

WaterWare Release 6.0:

A web-based, distributed basin scale water resources management information and multi-criteria decision support system for integrated water resources planning and operational control

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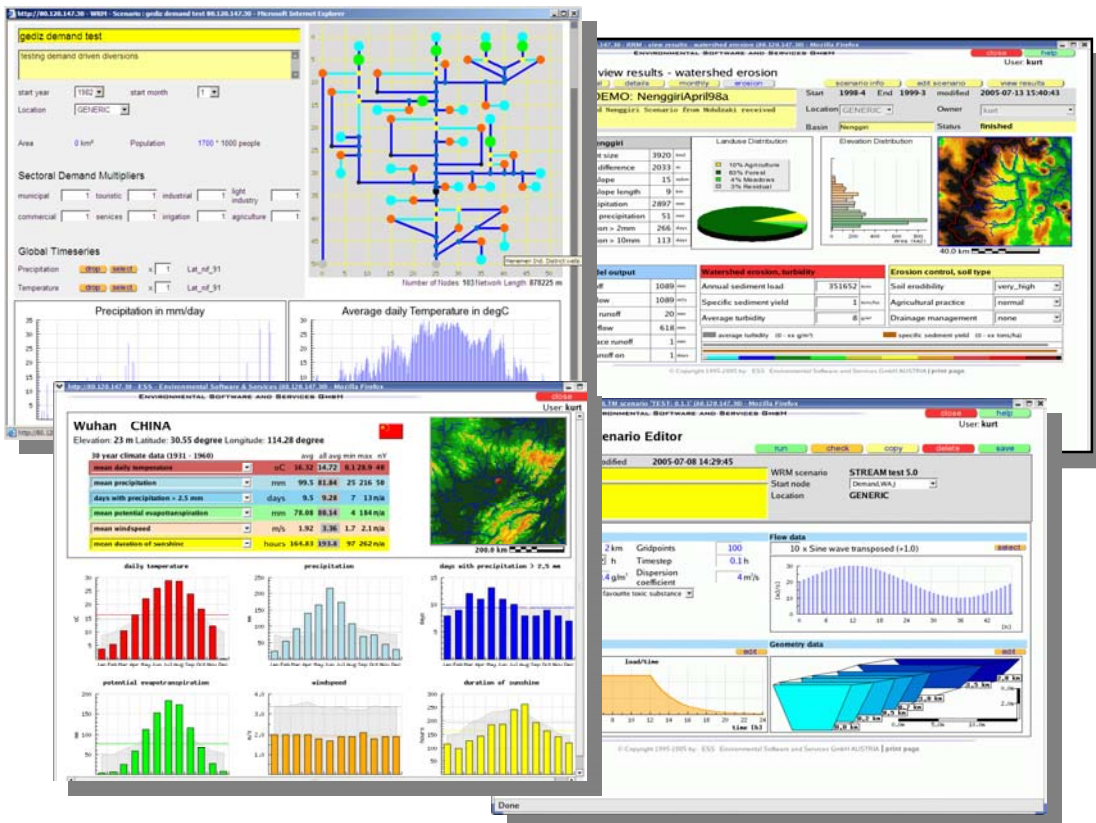
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Basic Functionality

WaterWare integrates a set of tool and models within one consistent and easy to use framework. The major components include:

- Data base management for all components of a river basin including monitoring time series. This also includes support for real-time (SCADA) data, and a range of data analysis tools;
- Embedded GIS functionality
- A set of dynamic simulation and optimization models, the base system includes:
 - A dynamic (hourly or daily time step) water resources model, including conjunctive use, with aggregate performance statistics and economic assessment (CBA),
 - A dynamic rainfall-runoff model including soil erosion and turbidity estimates for ungaged sub-catchments, providing input to the water resources model;
 - An irrigation water demand model, providing input to the water resources model
 - A basin-wide water quality model with economic assessment, linked to the hydraulic results of the water resources model.
- Optional components include:
 - Meteorological forecasts, 3D nested grid dynamic non-hydrostatic (prognostic) models with hourly resolution
 - Automatic calibration for the rainfall-runoff model
 - Multi-criteria optimization component for the water resources model, satisficing approach for supply demand, reliability, and node specific supply;
 - A waste-load allocation and optimization including in-stream benefits of recreational use for the water quality model;
 - A near-field water quality model for accidental spills
 - A 2D groundwater flow and transport model
 - A dynamic land-use change model
 - A rule-based expert system for screening level EIA tasks.
 - A real-time forward chaining expert system framework for operational control applications
- A set of management tools for data import, configuration, user management, etc.
- User support tools (CRM) including web-based problem reporting and tracing;
- On-line user manuals and tutorials including an optional distance learning environment.

These basic tools can be configured for a range of specific tasks and applications including scenario analysis, water allocation optimization, water quality management and waste load allocation, flood forecasting, and the operational control (optimization) of water resources systems.

WaterWare is offered with a complete support package that includes problem analysis, system configuration and customization, data acquisition and import, application building, training, user support, and continuing maintenance and update of the system in close cooperation with the client.

Modes of operation

The WaterWare system can be used

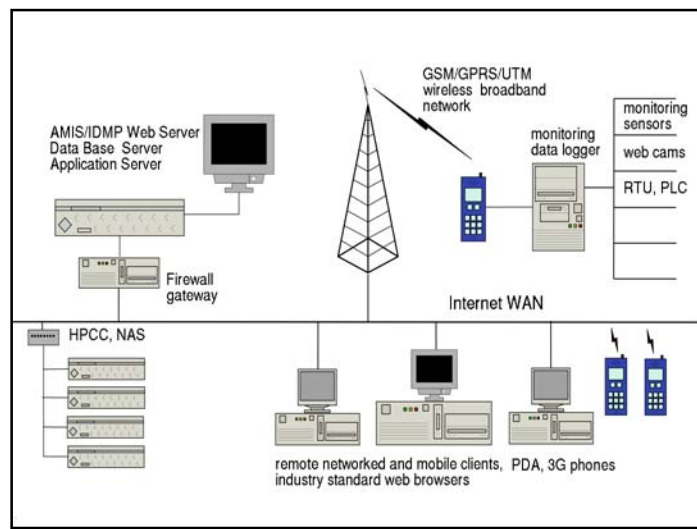
- Interactively for scenario analysis, including model calibration, sensitivity analysis, and direct scenario comparison;
- Automatically for continuous monitoring and modeling, now-casting, and scheduled forecasting, and operational control (real-time optimization) within a real-time expert system IC3 framework;
- Automatically for event based operation triggered by user defined external events (monitoring sensors, remote sensing data) e.g., for operational flood forecasting

and any combination of modes as required by a particular application.

Technical implementation

WaterWare Release 6.0 is a fully web based client-server implementation. Model and data bases are located at a central server, user access the system locally or remotely through LAN or Internet with a standard web browser as the only client side tool required.

The main WaterWare servers and clients can be located anywhere on the web, on one single machine or a cluster of servers, within an end-user institution facilitating access through the institutional Intranet but also for distributed, remote departments, field offices and users, or with an external Application Service Provider (ASP) that also provides auxiliary services such as data compilation, processing, system configuration, model calibration, data base maintenance and data backup, etc.



Initial configuration and continuing support will be implemented at dedicated high performance servers and a compute cluster at ESS, accessible via a dedicated private (leased) Ether line with 8 Mb bandwidth, accessible unrestricted 7/24.

Please note that all WaterWare components are fully compatible, share and exchange data through common data bases, formats and protocols, and can be configured to address a large number of specific tasks and questions for integrated river basin and water resources management from operational control to long-term strategic planning

The River Basin Data Base

All WaterWare functions and tools share a common object data base. The data base is organized by OBJECT CLASSES, which include All the elements (nodes and reaches) of the simulation models.

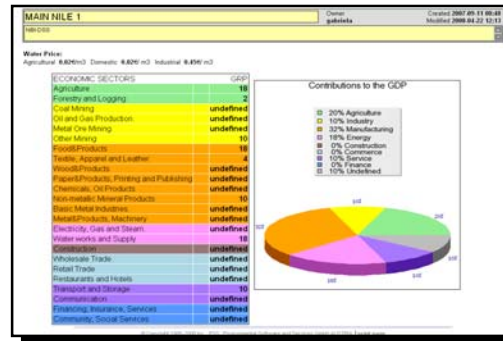
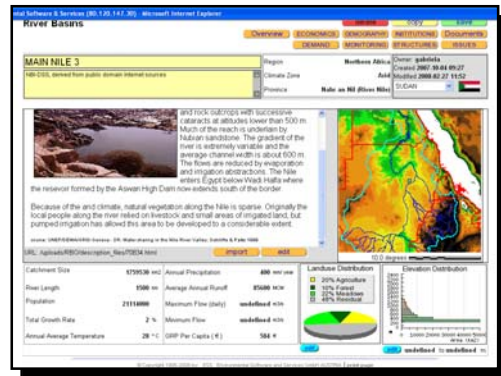
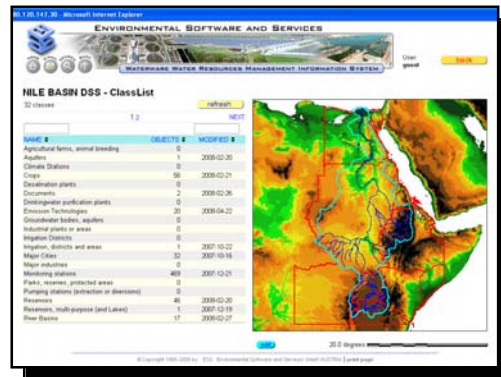
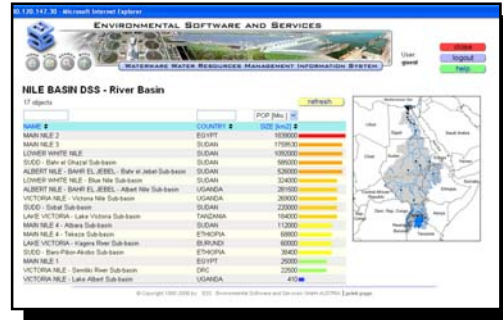
Basic object classes include:

- Watersheds and sub-basins or catchments down to hydraulic response units (HRU), including lateral catchments
- Monitoring stations and associated hydro-meteorological time series
- Structures (e.g., reservoirs including hydropower, weirs, well fields)
- Settlements, farms, irrigation districts, industries (both water users and sources of pollution)
- Treatment plants (waste water and water supply)
- Desalination plants
- Network components: river reaches (channels, pipelines)
- Crops
- Water technologies (techno economic data)
- Model scenarios.

All object data are geo-referenced, descriptions include

- a basic standard set of META data,
- type specific parameter sets
- multi-media descriptions

Data from the data base can be directly imported for model scenarios, providing default parameters for model components, and model results can be mapped onto the embedded GIS through the geo-referenced objects.



Meteorological modelling

WaterWare can include prognostic, 3D non-hydrostatic, nested grid meteorological forecasting models (WRF, MM5) that provide hydro-meteorological inputs for all dynamic water budget calculations.

These numerical weather forecast models can provide

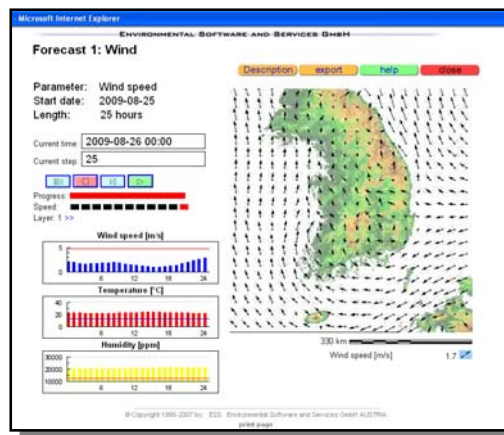
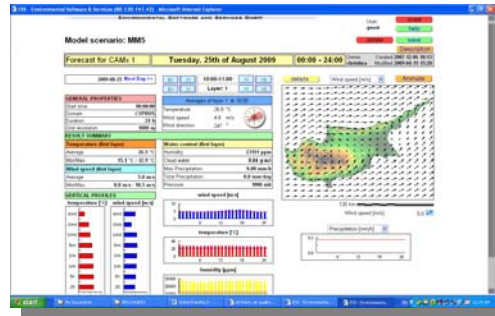
- daily operational forecast, hourly resolution, up to 10 days, based on dynamic downscaling of global (GFS) numerical weather forecasts;
- operational forecasts, but using ensembles of model runs to generate stochastic forecasts
- seasonal forecast (based on NCEP model runs)
- generation of historical time series of high resolution (1 km, hourly) and complete spatial coverage (dynamic downscaling of 6-hourly re-analysis of global meteorological data).

In WaterWare, meteorological input data drive components such as

- Rainfall-runoff modelling
- Flood forecasting
- Drought forecasting and management
- IWD irrigation water demand model
- WRM water resources model

Meteorological output is provided as

- 3D dynamic data fields, raster and associated statistics tables;
- Data exported as time-series to the available (or hypothetical user defined) monitoring station
- Animations (mpeg files).



The Water Resources Model

WRM, the dynamic (hourly or daily time step) water allocation and budget model is the central model in WaterWare.

The entry point is a selector of scenarios, which can be sorted and filtered by several properties such as name, author, modification date, or location.

Another option at the level of the scenario selection is the possibility to create a new scenario with an empty template. To facilitate and simplify the generation and editing of new scenarios, it is also possible to copy an existing one and modify it incrementally under a new name.

Once selected, the summary information about a scenario includes its name and a short description, the author (the only user that can change or delete that scenario), location, and start date for the simulation and water year.

Model parameters at the scenario level include multipliers for sectoral water demand (municipal, industrial, agricultural, tourism) as well as global time series for temperature and precipitation that are used through out the scenario unless specified otherwise at the level of individual nodes or reaches.

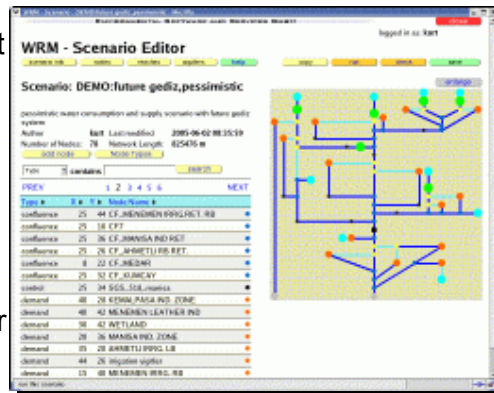
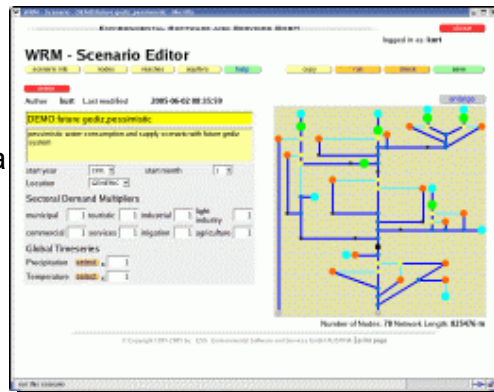
Properties or parameters of a node depend on its type.

They include basic properties including its location and elevation, specification of release or allocation/diversion strategies, time series of demands or flow targets, and loss rates, consumptive use factors, etc. For economic evaluation, costs and benefits of water supply and use can also be specified as unit costs.

The main components of a WRM scenario are In addition to the global parameters,

- nodes, including reservoirs,
- reaches, including options for lateral inflow,
- and aquifers

together with their parameters and the time series of inputs and demands. A selector of all available nodes and the possibility to a new node to the set lead to the node editor tool.



The time series that specify the dynamic behavior of the nodes and reaches and also control aquifer dynamics can be selected from a common data base of model related time series, including an interactive time series editor. The common selector tool provides a choice of applicable data sets, organized by parameters and constrained by locations. An import function supports uploading of data sets in simple formats like csv.

A preview function facilitates inspection of the data set before its selection and linking to a node. For each time series, a scaling factor or multiplier can be chosen to efficiently define alternative scenarios, e.g., by scaling demands.

Together with the nodes, reaches complete the network representation of a river basin. Reaches are defined as the connection between two nodes, and have geometric properties (length and cross-sections), the slope being derived from the elevation difference of the nodes connected.

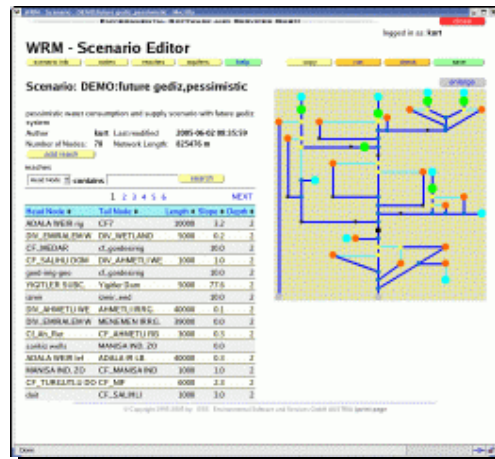
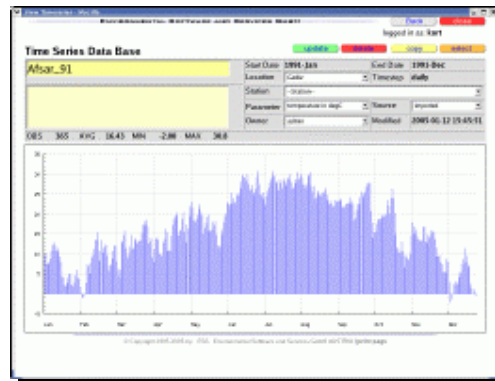
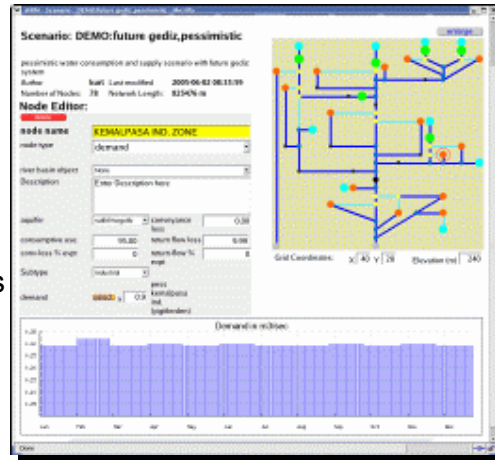
Reaches can also received lateral inflow from their immediate sub-catchments, which can be specified directly with a time series of flow data, or through daily rainfall data and a runoff coefficient.

Reaches can also interact with the groundwater to simulate exfiltration and infiltration depending on the respective water levels.

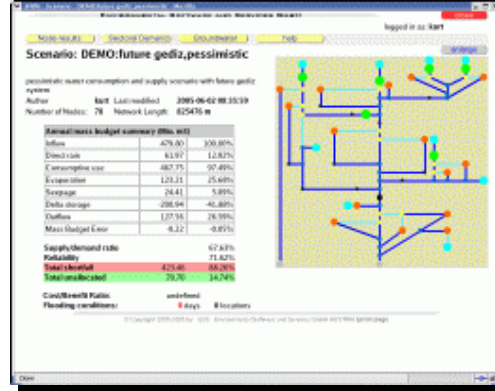
Model results are summarized into an overall basin wide mass budget, keeping track of all

- inputs depending on the spatial organization of the basin (sub-catchment runoff, natural springs and pumped wells, inter basin transfers, desalination, direct rainfall; and
- outputs (outflow, evaporation, consumptive use, inter-basin transfers)
- and storage changes (reservoirs, groundwater system).

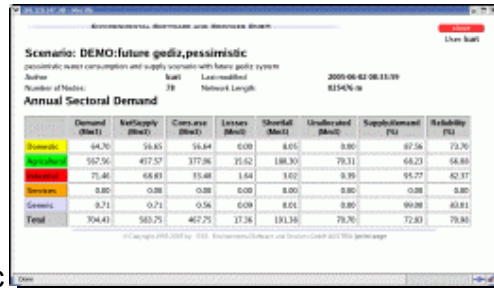
The models also keep track on supply /demand ratios, reliability of supply, and special conditions like foods or droughts.



Water supply, demand, a supply/demand ratio, consumptive, use, losses, and reliability are also shown on a sectoral basis to facilitate keeping track of different allocation policies and rules for a scenario. These can be controlled with the global sectoral multipliers defined for the scenario, or with individual multipliers and scaling factors for each of the demand nodes in the system.

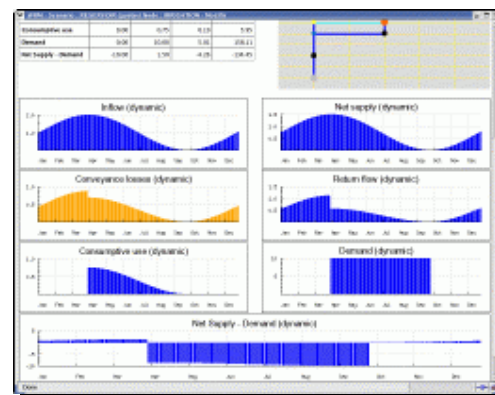


In addition to the aggregated results for the entire basin and by sector, results can be shown and analyzed for every individual node, with a different structure according to the node type.



This includes a tabular summary of the respective mass budget, as well as the time series of individual node type specific concepts (see below) on a daily (365 days) or hourly (360 hours) basis.

The basic flow data for a WRM scenario resulting from hydrometeorological inputs, allocation and demand patterns, are then available as input to the basin wide dynamic water quality model STREAM.

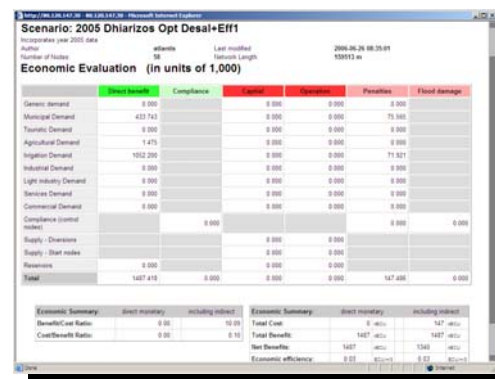


The time series cover

- all inputs (inflow from upstream sources)
- outputs (outflow or return flow to downstream, nodes)
- losses (evaporation and seepage),
- dynamic state (storage), and
- derived concepts such as shortfalls or excess flows (flooding conditions).

Economic assessment

This includes both direct and indirect costs and benefits, costs of supply, penalties for shortfall, benefits for demand met, and meeting flow constraints. Economic assessment is global, be economic sector, and node specific.



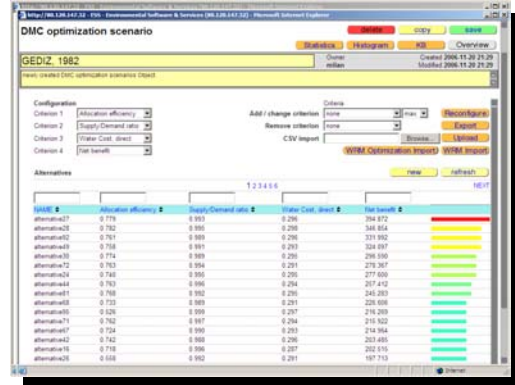
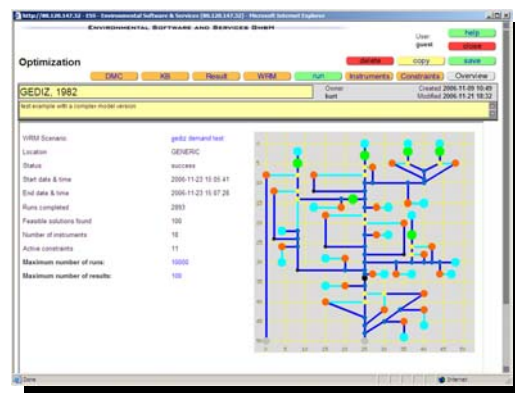
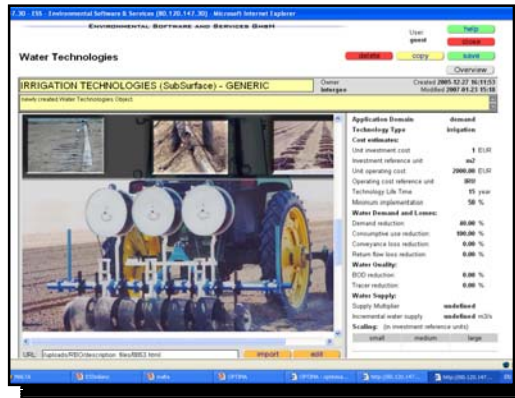
Multi-criteria optimization, DSS

For each of the Nodes of the water resources model, the economic sectors, or globally, a set of alternative water technologies describing instruments, policies, or measures, can be assigned from a generic technology data base. These instruments affect water supply, water demand, efficiencies and losses, as well as water quality. Each INSTRUMENT has associated costs (investment, operations and an application range.

The optimization location is defined by these water technologies or INSTRUMENTS, together with a set of CONSTRAINTS that define the desirable or feasible behaviour region of the system. The first step of the multi-criteria optimization uses a satisficing approach, generating alternative configurations or strategies that meet or satisfy all *a priori* constraints.

The optimization routine uses adaptive heuristics to generate large sets of feasible alternatives by applying the INSTRUMENTS and evaluating the systems response in terms of costs, benefits, and any of the criteria selected by the user such as supply/demand ration, reliability of supply, various efficiencies, etc.

In a second, final step a discrete multi-criteria DSS based on a reference point approach is used to identify an efficient (optimal) compromise solution from the non-dominated subset of the feasible alternatives.



River Basin Object Data Base

River Basin Objects are the central data type in WaterWare.

Objects can be georeferenced (like reservoirs or monitoring stations), or generic, like crops.

The primary selector shows the object classes supported and available. With every class name, the number of elements or instances is shown.

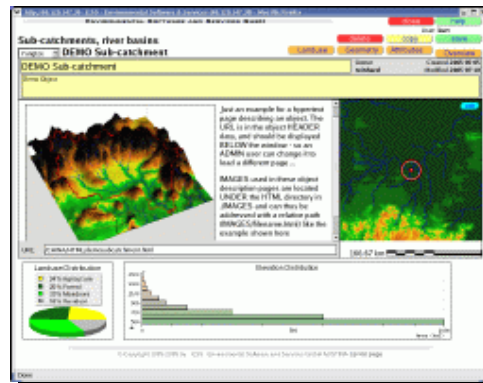
For each object class, there are generic and type specific functions, data structures and editing tools available.

The basic object display page shows the usual meta data together with

- a map indicating the location of the object where applicable,
- a hypertext page describing it,
- a set of buttons leading to specific detailed pages depending on the object class;
- one or more selectors leading to related or child objects "belonging" to the parent object, like monitoring time series data to a monitoring station.

Specific Data describing an object in detail can include:

- Basic attributes in tabular form;
- Administrative information, contact addresses;
- area-elevation table and graph for sub-catchments;
- depth-area-volume table and graph for reservoirs.
- land-use table and pie chart for sub-catchments;
- crop table and pie-chart for irrigation districts;
- instrumentation description for monitoring stations;
- temporal distribution of water demand etc. for crops.



- shading factor, reducing soil evaporation;
- Kc factor used in the CROPWAT model (multiplier for potential evaporation).

These data can be specified in a table, with ten value distributed equally over the growing period, i.e., every value representing 10% of the relevant growing period.

Monitoring stations and time series data

A central class in WaterWare are the monitoring stations and their associated time series of observation data: meteorological variables, river flow or levels, water quality, reservoir and groundwater levels, release and pumping rates.

The primary selector shows the monitoring stations. With every monitoring station, the basic meta data attributes such as name, owner, and last modification dates (most relevant for real-time data acquisition stations) are shown.

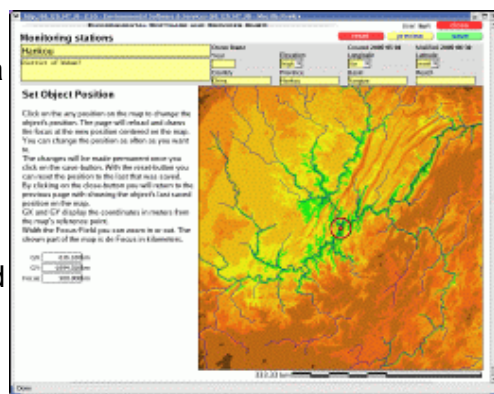
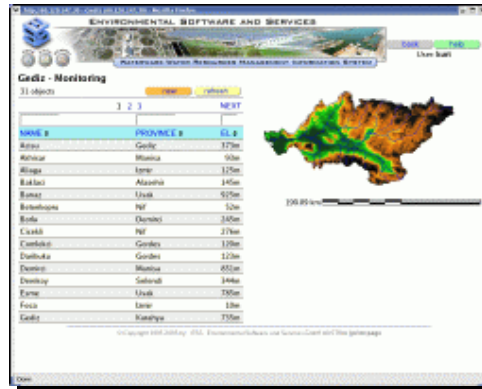
A monitoring station object is defined by its name, meta data including owner/user, creation and last modification dates, a hypertext link to descriptive multi-media data.

The station location is shown on a map of the stations surroundings.

The primary attributes of a monitoring stations are the time series of monitoring data, These are shown in a selector at the bottom of the page, where time series data files can be sorted by parameter, temporal coverage, and number of observations, and last update, important for real-time data acquisition cases.

The map display of the station location and surroundings can be interactively configured by the user, subject to his write privileges i.e., ownership of the object data.

The position of the station can be set interactively on the map by just clicking on the desired location, or alternatively, by directly specifying the location's coordinates.



The zooming factor of the local map is defined by specifying the radius to be shown around the station location, with the station always centered in the map window shown.

The monitoring data time series is shown

- in a tabular summary of the overall statistics;
- in a compressed overview of the entire observation period;
- for the last, most recent period.

The period shown and the aggregation of the data depend on the original temporal resolution or time step, and the temporal coverage of the available data.

For the analysis of a time series, a number of specific functions are available. They include, in addition to basic descriptive statistics:

- histogram of a single data set's distribution
- direct comparison of two stations or two parameters
- correlation of two synchronized data sets
- compliance with a standard
- outlier detection (data quality assurance).

The direct comparison option shows two user selected data sets, synchronized, together.

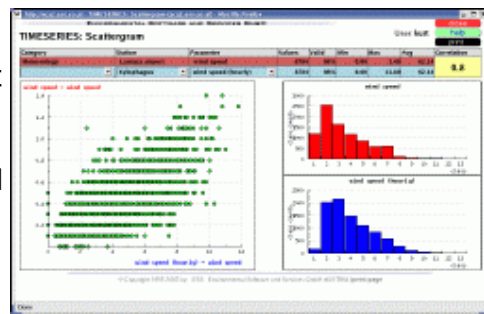
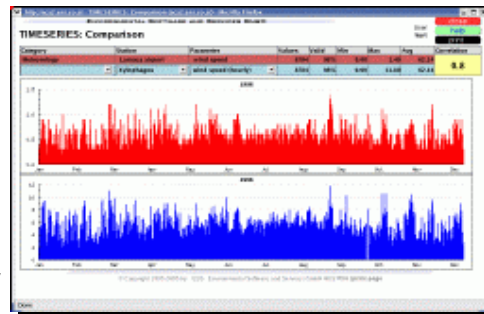
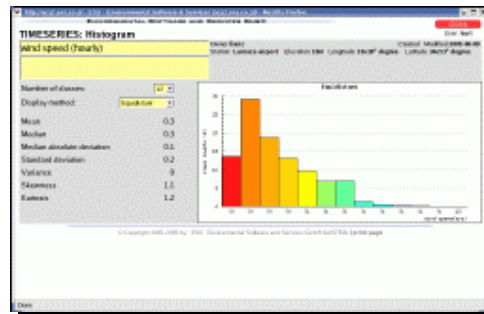
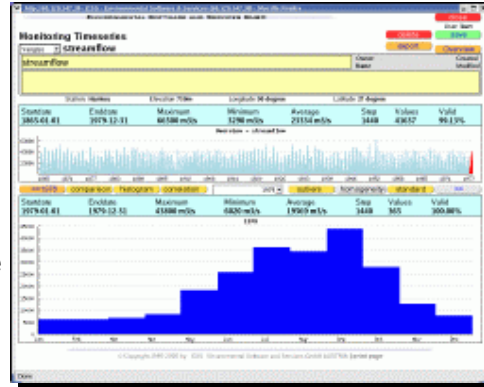
The user can select the second data set from the list of available stations and variables that have data overlapping in time that can be synchronized. The display includes:

- table of descriptive statistics (statistical moments of the distributions)
- display of the two time series data on top of each other.

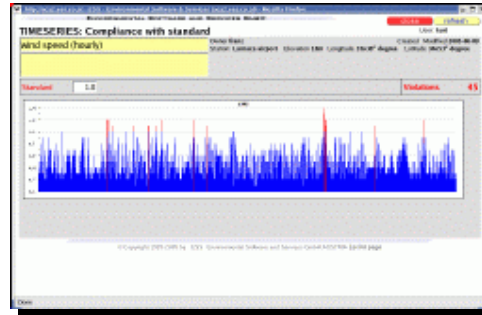
The correlation analysis includes, in addition to the statistical analysis as above,

- scattergram, plotting the two data sets against each other, and the corresponding linear correlation coefficient;
- histograms for the two data sets.

The compliance analysis determines the number of observations that exceed a user



specified threshold value. The analysis indicated the number of exceedances, as well as the AOT (average above threshold) value.



The outlier detection attempts to find erroneous values in an observation data set. Several test can be performed individually or together. They include:

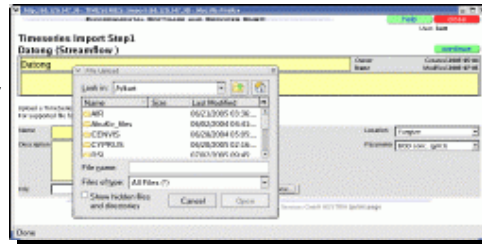
- bounds checks whether value are within a user defined interval;
- absolute delta: puts an absolute limit on increase or decrease from one value to the next;
- relative delta: same as above, but in relative terms;
- duplicates: finds neighboring values that are exactly the same, sometimes suggesting a data entry error.

Time Series Data Import

To import Time Series Data into the system, a dedicated import dialog is available.

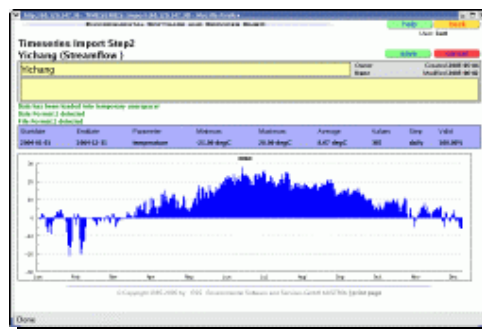


In the first step, a monitoring station that the time series to be imported belongs to has to be selected.



Once imported, the data set is displayed for visual inspection.

A summary of descriptive statistics and a time series graph are shown.



After inspection, the data set and its association to the monitoring station selected can be saved, or the import sequence can be aborted (red cancel button).

RRM Rainfall-Runoff Model

RRM is a dynamic (hourly or daily) rainfall-runoff and water budget model for (ungaged) sub-catchments.

The entry point is a selector of scenarios, which can be sorted and filtered by several properties such as name, author, modification date, or location.

Another option at the level of the scenario selection is the possibility to create a new scenario with an empty template. To facilitate and simplify the generation and editing of new scenarios, it is also possible to copy an existing one and modify it incrementally under a new name.

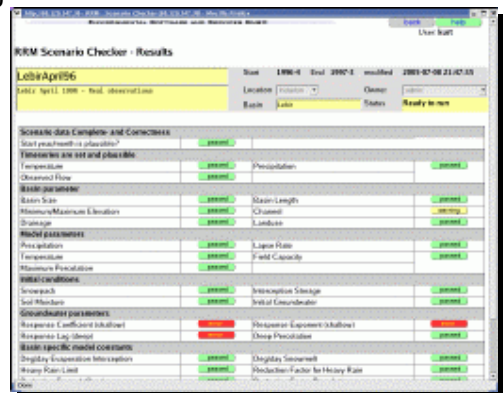
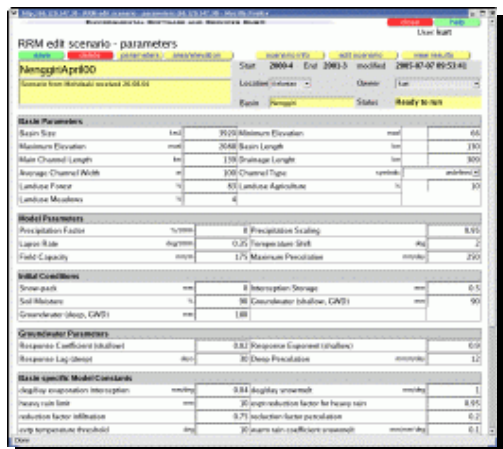
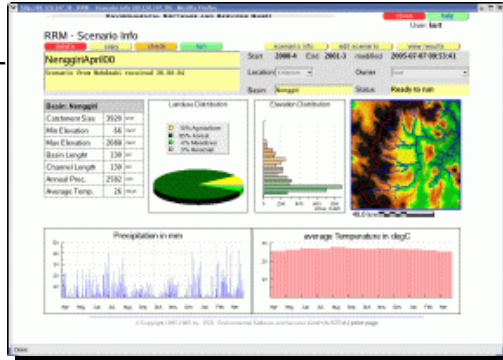
Editing a scenario for the rainfall-runoff model involves four major components:

- Basic scenario (meta) data
- choice of the time series data for rainfall and temperature, optional flow data for comparison (also used in the automatic calibration option);
- setting the basin characteristics and model parameters;
- defining basin geometry.

The model parameters are grouped into several sets:

- Basin characteristics such as size, channel characteristics, drainage density etc.;
- Specific model parameters including the initial conditions;
- Land use (forest, pastures, agriculture, built up areas, and residual)
- Model constant such as degree day coefficients, which only have to be adjusted to adapt the model to different physiological or climatic situations.

Prior to running the model, all parameters are automatically checked for completeness, consistency, and plausibility (see below).



A special set of parameters with a dedicated editor describes the basin orography, or area-elevation distribution.

For every 100 meter altitude layer, the user specifies the corresponding area. While the model is spatially (horizontally) lumped, it is vertically distributed: it uses the elevation distribution of the basin to correct temperature and precipitation values varying with elevation, and keeps track of snow and snow-melt where applicable.

Checking scenarios: attached to the editors for all models, a checking routine to check for

- completeness
- consistency
- plausibility

of all scenario data and user selections is available.

This routine can be triggered interactively, on demand, or it is run automatically whenever the model should be run to ensure proper inputs and thus meaningful model results.

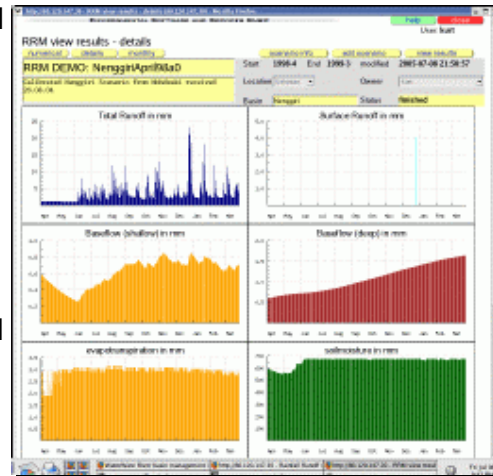
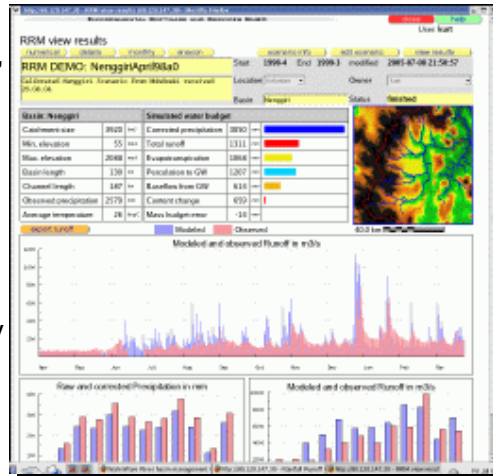
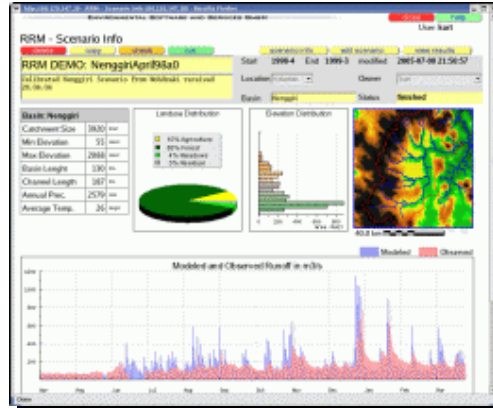
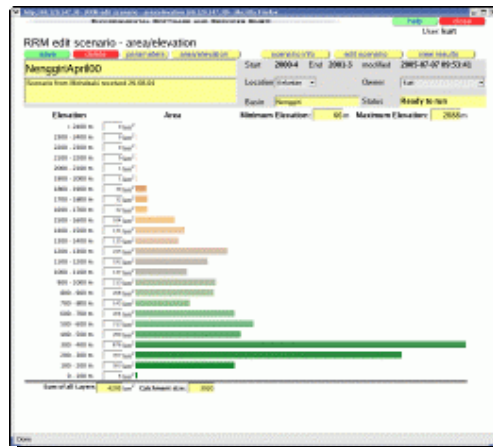
Model results:

On the main scenario page, the model results are shown as a time series of daily runoff.

Where specified, these data are shown together with the observed runoff data that can also be used for automatic model calibration.

The display shows the simulated runoff together with an (optional) observation data set.

The main results page shows a tabular summary of the main parameters and the overall annual basin water budget, as well as a map of the basin simulated.



Together with the daily/hourly results, a monthly/daily aggregate for the main variables:

- inputs (temperature and precipitation)
- output (simulated flow and optional observed flow)

is shown in graphical form as a time series graph.

Another output page (button: Details) shows several panels with individual variable over time. These include:

- surface runoff and baseflow;
- soil moisture and evapotranspiration;
- deep percolation and groundwater levels.

Yet another output page (button: Monthly) shows a tabular summary of monthly water budget components, corresponding to the detailed time series above.

Components include

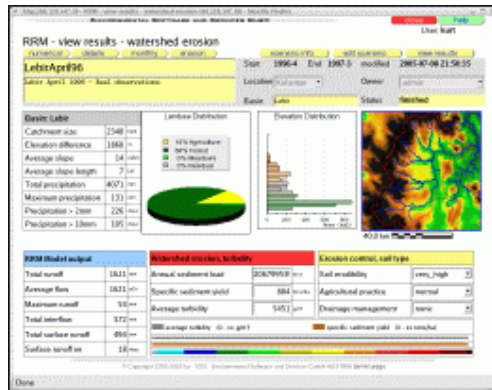
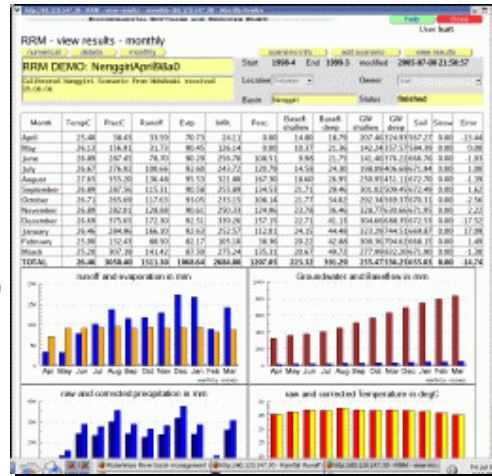
- raw and altitude corrected inputs (precipitation and temperature),
- evapotranspiration,
- inputs to the groundwater system,
- runoff and baseflow contribution,
- the overall mass budget.

A final results page shows estimates of watershed erosion: sediment yield and average turbidity.

Inputs used are the simulated flow together with

- basin morphometry (slope and average slop length),
- soil erodibility,
- agricultural practices,
- erosion control measures

defined by the user in symbolic terms.



Irrigation Water Demand Model

IWD is a dynamic (daily) model to estimate supplementary irrigation water demand for irrigation districts.

The model handles multiple crops from an integrated crop data base. Climate (daily temperature and precipitation), soil characteristics, irrigation technology and crops and cropping patterns are the main inputs defining a scenario.

The model generates time series of irrigation water demand (including the operation of an optional buffer storage reservoir) that can be exported for use in the [Water Resources Model](#).

The irrigation model can handle several, crops in parallel. A limit of five is recommended for better interpretation of the results, but not enforced in the model.

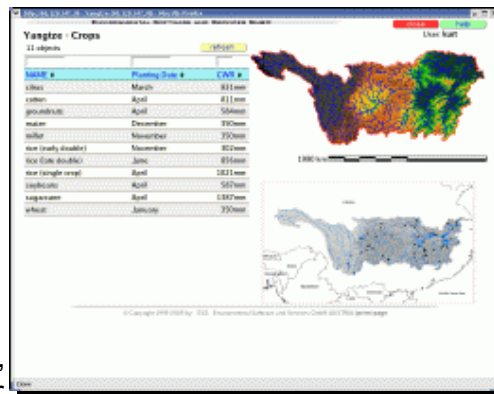
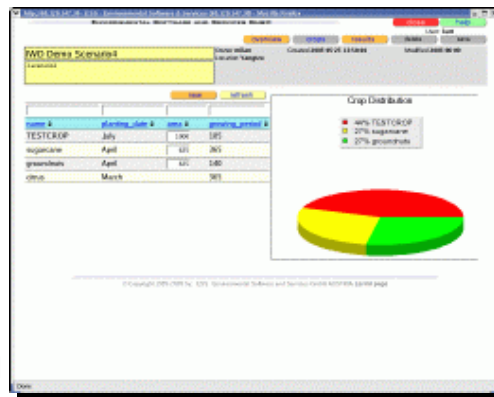
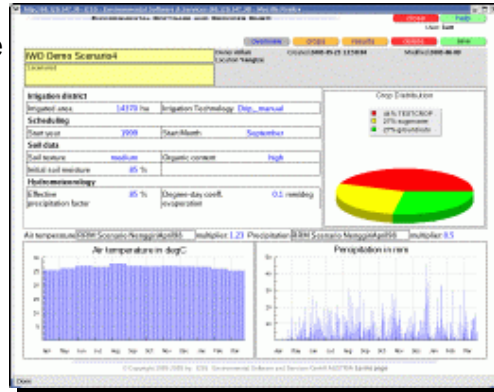
Crops can be selected from the embedded crop data base. They are defined in terms of the area they occupy, planting date, and growing period until harvest time.

Each crop used in a scenario inherits its generic properties like physiological water demand etc., but the user can overwrite them to better represent local conditions.

Additional crops can be selected from the embedded crop data base. This offers a selector showing crop names, planting dates, and the average crop water demand in mm (assuming optimal growing conditions) over a growing cycle or year for perennial plants like fruit trees.

Selecting a plant from the listing will show its data base entry.

The crop data base contains a basic listing of common crops subject to irrigation.

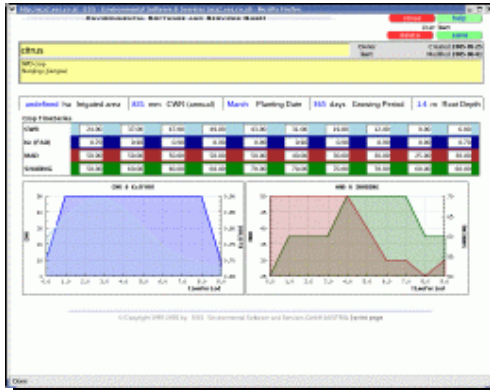


Crops are shown with their common and scientific name, as well as a short description of the data record indicating, for example, the source of information and any bibliographic references or links. Author, creation and modification dates complete the meta data.

The core of the description is multi-media material, shown in an embedded browser window, basic descriptive data like the CROPWAT Kc factor, average physiological water demand, planting date, and growing period.

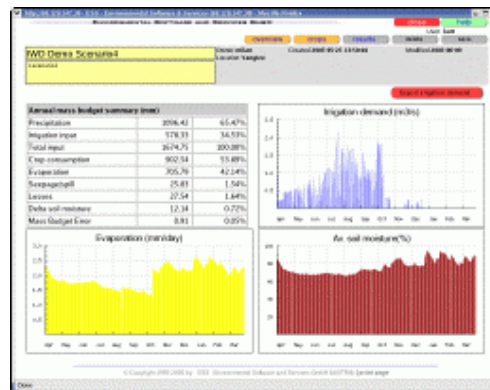
A separate window shows the temporal variation of the basic data:

- physiological water demand in mm;
- soil moisture tolerance, expressed as a fraction of field capacity (saturation).
- shading factor;
- CROPWAT Kc factor;



The model results are presented as a tabular summary of the water budget:

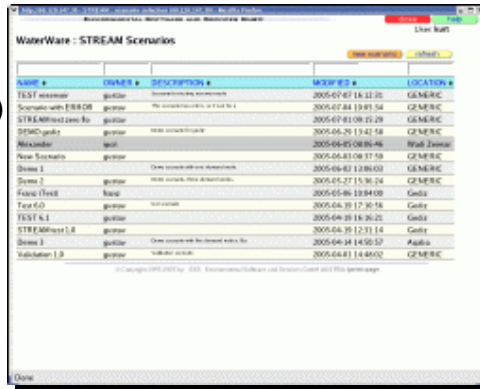
- Inputs composed of rainfall and supplementary irrigation;
- Plant water consumption and transpiration;
- Evaporation from the soil system;
- Application and Percolation losses;
- Storage change (soil moisture).



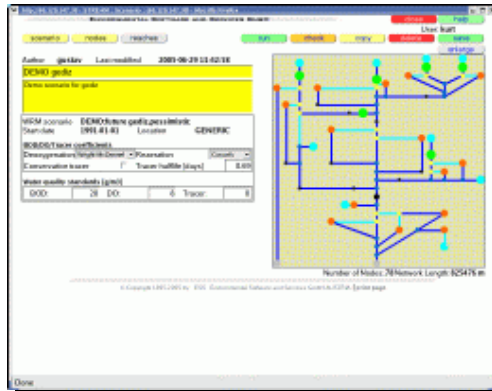
STREAM Surface Water Quality Model

STREAM, a basin wide dynamic surface water model for open channels is the central water quality model in WaterWare. The model uses the hydraulic results (flow) from the WRM water resources model as the driving input and inherits the time step (hourly or daily) and scope (3060 hours or 365 days).

The entry point is a selector of scenarios, which can be sorted and filtered by several properties such as name, author, modification date, or location.

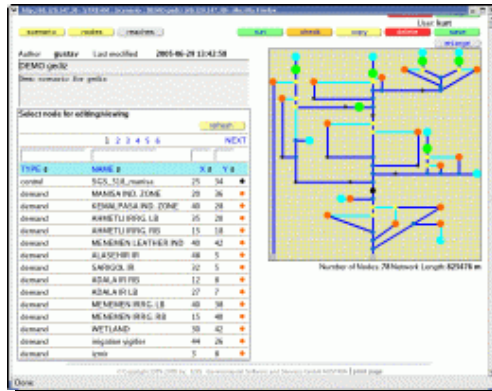


Another option here is the possibility to create a new scenario with an empty template, or by copying an existing one. The first step there is to select the WRM scenario to be used as the basis for a new STREAM model scenario.



Once selected, the summary information about a scenario includes its name and a short description, the author (the only user that can change or delete that scenario), location, and start date for the simulation.

Model parameters at the scenario level include the choice of pollutants, the decay characteristics (specified as half time) and water quality standards, as well as choices on model equations to be used.

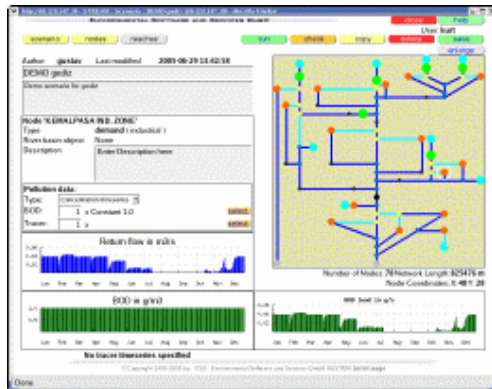


Initial concentrations and pollutant load or emission data are specified on a node level.

To select a node from the existing WRM network scenario, a selector shows all relevant node types

- start nodes
- demand nodes
- control nodes

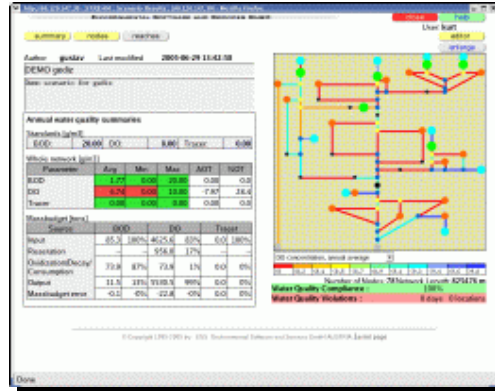
for which STREAM specific data and time series have to be specified.



The node type specific data include:

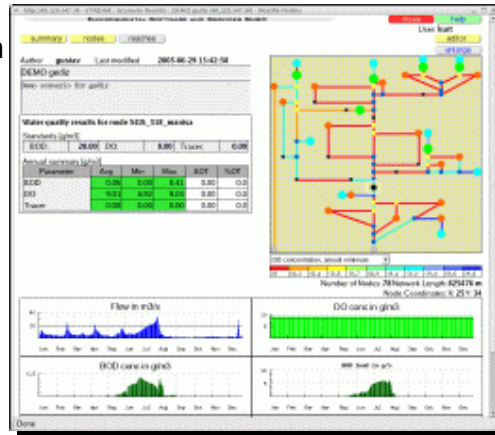
- For Start nodes, an initial concentration for DO, BOD, and the pollutant are specified.
- For demand nodes, pollutant load is specified.
- Control nodes are passive observation points that keep track of any violations of the water quality standards.

The model results are summarized in tables for average, minimum and maximum concentrations for DO, BOD, and an arbitrary pollutant (conservative or first order decay).



Parallel to the tabular results, a color coded interpretation of water quality parameters along the reaches of the river network is shown, with a selection mechanism to switch between water quality parameters:

- average and minimum DO;
- average and maximum BOD;
- average and maximum tracer or user selected pollutant.

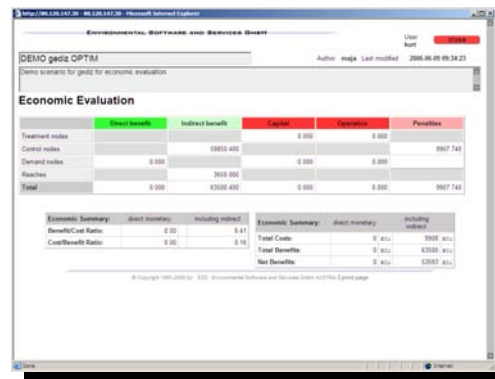


Detailed results are shown on a node basis, for control nodes only. Tabular data include the basic statistics of the time series, plus the number and % of standard violations. The output time series include:

- Flow (inherited from WRM);
- BOD;
- DO;
- User defined pollutant.

Economic evaluation

This includes the cost of treatment and of alternative production technologies at all demand nodes that reduce waste water flow or concentration. Penalties accrue from violating water quality standards at control nodes. Benefits are based on demands met with water that meets the quality standards, and in-stream benefits by reach for days at which the standards are met.



SPILL/BLTM Surface Water Quality Model

SPILL/BLTM, a near-field surface water model for open channels is the second water quality model in WaterWare. It is designed to represent highly transient situations like the effects of storm water runoff, treatment plant failures, or accidental spills over short periods of time and immediately downstream of a source.

The entry point is a selector of scenarios, which can be sorted and filtered by several properties such as name, author, modification date, or location.

Another option here is the possibility to create a new scenario with an empty template, or by copying an existing one. The first step there is to select the WRM scenario to be used as the basis for a new STREAM model scenario.

Once selected, information about a scenario includes its name and a short description, the author/owner, location (defined by a WRM node and the reach downstream of it), and the overall duration of the episode (simulation time, together with the time step. A 48 hour duration, and an hourly time step are the defaults. In addition to the basic control parameters, the scenario is defined by:

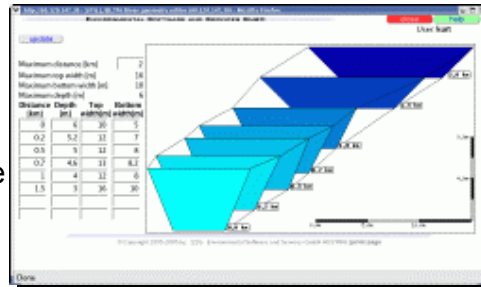
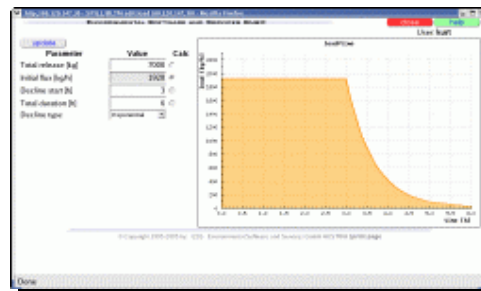
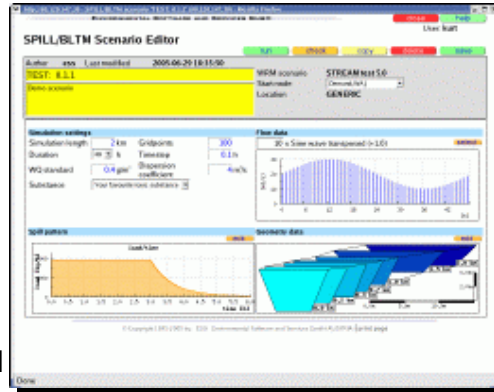
- detailed reach geometry;
- flow pattern (hourly);
- pollutant load, amount and pattern.

The load pattern for the pollutant (the spill) is defined in a separate editor: this includes setting

- the total mass of pollutant involved,
- the duration of the spill
- the start of the decay of the spill rate
- the decay pattern (linear or exponential).

Alternatively, the user can specify the maximum initial pollutant flow, from which the total mass involved will be calculated.

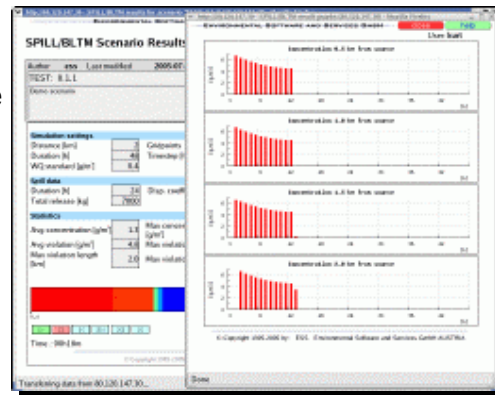
The detailed geometry of the reach affected is specified in terms of a set of trapezoidal cross sectional shapes. The user specifies the total length of the



reach, and for each of the cross sections its distance along the reach, its depth, and the bottom and surface width, using the simple trapezoidal approximation.

The model results are summarized in tabular form, indicating maximum concentration values and the exceedance or violation of water quality standards.

The main output format is an animated display of the river reach with a color coded representation of the pollutant concentration. A tape-deck like control tool supports continuous animation/play, or single stepping through the simulation results, and jump to the first and last time-step, respectively.



In parallel, breakthrough curves (pollutant concentration over time) are shown for selected location along the reach. They are relevant, for example, to control water intakes including bank filtrate during a pollution episode.

The increasing distance of the control points is reflected in the time delay in the arrival and passing of the pollutant plume along the river.

XGW 2D Groundwater Flow and Transport Model

XGW is a 2D (vertically integrated) dynamic (fully transient) groundwater flow and transport (quality) model. Scenarios are defined by: scenario meta data, the model parameters (grid size and resolution, time step and duration), a set of matrices that describe initial and boundary conditions, set of wells/pumps, time series of dynamic inputs.

The matrices used in the model include: depth of the aquifer, porosity, transmissivity, initial head, recharge multiplier, initial concentration.

The main input are defined for individual location, or wells. They can represent:

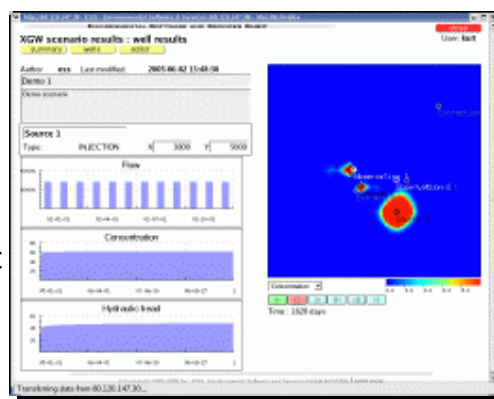
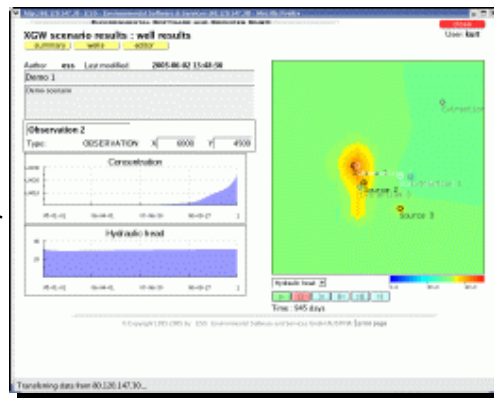
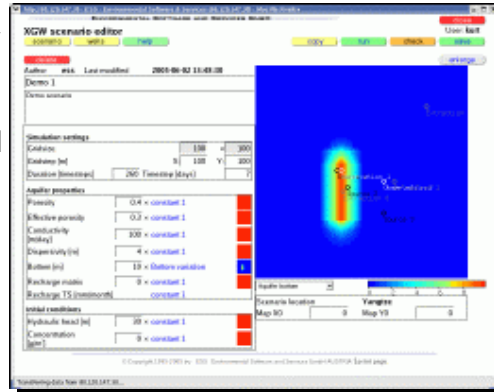
- extraction wells, with a dynamic flow,
- observation wells (passive, only for output),
- recharge wells, with a dynamic flow,
- pollution sources with flow and concentration, both time variable.

The time series of flow and concentration values are selected, loaded, and possibly [imported](#) with the standard set of tools.

Model results consists of a sequence of matrices with the two main variables:

- head and concentration and time series of these values for the set of well/pump locations.

The individual locations are shown on a selector list indicating the types (extraction or recharge well, observation well, pollution source) and its location in model grid coordinates. Results at a given well location are shown as time series. In parallel, the matrices for hydraulic head and concentration can be viewed in an animated sequence under a tape deck like control. The time series graphs show both concentration and hydraulic head, as well as the pumping rate in the case of an extraction or recharge well or a pollutant source. The user can switch between the two output variables, hydraulic head and concentration, and combine the animated display with the graphs for specific location selected from the list of all wells and observation points. A color coded



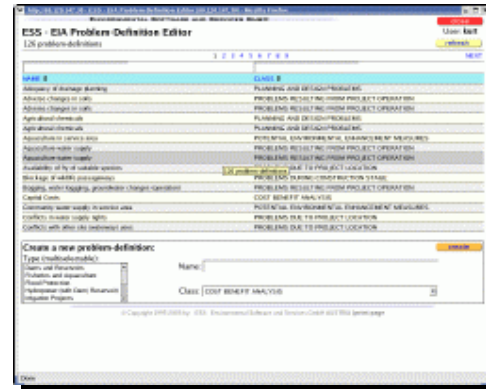
The descriptor definition includes:

- the legal values (symbols and numerical ranges);
- the question text that is used in the editor tool (Java applet);
- the list of associated rules.



The editor also offers a preview function for the definition.

The preview shows how the definition is interpreted by the interactive editing tool (a Java applet) that uses the Descriptor definition to configure the tool used to set a specific value.



The rules associated with a Descriptor fall into two groups:

- Rules that set that Descriptor
- Rules that use the Descriptor.

These are first order production rules, implementing first order logic principles or *modus ponens*.

Rules are of the generic format:

IF [condition]
 AND/OR [condition]
 THEN [action]

where both the condition and action parts can include arbitrary (external) evaluation functions; the basic condition involves the triplet

DESCRIPTOR [operator] VALUE

for the comparison of the current value of a systems variable (observed, simulated, or user supplied, a Descriptor in the dynamic knowledge base) with a reference value.

Rules can be nested to arbitrary depth, and the instantiation of a Descriptor can use a series of alternative methods that are tried in sequence depending on the availability of the necessary data (precursors) for the inference.

For the real-time forward chaining version (RTXPS) conditions include the setting and reading of TIMERS (real, system, elapsed) for operational control applications and the processing of (external sensor) events.

MapServer embedded GIS

GIS data are managed by the MapServer.

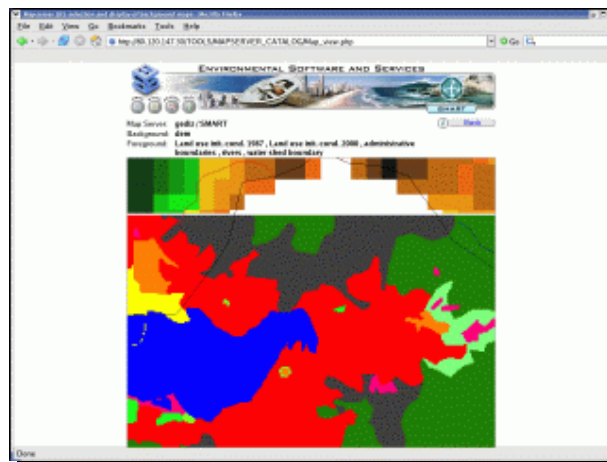
The server has three basic modes of operation:

- with an interactive interface to manipulate and display map layers for dynamically generated maps;
- embedded with object and model (output) display pages;
- an administrative mode for the configuration of new mapsets.



For the interactive generation of maps, the user can select:

- one background layer (usually opaque with full coverage);
- one or more foreground layers (usually transparent or line features);
- a size for the resulting map image;
- layout specifications for a scale bar.



The resulting map is then displayed in the size specified.

The map generated is a composite of the layers selected: on top of the (opaque) background map (a DEM in this example), one or more overlays consisting of line features and/or transparent layers can be placed and displayed.

In the embedded mode, a mapset associated with an object, scenario or location is shown as part of the object display.

The object defined the mapset, a reference point, and an area of interest defined as a radius around the reference point, as well as the size of the resulting map image.



The image can be any combination of

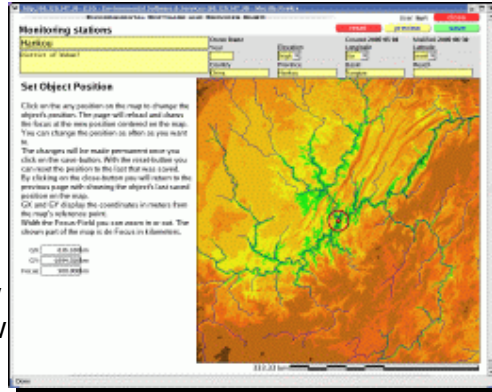
- rasters such as satellite imagery or aerial photography;
- polygons (opaque or transparent);
- line features.

Every embedded map has an EDIT button in the upper right corner that leads to a configuration tool.

The user can choose the reference point by either

- clicking on the desired map location
- specifying the exact coordinates

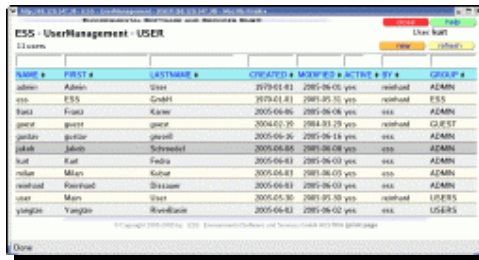
In parallel, the extent of the area of interest can be defined as a radius around the reference point in the center. Saving the new settings to the data base will lead to a redraw of the map with the new specifications.



User Management

Release 6.0 has installed its own user management to control remote access. Access is controlled by user name and password. Users are organized in several groups with different privileges:

- GUEST - a shared account for guest external visitors,
- USERS - normal, named accounts that have read access to all file, and write access to their own file,
- ADMIN - administrative user that full red and write access to all files
- ESS - users for the remote support group.



User management starts with a list of current users; they can be selected for editing, or a new user can be added.

A new user is defined by

- a user name
- first and last name, email address (this is used to re-send the current password on request);
- Group affiliation;
- Password (and a Confirmation field when creating or changing a password);
- Status (active or not).