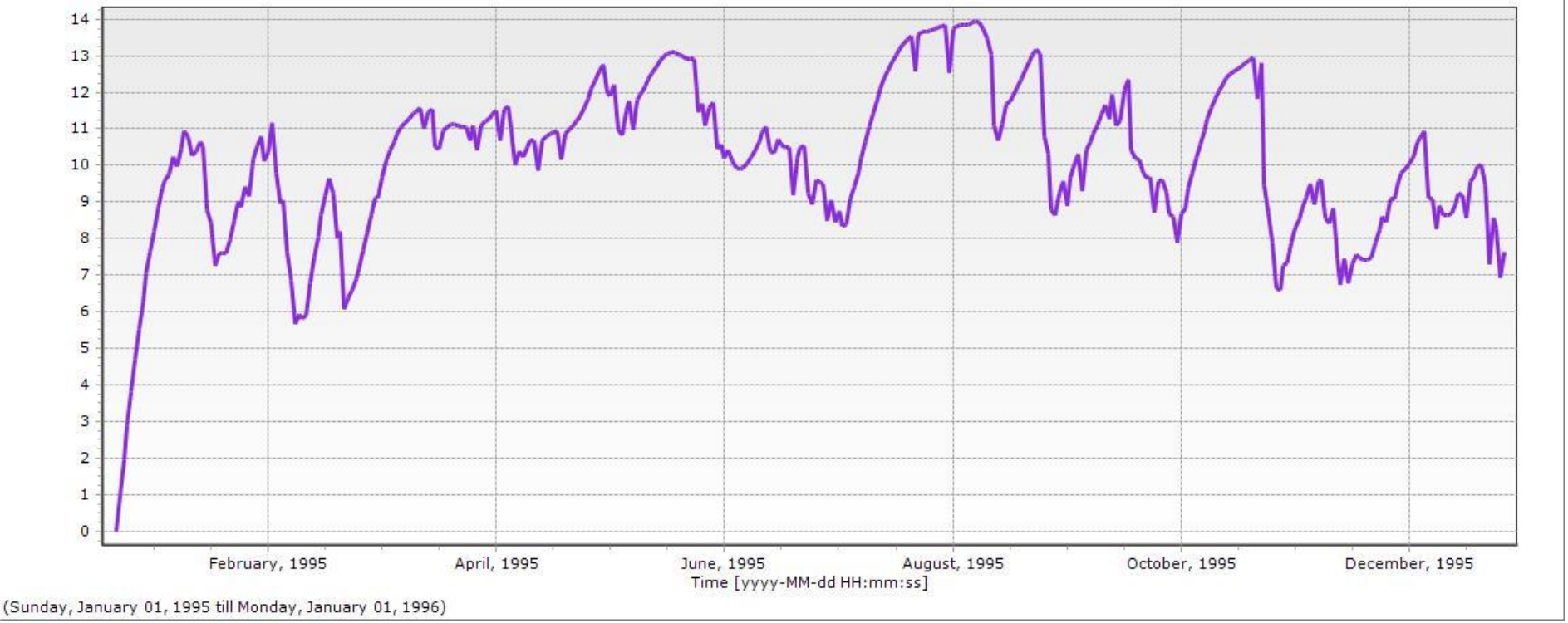
Calculation of the “age” of the water

Age of water at Lobith



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Second example (Western Scheldt estuary)

Start video

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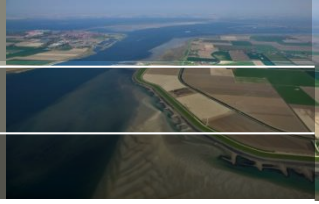
Software producing a hyd-file



Software	Producing *.hyd file
D3D-FLOW	Yes.
DFLOW-FM	Yes.
Sobek3	Yes.
WFLOW	Yes.
EHYPE	Yes. Developed in FP7 SOLUTIONS project.
RIBASIM, Sobek2	Partial. To be extended.
MODFLOW	Ambition
D-RTC	Ambition
3Di	Ambition
HECras, MIKE, HBV, LARSIM	Not yet, but can be implemented by model owners.

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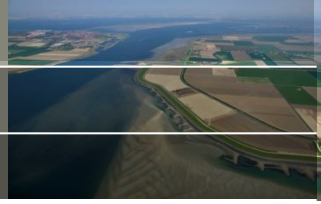
Concluding remarks



OpenTracers offers post-processing hydrological models, including the analyses of the sources of water, a water balance and the age of the water.

Calibration of hydrological models focusses on water levels and discharges. OpenTracers offers additional features for hydrologists.

Water quality models are using the results of hydrological models.

OpenTracers provides (partially) the pre-processing for water quality models, and facilitates the coupling between hydrology and water quality.

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