WaterWare: water resources management, dynamic water budget modeling, multi-criteria optimization

ESS GmbH develops, distributes and supports WaterWare, an Integrated Water Resources Management Information and Decision Support System, based on dynamic water budget modeling.

WaterWare provides an open, modular framework for a range of data bases, embedded GIS, cascading simulation and optimization tools in a web-based client server framework. Dynamic water budget modeling and economic assessment are the basis for river basin management tasks in support of the EU Water Framework Directive 2000/60/EC.

WaterWare (http://www.ess.co.at/WATERWARE/) is designed as a river basin management information system, including multi-criteria optimization of water allocation, economics of use/distribution, investment projects, surface and groundwater pollution control, wastewater management. Related application domains and applicable model systems include dynamic land use change, regional development, waste management, land reclamation, ranking and benchmarking, site suitability analysis, environmental impact assessment, integrated coastal zone management and vulnerability analysis, computer assisted technical training.

Integrated Water Resources Management

The WaterWare river basin management system (http://www.ess.co.at/WATERWARE/) is used for optimal water allocation, economics of water services (use/distribution) surface and groundwater pollution control, wastewater management.

Dynamic mass budget models with economic assessment and multi-criteria optimization for optimal water allocation and efficient use, conjunctive use of surface water, desalination, and groundwater, including water quality and wastewater management, also links to coastal water quality, and Climate Change Impacts.

WaterWare is designed for Integrated River Basin Management (European Water Framework Directive 2000/60/EC) including large and international river basin, with conflicting water use, allocation conflicts, scarcity, extreme events such as floods, and water quality problems. WaterWare combines hydrological, economic, and environmental aspects of IWRM in one consistent, easy to use management information system with distributed web and 3G SmartPhone access.
WaterWare can be configured and operated for
- Strategic planning, scenario analysis
- Water resources optimization (multi-criteria, economic valuation)
- Urban water supply: reliability and sustainability
- Irrigation and drainage planning and management
- Operational control, real-time basin management (SCADA)
- Specific research tasks (model framework).

Dynamic water budget modeling

WaterWare is based on the conservation laws and water budget modelling at various spatial and temporal scales as the paradigm for all basin management tasks. Models for the calculation of dynamic water budgets include:

- Prognostic meteorology: MM5, WRF 3D nested grid non-hydrostatic prognostic models, using NCEP FNL (historical re-analysis) or GFS (daily or six-hourly operational forecasts), calculates precipitation estimates, temperature, humidity, evapotranspiration and soil moisture estimates. Dynamic downscaling of global synoptic data to 3 km spatial resolution, subsequent diagnostic interpolation to 1km, temporal resolution from 2 min to hourly. For synoptic validation, satellite imagery (Meteosat, MODIS) can be used. The numerical weather forecasts provide the hydro-meteorological inputs for all models below.

- Fully distributed rainfall-runoff modelling at the catchment scale based on high-resolution DEM (30 global sources or 1m resolution LiDAR scans) distributed rainfall data (dynamic downscaling of NCEP FNL of GFS synoptic meteorological models (MM5, WRF) using a concept of concentration areas and stream-flow paths as well as gravity flow or pumped drainage systems (canal, pipeline), represented by hydraulically linked cellular automata. Governing parameters include elevation, slope and aspect, vegetation and land cover (imperious, sealed surfaces), soils, connectivity to the drainage system. The temporal resolution is 1 hour or below. A typical application domain is urban flooding.
Water Resources Management: dynamic water budgets

- **RRM**: Semi-distributed rainfall runoff model at (sub) catchment scale (cascading non-linear reservoirs including snowmelt and -accumulation, multi-component groundwater, and an embedded automatic calibration routine based on pattern matching. Operates on daily or hourly time step. The model includes estimation of evapotranspiration and several parallel runoff pathways such as surface runoff (Hortonian sheet-flow) infiltration and interflow, deep percolation and groundwater contributions (baseflow). Model can be driven by observed or simulated (distributed over sub-catchments) meteorology. Individual sub-catchment model can be linked in the topological network.

- **IWDM**: Crop water demand, soil moisture model: A dynamic simulation model that calculates and detailed annual water and soil moisture budget for a vegetated (multiple plants or crops), designed for the estimation of supplementary irrigation water demand, optimum irrigation scheduling, crop yield under water scarcity, and the economics of single or multiple field level irrigated agriculture. The model uses plant physiological data from an embedded crop data base, observed or model generated meteorology, and a range of decision variables to define water management strategies. The model estimates water demand for irrigation districts or large form for the WRM model. It can be run in planning/scenario analysis mode, as part of a real-time operational control system.

Continuous monitoring of canal flows, pumping rates and soil moisture data can be used for real-time data assimilation.
• WRM: Topological river basin model, network representation of nodes (catchments, reservoirs, points of water demand, treatment plants) and reaches (open channel or pipelines). Water inputs include direct precipitation, runoff from sub catchment (see the rainfall-runoff model above), natural springs, pumped wells, and optional inter-basin transfer. Water use is defined for demand nodes (agriculture, urban, industrial, wetlands). Losses include evapo-transpiration on all areas and open water surfaces, including specific treatment for bank evaporation; and seepage losses that contribute to groundwater recharge, together with optional groundwater recharge. Reaches route the water from node to node. The can receive direct precipitation, and contribute to evapo-transpiration, directly from surfaces and through bank evapo-transpiration. Lateral inflow from immediate catchment provides another source of direct input. Interaction with groundwater includes both infiltration and exfiltration driven by different surface- and groundwater levels, as well as temporary bank storage and delayed exfiltration. The WRM (Water Resources Model) uses daily time step, but an internal hourly or adaptive time step for rapidly changing flow conditions (e.g., reservoir release)

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 ungauged sub-catchments, providing input to the water resources model;
    • An irrigation water demand model, providing input to the water resources model and farm-level water management
- 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, and multi-criteria optimization;
- 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 6.2 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 or 3/4G mobile phone 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 can be implemented on 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.

For more detail, examples, documentation and reports, please visit:

- [http://www.ess.co.at/WATERWARE](http://www.ess.co.at/WATERWARE)
- [http://www.ess.co.at/WATERWARE/images.html](http://www.ess.co.at/WATERWARE/images.html)
- [http://www.ess.co.at/REPORTS](http://www.ess.co.at/REPORTS)

or contact ESS: [info@ess.co.at](mailto:info@ess.co.at)