Deltares

RIBASIM

River Basin Planning and Management

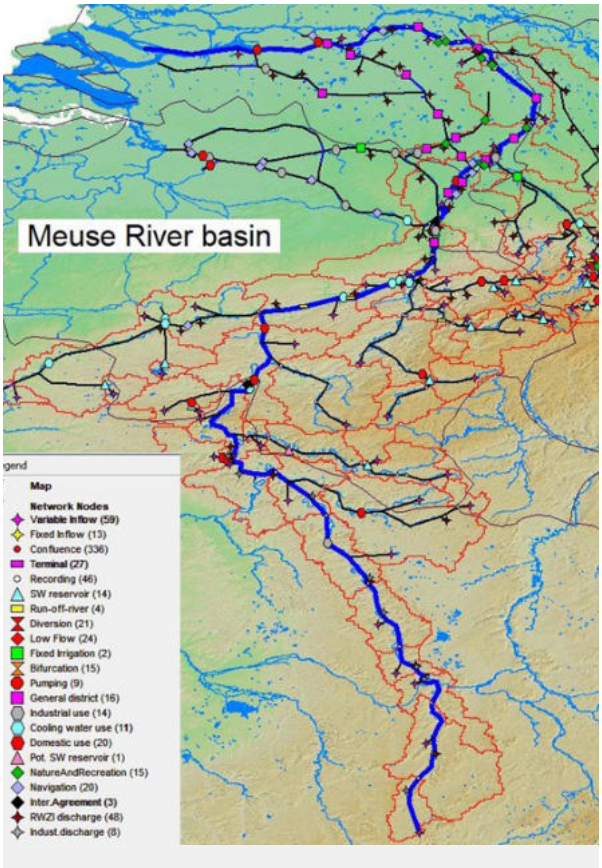
An integrated approach to the water system and its surroundings is the basis for long-term, sustainable management of the environment. Multi sector planning to allocate scarce resources at the river basin level is increasingly needed in the water sector, as water users and governmental agencies become more aware of the trade-offs between quantity, quality, ecology, costs and reliability. The RIBASIM (RIver BAsin SIMulation) software provides an effective tool to support the process of planning and resource analysis.

RIBASIM is a generic model package for simulating the behaviour of river basins under various hydrological, socio-economic, agriculture, climate variability and change and water quality scenarios. The model package is a compre hensive and flexible tool which links the spatial and temporal variation of hydrological water inputs with the water-user's requirements in the basin. RIBASIM enables the user to evaluate a variety of measures, strategies, development and adaptation pathways related to infrastructure, operational and demand management and to judge the results in terms of water quantity, water quality and water flow distribution and composition.

Since 1985, RIBASIM has been applied in many countries and it is used by a wide range of national and regional agencies, consultants and universities worldwide.

RIBASIM is a WINDOWS-based software package and includes the standard Deltares analysis tools to setup a decision support system.

Figure 1 RIBASIM network schematization of the Meuse River basin (France, Belgium, Luxembourg, Germany, Netherlands).



Keywords: water balance, surface water, groundwater, integrated water resource planning and management, socio-hydrology, eco-hydrology, water security, water energy food nexus, drought, water scarcity, simulation, stochastic, water demand, water allocation, water distribution and transfer, irrigation, crop yield, water infrastructure, environment, environmental flow, domestic, municipal and industrial water use, hydropower, energy production, reservoir management, reservoir operation, hydrologic flow routing, water quality, flow composition, fraction simulation, socio-economic, agriculture, climate change and variability, scenario's, measures, strategies, adaptation pathways, development pathways, collaborative modelling,

Open structure and flexibility

The structure of RIBASIM is based on an integrated framework with a user-friendly map-based user interface. This framework is built using the standard general applicable Deltares tools to set-up decision support systems. Functions provided by the tools include the following interactive components:

- design of the river basin network from a map of the basin,
- data entry with nested tables
- set-up of an object-oriented river basin data base,
- presentation and animation of results on maps,
- case management, and
- analysis of time series results.

It is also possible to run RIBASIM outside the standard user interface in a self-designed setup, usually based on batch files or Python scripts. The completion of a simulation case consists of the execution of several software components in sequence. This procedure can be useful if many simulations must be carried out and/or the advanced user wants to have individual flexibility in automatic data pre- and processing.

Typical RIBASIM applications

RIBASIM can be used to evaluate the limits on resources and/or the potential for development in a region or basin. Typical questions that can be answered with RIBASIM are:

- Given the available water resources and their natural variations, to what extent can a river basin be developed in terms of water storage reservoirs, irrigation schemes, water supply systems, while avoiding unacceptable shortages for users?
- What is the safe operating space of the basin within environmental limits under normal conditions? And how does the basin perform under hydroclimatic extremes and drought in a stress test?
- When and where will conflicts between water users occur?
- What is the effect of human interaction on the hydrological cycle (socio-hydrology) for the performance of the basin?
- Which combination of infrastructure and operational management will provide an optimum use of the available resources?
- What is the complex and dynamic interrelationships between water, energy and food and how can we use and manage its limited resources sustainably (Water Energy Food Nexus)?

RIBASIM can also evaluate measures to improve the water supply or water quality situation. Additionally, the implementation of the measures can be scheduled over time, representing a development and adaptation pathway. A few examples of these measures are:

- Measures concerning changes in the infrastructure;
- Operational management choices of water allocation and/or water sector infrastructure;
- Sector-specific demand management options;
- Measures which are activated if a specific site condition occurs.

RIBASIM facilitates quick water quality analysis by evaluation of the origin of water for every location in the river basin. The effect of the measures on the distribution of water from the various sources in the basin is calculated (influence area of a source of water) without the necessity of having available information about waste loads, waste water discharges and water quality of (upstream) sources.

RIBASIM provides the means to prepare a system water balance with the level of detail corresponding with the requirements of the study, either basin, regional or transboundary scale, taking for example into account re-use of water by different sectors. The comprehensive set of results parameters can be used directly for policy development studies, such as River basin management plans, Integrated Drought Management plans, Water Energy Food Nexus assessments, Climate Change vulnerability and impact assessments, or indirectly as an input for sector specific overviews of water demand and use patterns in combination with climate change scenarios.

Additional applications of RIBASIM include:

- supporting tool in collaborative modelling setting to increase stakeholder participation and incorporate locale knowledge and information in schematization and model data input.
- generate flow patterns which provide a basis for detailed water quality and sedimentation analyses in river reaches and reservoirs
- function as the water allocation component in a Drought Early Warning System (based on the Delft FEWS software)
- provide insight in transboundary water allocation conflicts
- detailed, comprehensive integrated system modelling, by easy connection of RIBASIM to other software packages, being part of a larger model suite and run in a workflow (e.g. Deltares software package like wflow for hydrology and sediment, Delwaq for water quality, iMod for groundwater, FIAT for floods and drought impact, etc. or any other package)

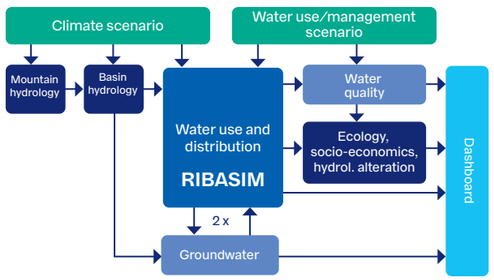


Figure 2 Schematic of the integrated system models in the Ganga Water Information System (India)

Structure of the analysis

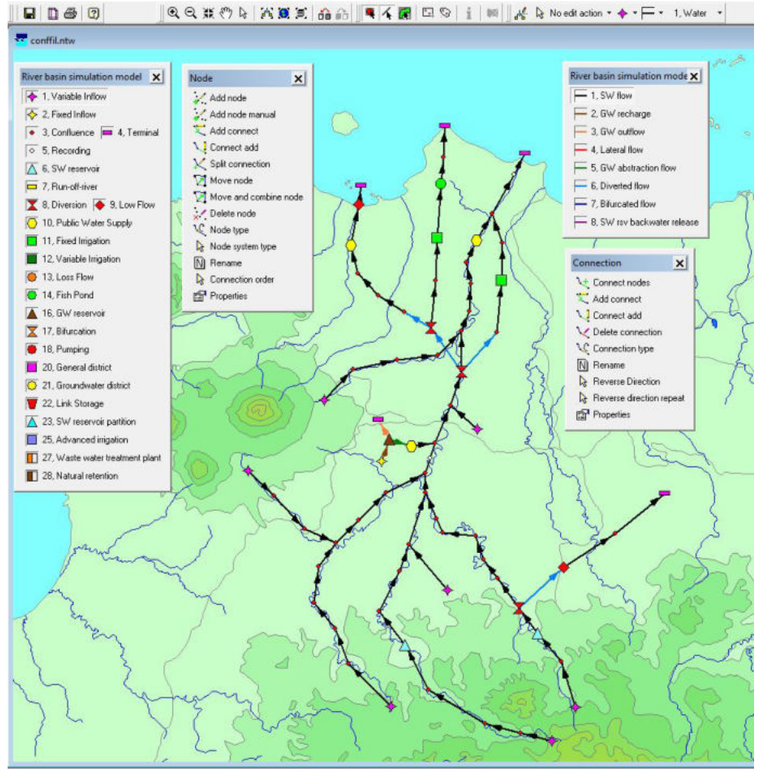
The main RIBASIM user interface is presented as a flow diagram of colour changing blocks representing the consecutive tasks to be carried-out to complete the simulation process. The interface guides the user through the analysis from data entry to the evaluation of results. The user can save the session at any time and continue at a later stage exactly at the last completed step. The results of various simulation cases can be analysed together without the need to access the underlying file and directory structures. The interface has an open structure which makes it possible to add or remove blocks from the flow diagram and to adapt the interface to project requirements.

Figures 3 Structure of the analysis by a flow diagram of task blocks.

Interactive schematization of the river basin

RIBASIM enables a schematization of the river basin to be prepared interactively from a map via a network of nodes connected by links. The nodes represent reservoirs, dams, weirs, pumps, hydro-power stations, water users, inflows, man-made and natural bifurcations, intake structures, natural lakes, swamps, wetlands, etc. The links transport water between the different nodes. SSuch a network represents all basin's features which are significant for its water balance and it can be adjusted to provide the exact level of detail required, to enable schematization of small and simple and large and complex river basins. The river basin is presented as a map with the network schematization superimposed as a separate map layer. The background map can be produced by any Geographical Information System.

The attribute data of the network elements are entered and linked to the map of the river basin and its network schematization. Where applicable data entrance is supported by automatic routines for easy set-up, leveraging open global datasets that are available. Within the same user interface, data consistency tests are done.



Figures 4 Interactive design of network schematization for Ciujung River basin (Indonesia).

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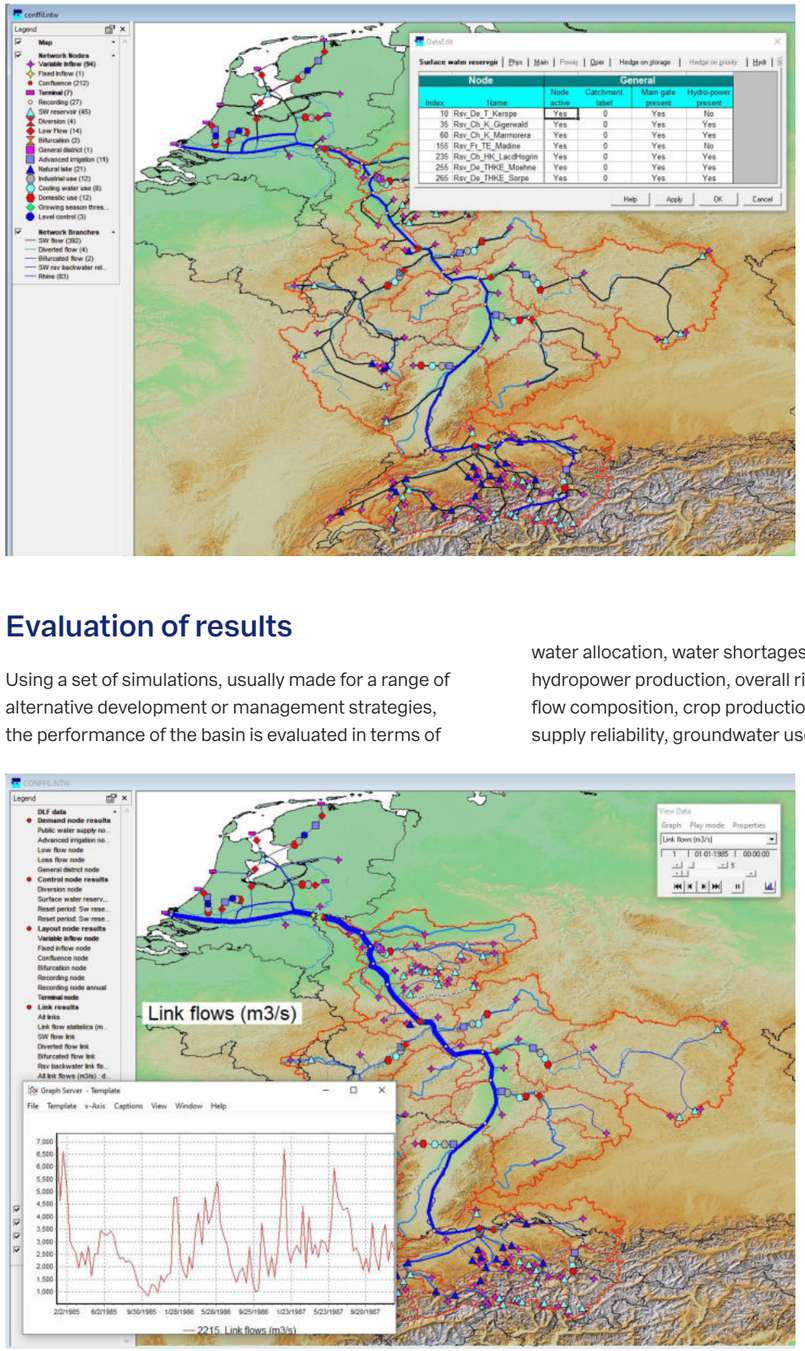
River basin simulation

Simulations are usually made over long time series (multiple years) to include the occurrence of dry and wet periods. The simulation time step is defined by the user, for example monthly or 10-daily, but the computation can also be done daily. Within each time step, the water demand is determined, resulting in targets for water releases from reservoirs, aquifers, lakes, weirs and pumping stations. Then, the water is allocated to the users according to the release targets, water availability, operation rules and water allocation priorities.

Water allocation to users can be done in several ways. At its simplest, water is allocated on a "first come, first served" basis along the natural flow direction. Other ways are the allocation with priority to particular users and an allocation proportional to the demand.



Figures 5 Spreadsheet based interactive entry of reservoir data for Rhine River basin model (Swiss, Italy, Liechtenstein, Germany, France, Luxembourg, Belgium, Netherlands).

Evaluation of results

Using a set of simulations, usually made for a range of alternative development or management strategies, the performance of the basin is evaluated in terms of water allocation, water shortages, firm and secondary hydropower production, overall river basin water balance, flow composition, crop production, flood control, water supply reliability, groundwater use, etc.

Figures 6 The flow in Rhine River basin (West Europe) is visualised by blue coloured width of the links for the selected time step and in the graph over the whole simulation period.

The user can select how the output data is shown: graphs, thematic maps, tables, spreadsheet or reports. A wide range of functions are available to provide insight into the behaviour of large and complex river basins, like an animation of the basin in which flow is indicated with arrows and the size of the flow is shown in different colours and/or line thickness. Similarly, other output parameters can be shown. By clicking the item on the map and then selecting the desired output parameter, time graphs can be presented. Moreover, all output data can be exported into other formats.

Features

1. RIBASIM considers all stakeholders (water users) and water using activities in a basin. These include (irrigated) agriculture, fresh and brackish water aquaculture, domestic supply, municipal supply, industrial water supply, wetlands, livestock, navigation, recreation, ecology and environment, water rights, inter-basin transfers, groundwater recharge, river ice, hydro-power generation. Detailed features for water demand and allocation computation are included for the irrigated agriculture, domestic, municipal and industrial water, environmental flow and wetland.
2. RIBASIM has an integrated agriculture component that assesses water demand, water allocation, crop yield and production costs based on crop and soil characteristics, crop plan, irrigation and agriculture practise, expected and actual rainfall, reference evapotranspiration, seepage, actual field water balance, potential crop yield and unit costs.
3. RIBASIM has a map-based user interface for interactive designing the river basin network but also for crop cultivation planning.
4. RIBASIM contains a comprehensive reservoir operation simulation component used to model single and multi-purpose reservoirs, lakes and storage basins. The reservoir can be configured with main gate, spillway and any number of head sluices with or without hydro-power station and turbine gate. The operation of the reservoir is done using rule curves for flood control, maximum energy production, firm storage, zoning of the reservoir storage and hedging (water rationing) of target releases. Time and site conditional operation rules, and rules for multiple reservoirs in series and/or parallel can be defined. Firm energy demand per time step can be set.

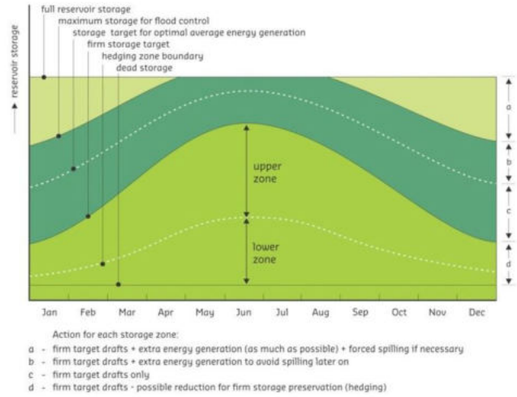
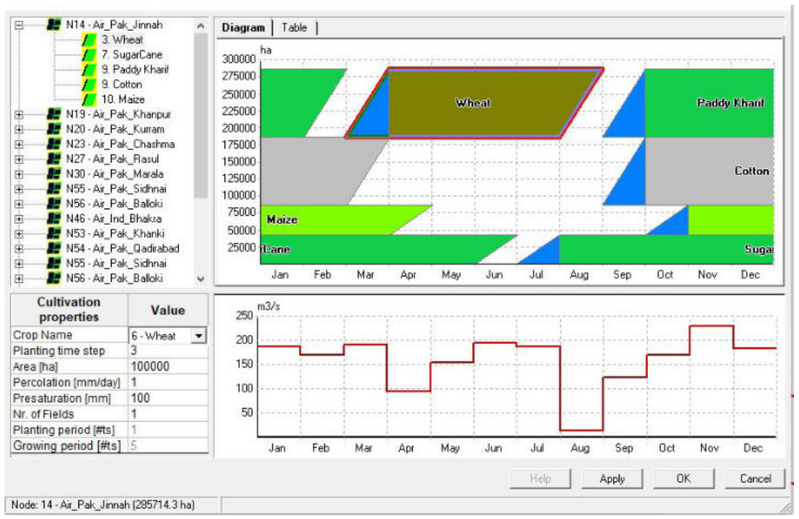


Figure 8 Annual reservoir operation rules and associated actions.

5. RIBASIM contains a groundwater simulation component and computes the aquifer water balance. Groundwater is used as a separate source for various users with its own characteristics like pumping capacities and water management. Conjunctive use of surface (river and reservoir) and groundwater can be modelled. >>



Figures 7 Interactive graphical design tool of a crop plan for irrigation area in Indus River basin (Pakistan, India)."

6. RIBASIM can be used to model optimized water management with various parameters like water allocation priority per individual user, source priority (preference) per individual user, operation rules for individual reservoirs and groups of reservoirs, groundwater management rules, proportional water allocation and re-use of drainage water.

7. RIBASIM supports a default and user-defined source analysis (flow water composition, fraction simulation) that provides insight in the water's origin and residence time at any location of the basin and at any time within the simulation period. This analysis can be used as a quick water quality assessment.

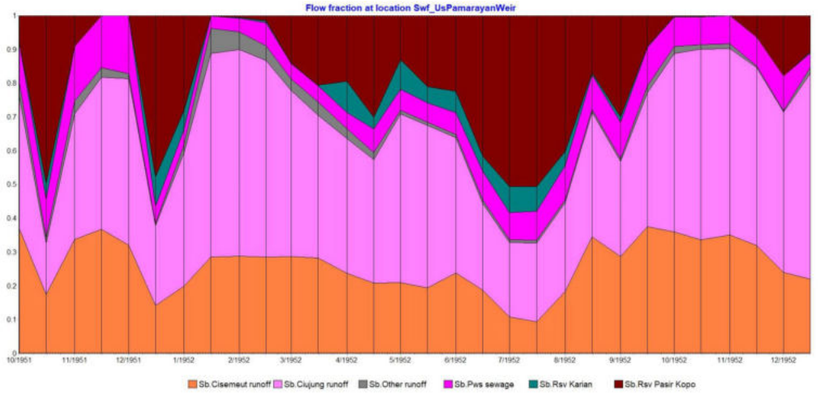


Figure 9 The composition of the flow over 3-year period in term of the water's origin at a downstream location in the Ciujung River basin, Indonesia.

Figure 10 The composition of the water in the Massira reservoir in the Oum Er Rbia River basin (Morocco) over 10-year period and the residence time of the water.

8. RIBASIM accepts basically any time step size. However, most basin simulations are executed on monthly, half monthly, 10 days (decade), week or daily basis. The selected simulation time is such that mass equations are used for the routing of the water thru the network. In situations that this is not valid, other hydrologic channel and reservoir routing procedures are available, such as Manning formula, flow - water level relation, 2-layered multi-segmented Muskingum formula, Puls method and Laurenson non-linear "lag and route" method.

9. RIBASIM supports basic water quality modelling and detailed modelling of biological and chemical processes using the standard Delft water quality model Delwaq.

10. RIBASIM can easily be linked to the Deltares software for the modelling of distributed rainfall-runoff (Wflow), groundwater flow (Modflow and SEAWAT), water quality processes (Delwaq), ecological knowledge rules (WFD Explorer - Water Framework Directive), operational management of structures (RTC tools), reservoir sedimentation (RibSERES) and hydro-dynamic models (Delft3D suite). Linkages to other model software packages are also possible.

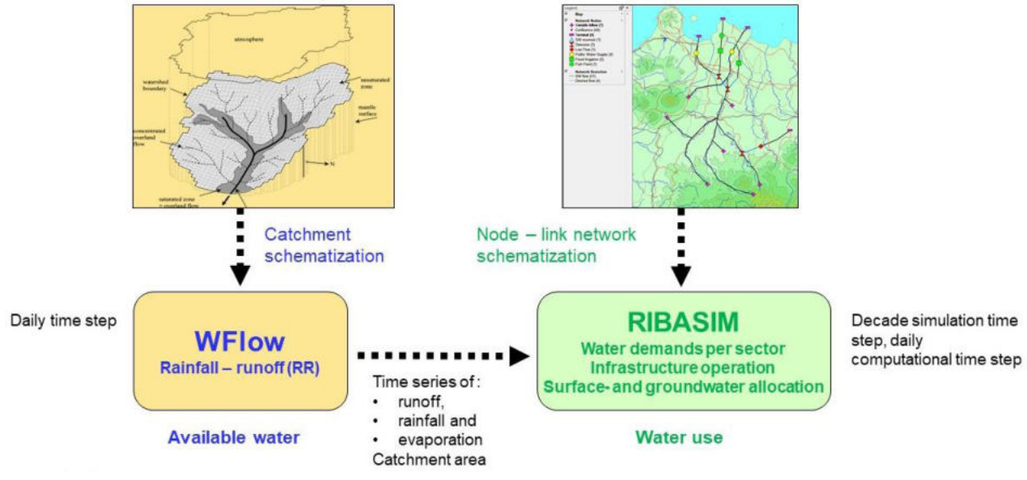


Figure 11 Link between Deltares rainfall-runoff model Wflow and RIBASIM.

11. RIBASIM can be incorporated in the operational framework Delft FEWS / DEWS (Flood and Drought Early warning System).

12. RIBASIM can be linked to land-use and spatial planning models for water resources, for example the Java Spatial Model via the land-use and population (socio-economic) scenarios.

13. RIBASIM facilitates the analysis of adaptation and development pathways which consist of a sequence of actions or measures over time and is modelled by measures to be activated after some years. This method fits well the IWRM planning process as outlined in the framework for analysis.

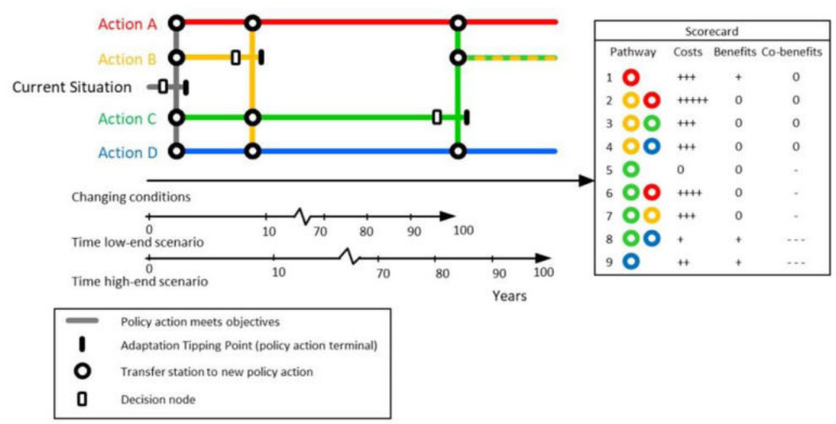


Figure 12 Example representation of adaptation pathway consisting of a variety of actions or measures over time.

14. RIBASIM supports stochastic simulation by resetting the initial settings after several simulation years and is applied for example to determine the best reservoir filling and operation strategy with one synthetically generated hydrological time series. The hydrological input time series are split into a set of shorter time series. The results are an ensemble of reservoir level and releases time series.

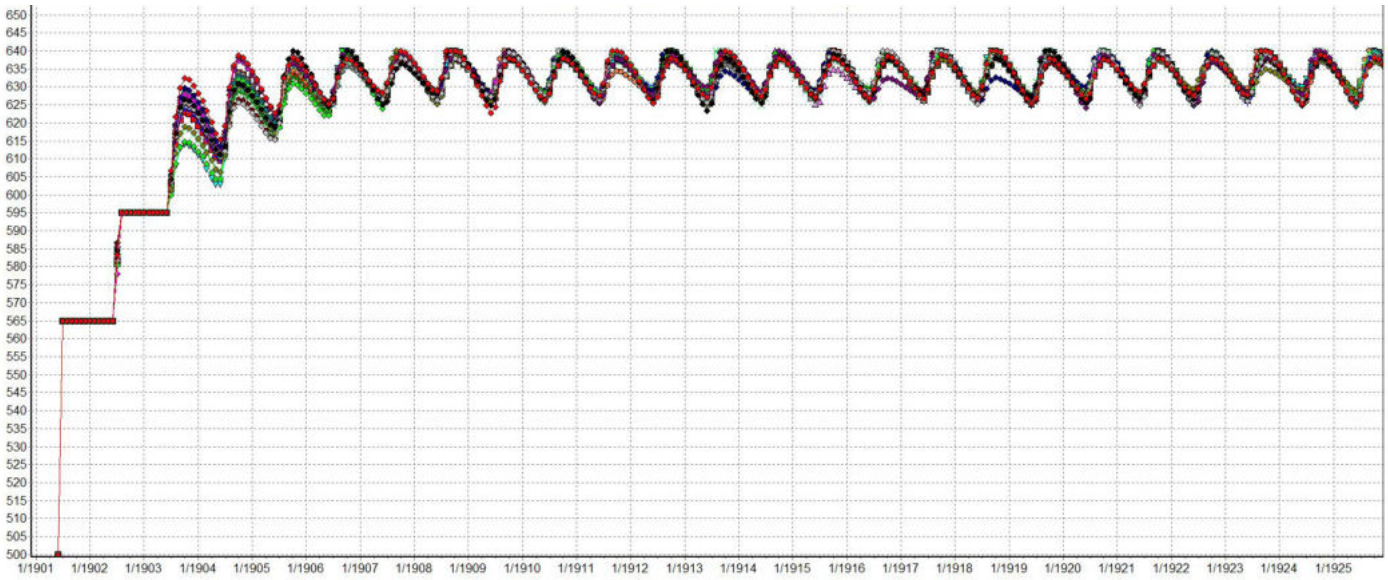


Figure 13. Ensemble of reservoir levels over a 25-year period for a number of hydrological inputs starting from the same initial level to analyse the best filling strategies.

System requirements

The RIBASIM interface is based on MS Windows. RIBASIM does not require specific hardware or any software from third parties. All you need is a standard pc or laptop with MS Windows.

More info:
ribasim.info@deltares.nl