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MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

Mongkol Borey – Tonle Sap (9C-9T) Sub-basin Hydrological Modelling Guidance

MEKONG RIVER COMMISSION - JOINT PROJECT ON FLOOD AND DROUGHT MANAGEMENT

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Prepared by

MRCS-GIZ Joint Project team comprising Sophearin Chea, Chief River Basin Planner, MRCS; Nittana Southiseng, Deputy Project Director of GIZ; Yia Yang Technical Advisor, GIZ; Nike Hestermann, Development Advisor, GIZ; Richard Mueller, Development Advisor, GIZ.

Supported by the ICEM team comprising Hubert Lohr, Jeremy Carew-Reid, Harvey Rich and Nguyen Thi Phuong Thao.

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More information

http://www.mrcmekong.org/
Unit 18, Ban Sithane Neua, Sikhottabong District, Vientiane 01000, Lao PDR
Ph: +856 21 263 263.

Front page and back page photos

ICEM

ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
BMZ	German Ministry for Economic Cooperation and Development
CNMC	Cambodia National Mekong Committee
CPU	Central Processing Unit
ESA	European Space Agency
FAO	Food and Agriculture Organization
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
GIS	Geographic Information Systems
HEC-HMS	Hydrologic Engineering Center Hydrologic Modelling System
HEC-RAS	Hydrologic Engineering Center River Analysis System
ICEM	International Centre for Environmental Management
ISRIC	International Soil Reference and Information Centre
MOWRAM	Ministry of Water Resources and Meteorology (Cambodia)
Mbps	Megabits per second
MRC	Mekong River Commission
MS	Microsoft
NASA	National Aeronautics and Space Administration
NbS	Nature-based solutions
NWG	National Working Group
ONWR	Office of National Water Resources (Thailand)
RFDMC	MRC Regional Flood and Drought Management Centre
RSC	Regional Steering Committee
WCF	Microsoft Windows Communication Foundation
XML	Extensible Markup Language

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1 INTRODUCTION

1.1 The 9C-9T Joint Project on Flood and Drought Management

The 9C-9T is a shared sub-basin of the Mekong River basin – it is bisected by the international border between Thailand and Cambodia and encompasses what is called the Tonle Sap River basin in Thailand and the Mongkol Borey river basin in Cambodia. The river headwaters rise in the Dangrek Mountains in the north, the Sankamphaeng Mountains to the west and the north-western edge of the Cardamom Mountains to the south, flowing down to form the Mongkol Borey river in the flood plain near Sisophon and then into the great lake - Tonle Sap.

The 9C-9T river basin is highly degraded. Over the past two decades the basin has seen significant socio-economic change with increased urbanization, agricultural expansion and intensification, and unsustainable use of forest resources. Because of these changes significant areas of forest have been lost though logging and conversion to agricultural land, and to urban uses without adequate spatial planning or environmental assessment. The basin faces increasing issues with land degradation, erosion, flooding, water shortages and drought. These problems have been compounded by uncoordinated and poorly planned infrastructure development. Increasingly variable rainfall and higher temperatures due to climate change will pose further challenges to water management in the basin.

In this context, in 2018, Cambodia and Thailand established a partnership for the management of the 9C-9T sub-basin of the Mekong River with facilitation by the Mekong River Commission (MRC). The cooperation is supported by Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) on behalf of the German Ministry for Economic Cooperation and Development (BMZ). The goal of this collaboration is to improve joint planning and implementation in the sub-basin to reduce the risk of floods and droughts. A 9C-9T Flood and Drought Master Plan has been developed under this programme of cooperation and implementation of the plan started in 2022.

The Joint Project has begun addressing the need for shared information on flood and drought with the development of flood maps for the 9C-9T sub-basin, the development of a high-resolution hydrological model and the preparation of climate change projections.

1.2 Model rationale and alignment to the 9C-9T Master Plan

A key output of the 9C-9T Flood and Drought Master Plan is the development of a hydrological model for the 9C-9T sub-basin. The development of the model fulfils elements of the following Master Plan output:

- Strategic Priority 4 activities will develop capacities in flood and drought modelling and communication of results to build on the models developed under the MRC-GIZ Joint Project, in partnership with the MRC Regional Flood and Drought Management Centre (RFDMC). This includes Output 4.1.2: Establish joint mechanisms for exchange of real time hydrological monitoring data and early warning (national, provincial and local level at target communities).
- Strategic Priority 5, Output 5.3.1: Develop capacities at regional and national levels for flood modelling, interpretation, and communication of results, with involvement of the MRC Flood and Drought Management Centre.

Phases I-III of the Joint Project have facilitated the establishment of a high-resolution hydrological model for the sub-basin – applying the Talsim-NG model. The 9C-9T hydrological model is now hosted on the MRCS server, transferred as part of a deployment and training workshop in November 2022.

1.3 Guidance document structure

This guidance document sets out to deploy the Talsim-NG 9C-9T hydrological model for MRCS and build familiarity with its use. It is intended for technical staff with a high level of background expertise in modelling of water resources, who use hydrological models on a regular basis for their work, and who are expected to support implementation of Joint Project activities in the 9C-9T.

The document provides an overview of the Talsim-NG hydrological model and its application for the 9C-9T sub-basin (Section 2). Instructions are provided for deploying the 9C-9T Talsim-NG hydrological model in Section 3, including pre-requisites and minimum server specifications for model transfer to the MRCS. Guidelines for future management of the application are detailed in Section 4, including on how to update the software. More detailed deployment guidance is contained in the Workshop and Tool materials (Annexes 2 and 3). Possible future opportunities to expand the model within MRC are presented in Section 5.

The training workshops were delivered by ICEM in November and December 2022, providing training in the deployment and management of the 9C-9T Talsim-NG hydrological model and supporting the final transfer of the model to the MRCS server. The model software and data were packaged and made available to participants of the workshop and participants successfully installed the software on their laptop computers and MRC server.

2 APPLICATION OF THE TALSIM-NG HYDROLOGICAL MODEL FOR THE 9C-9T SUB-BASIN

2.1 The Talsim-NG hydrological model

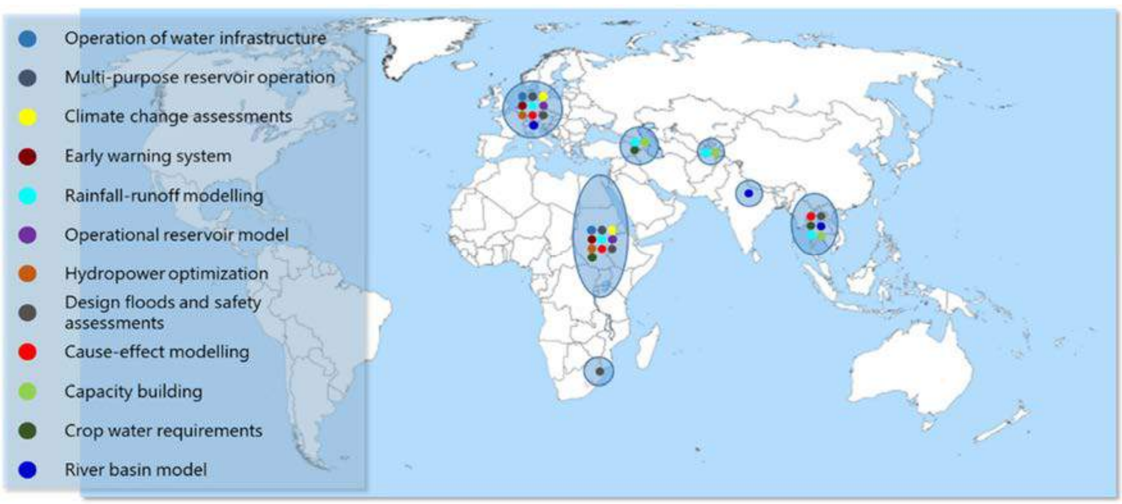
Talsim-NG is a high-end level hydrological model, developed in the 1990's at the Technical University of Darmstadt, Germany. The model is applied for scientific studies, practical applications and operational use, at all scales of river basins (< 10 km² and > 1,000,000 km²) in Europe, Africa and Asia (NBI, 2023), (Umweltbundesamt, 2019), (Tajikistan, 2018) (GFA Consulting Grop, 2017), (Lohr, Froehlich, & Bach, 2018), (Stasch, Gräler, Malewski, Förster, & Jirka, 2017), (NBI, nilebasin.org, 2022), (ENTRO & Lohr, 2016), (NBI & SYDRO, 2022). **The model can be used without license costs.** The main attributes of the model include:

- Client and Server technology;
- Precipitation-runoff modelling;
- Flood routing;
- Advanced atmosphere / vegetation / soil interface able to address ecohydrology, agricultural requirements and irrigation;
- Unlimited reservoir operation features;
- Flood control functions;
- Water quality assessment;
- Hydropower evaluation; and
- Scenarios and time series management.

It can be used for real-time operation of water infrastructure and for real-time early warning systems. Examples of its application include: real-time Early Warning System application for Baro-Sobat-Akobo river basins in Ethiopia and South-Sudan for the World Food Programme; modelling of the Se Bang Fai sub-basin (Lower Mekong Basin); Myanmar, Nam Paw river basin, for dam safety assessments; and various watersheds in Thailand for assessing nature-based solutions.

The entire value chain, from baseline studies through to operational use is possible. The modules embedded in the software offer various opportunities, as illustrated in Figure 1.

Figure 1: Talsim-NG software applications and locations. Source: SYDRO Consult GmbH (2022)



2.2 The model application for the 9C-9T sub-basin

The Talsim-NG 9C-9T model provides detail to support the assessment of basin conditions and hydrological scenario analysis in the future, not only for high flow conditions associated with flooding but also low flow conditions, important for drought assessment and management. Talsim-NG also supports drought assessment with in-built capability to represent crop water requirements, distinguish between soil layers and assess water deficits for a given season. These advantages of the

Talsim-NG hydrological model provide a highly credible model to support river basin master planning for the 9C-9T sub-basin.

The main Talsim-NG hydrological model features for the 9C-9T sub-basin are summarised here:

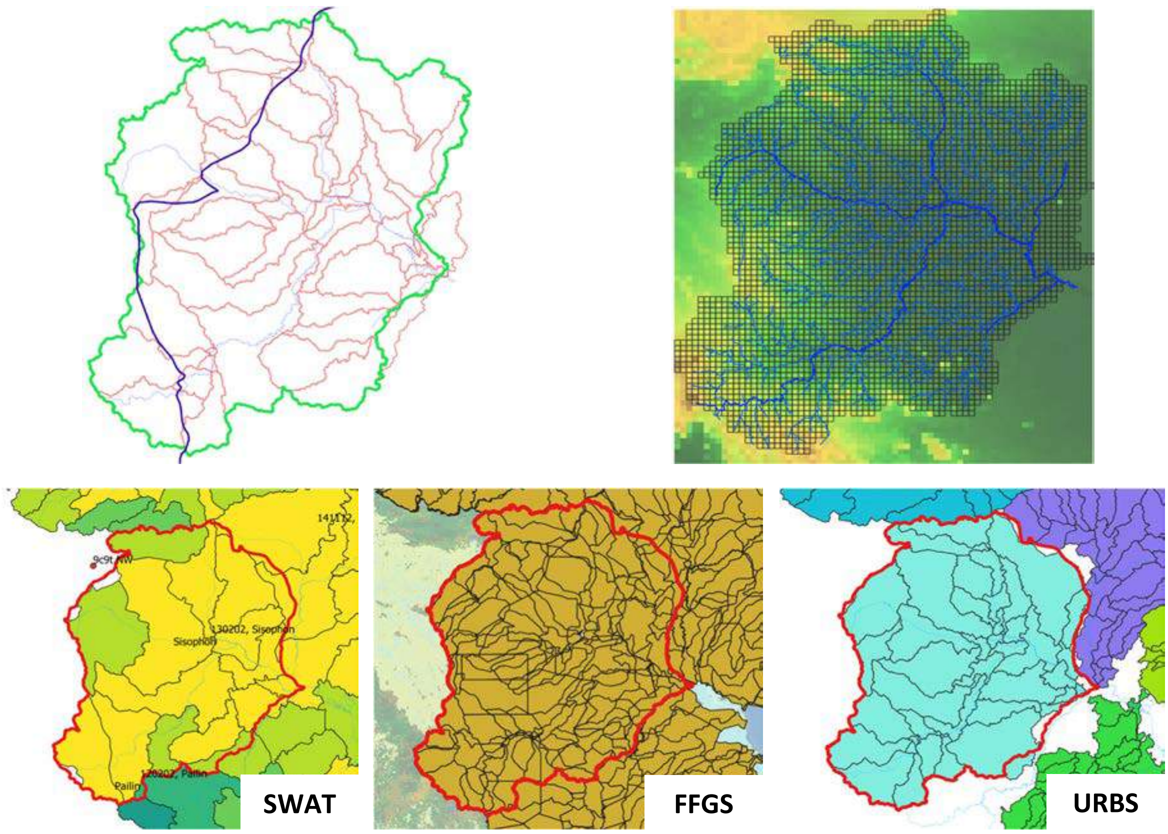
- Spatial resolution with 2x2 km grid with 4298 catchments;
- Temporal resolution (time step is 24h);
- Soil texture from the International Soil Reference and Information Centre (ISRIC) platform with six soil horizons;
- Soil texture data translated to physical soil properties, including wiling point, field capacity, saturation and permeability;
- Land use data from Landsat 2020;
- Integrated crop water requirement calculations, following the Food and Agriculture Organization (FAO) approach; and
- Interlinked surface and sub-surface flow between catchments.

2.3 Model evolution within the 9C-9T Joint Project

Phase I of the 9C-9T Joint Project incorporated basic hydrological and hydraulic modelling with the purpose of obtaining an overview of the hydrological situation of the entire 9C-9T sub-basin. Phase II of the Joint Project built on the output and findings of Phase I and was a direct continuation. The hydrological assessment for Phase II required a more comprehensive, high-end hydrological modelling approach. The hydrological model used in Phase I comprised two models developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers. These comprise the Hydrologic Modelling System (HEC-HMS), designed to simulate the complete hydrologic processes of watershed systems, as well as the River Analysis System (HEC-RAS), designed to perform one-dimensional and two-dimensional hydraulic calculations. Differences between existing model approaches and the 9C-9T model setup is illustrated in Figure 2.

Figure 2: Hydrological model resolution in Phases I and II (top), comparison with other models (bottom)

Hydrological model resolution Phase I *Hydrological model resolution Phase II*



Phase II of the Joint Project built on the outputs and findings of Phase I to:

- Obtain a deep understanding of the basin regarding hydrological and water resources, with a focus on both flood and drought;
- Perform a detailed basin characterisation;
- Identify hotspots of flood and drought problems;
- Support the development of potential interventions with nature-based solutions; and
- Provide results with a high spatial resolution as input for 9C-9T Basin Atlas where the Basin Atlas reflects the results of the basin characterization.

These objectives require hydrological modelling as observed flow data within the 9C-9T watershed are only available at few locations with hardly any overlapping time frames.

The hydrological model of Phase I was re-activated, parameters assessed and results checked. The result of the model check revealed that what was performed in Phase I was significantly different from the requirements of Phase II. The purpose of the hydrological HEC-HMS model in Phase I was to provide input flow data for the hydraulic 2D-model, but not to deliver a hydrological model for water resources assessments. Since Phase II required a more advanced approach, a high-end level hydrological model had to be applied. A one-to-one continuation with the HEC-HMS model from Phase I into Phase II was neither recommended nor feasible for the following reasons:

- The spatial resolution of the Phase I model was too coarse. All objectives of Phase II require a significant higher resolution in order to account for hydrological effects and parameters depending on the actual distribution of land cover, soil and topography etc.
- HEC-HMS is limited in terms of its spatial and temporal resolution, as the software has a limitation of maximum allocatable memory. In other words, spatial resolution and temporal resolution (simulation period) cannot be enhanced independently and either spatial resolution must remain coarse or simulation period short.
- The 9C-9T Basin Atlas, developed within Phase II, required a raster-based approach with a high spatial resolution. HEC-HMS facilitates a raster-based approach only for input parameters like precipitation but not for sub-basin units.
- The plain territory of the project area, in particular in Cambodia, required that the sub-surface flow and soil components should be interconnected between the sub-basin units of the model to reflect the reality of the soils and groundwater ecosystems. This was not feasible within HEC-HMS.

Results of the model facilitated the Basin Atlas approach, which means detailed raster-based results were required. This was not possible within HEC-HMS effectively. The HEC-HMS was not calibrated in Phase I. It was used only for storm event-modelling but was not checked against observed flow.

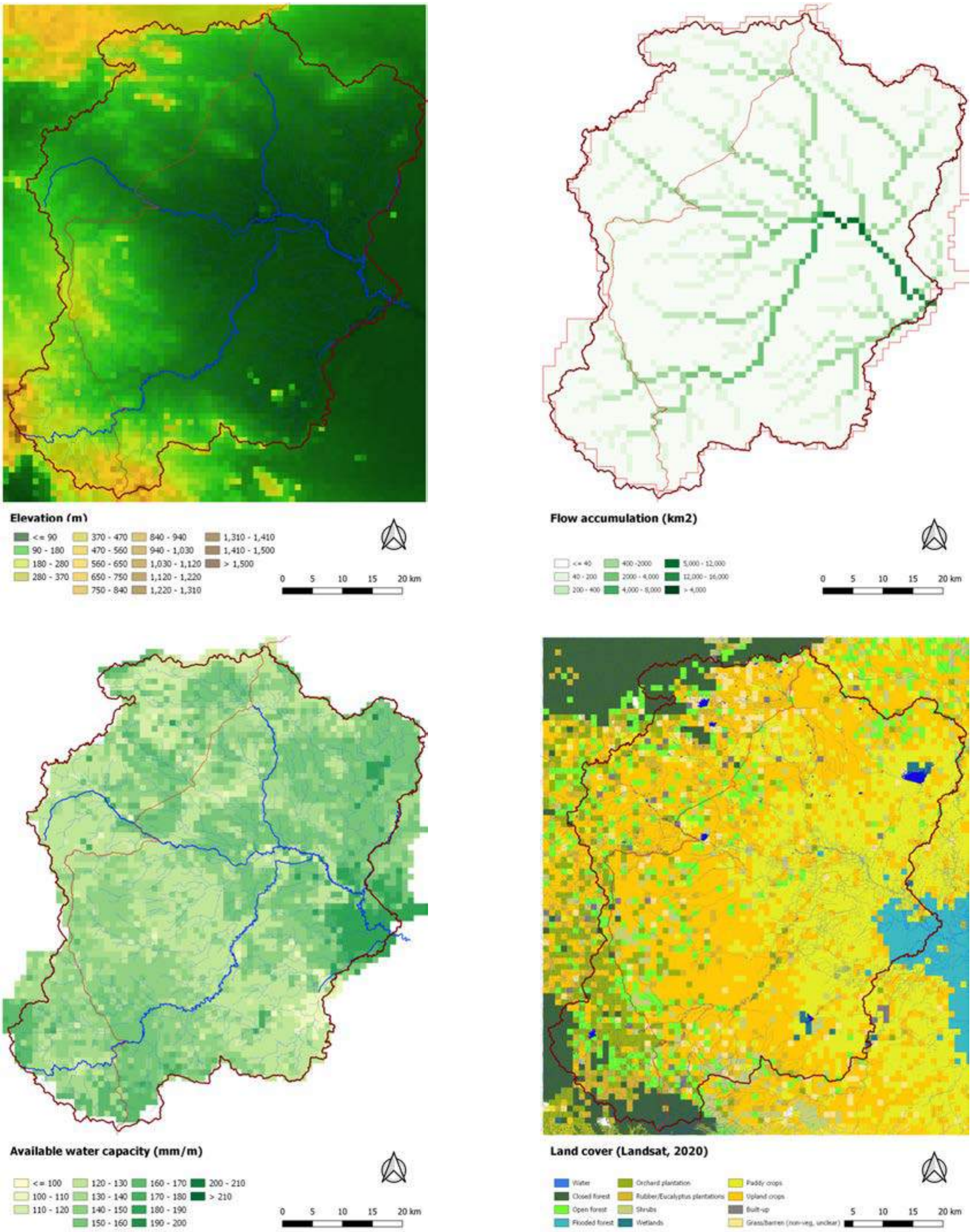
In addition to the hydrological model, a 2D hydraulic model based on HEC-RAS was developed for a detailed analysis of flood mitigation at Poipet. This was model is not linked with the HEC-RAS modelling in Phase I because the level of detail was much higher as it focused only on the Khlong Nam Sai (river) passing by Poipet.

The main sources of data used to set up and calibrate the 9C-9T hydrological model are presented in Annex 1.

2.4 Model output within the 9C-9T Joint Project

The setup of a distributed, physically-based hydrological model contributes to the basin characterisation as water-relevant features of a watershed are structured, assessed and implemented in the model. Topography, flow direction and flow accumulation, as well as physical soil properties and land use characteristics, are the most important parameters. Examples are presented in Figure 3.

Figure 3: 9C-9T model parameters for elevation, flow accumulation, available water capacity and land cover



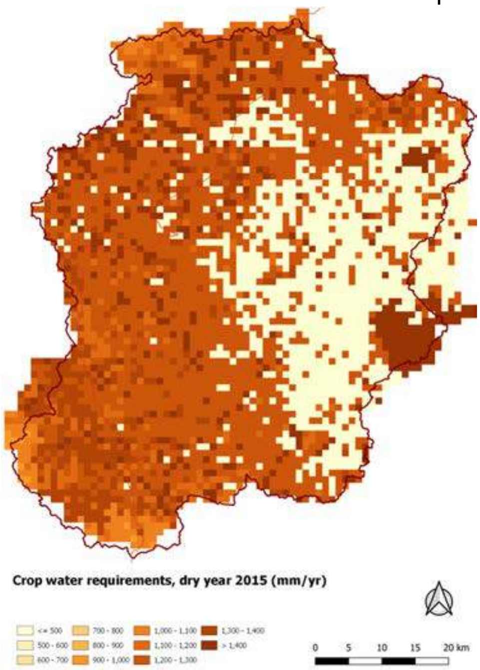
Physical soil properties in conjunction with land use determine the water holding capacity, infiltration, actual evapotranspiration and percolation, as well as soil retention. With this input in combination with long-term climate data, all components of a water balance can be calculated. This is important to understand the surplus and deficit of water during the course of a hydrological year, from month to month, or to identify the effects of wet and dry years.

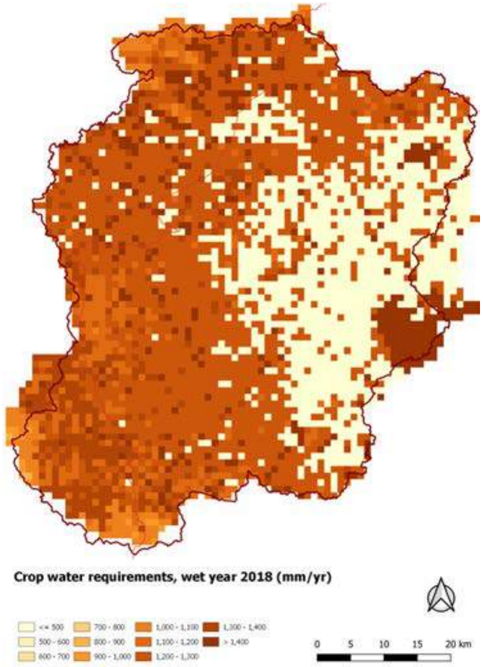
Example model outputs are shown in Figure 4 by comparing the 2015 dry year with the 2018 wet year. Crop water requirements or crop evapotranspiration is rather constant, as the potential evapotranspiration does not differ significantly. The value is determined by the land use/crop type and its growing stages. Percolation can be used to identify areas suitable for groundwater use/abstraction, assuming an aquifer exists in that area. Crop water deficit shows the difference between crop water requirements and actual evapotranspiration and is an indicator of water stress.

Figure 4: 9C-9T model parameters comparing the 2015 dry year with the 2018 wet year for available water, percolation, crop water deficit

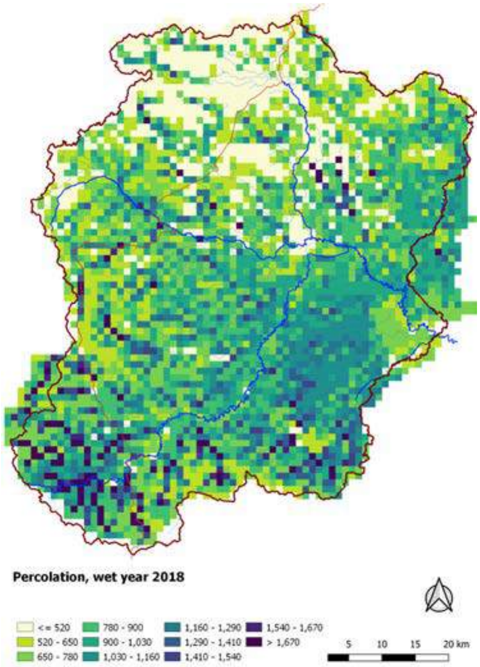
Dry year	Wet year

Actual crop evapotranspiration mm/a



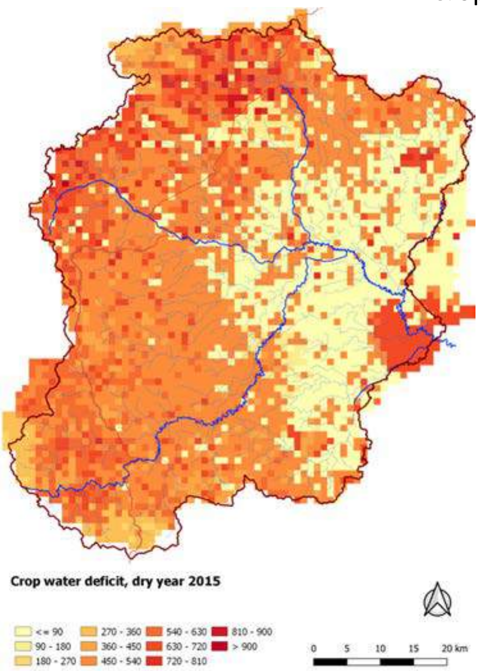


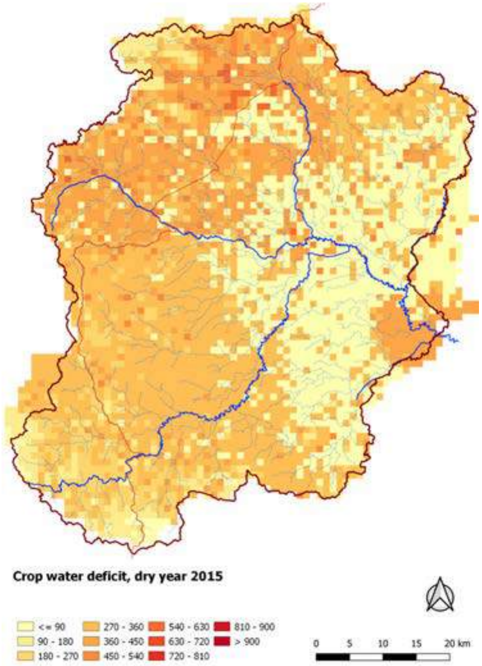
Percolation



Dry year	Wet year

Crop water deficit

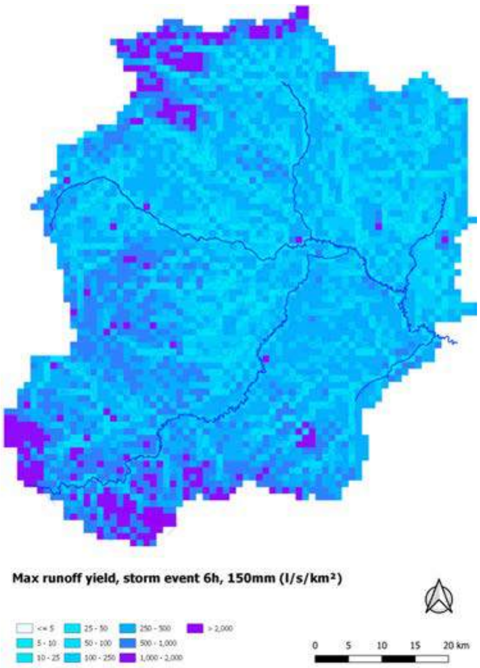


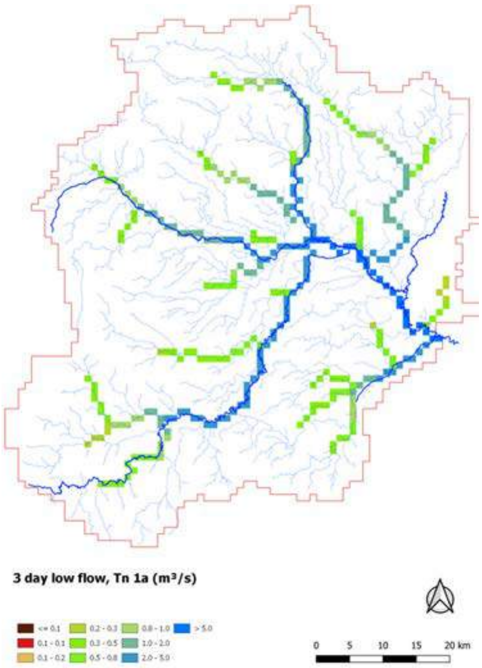


Maximum runoff yield (Figure 5) reveals areas where the combination of topography, soil and land use have a potential to generate high runoff rates. It should be noted that these areas are not necessarily areas with high flood risk. These results are generated by applying a homogeneous storm event for the entire watershed for a given duration and rainfall intensity. The runoff for each grid cell is then analysed.

The last example of results shows low flow conditions as they would occur under natural conditions (Figure 5). This helps identify which streams would fall dry for a given duration on an annual basis and serves as a first indication of environmental flow conditions.

Figure 5: 9C-9T model outputs for max runoff yield (L) and low flow conditions (R)





3 DEPLOYMENT OF THE TALSIM-NG 9C-9T HYDROLOGICAL MODEL

The deployment history of the Talsim-NG model application within the 9C-9T sub-basin includes:

- Setup of the model based on the digital elevation model from National Aeronautics and Space Administration (NASA) 30x30m resolution, ISRIC soil data (www.iscric.org), land use data from European Space Agency (ESA) satellite images as main input sources;
- Calibration based on observed streamflow at Sisophon obtained from MRC;
- Plausibility checks with regionalization methods of streamflow data from surrounding watersheds;
- Support the basin characterisation of the 9C-9T sub-basin in Phase II (2020-2021);
- Identification of hotspots for flood and drought;
- Support for the conceptualisation of flood and drought mitigation measures;
- First training workshop based on Talsim-Light, an excel application that covers an excerpt of the entire 9C-9T watershed; and
- Training intensive with deployment of the software to the MRC IT environment and installation on computers of MRC modellers.

3.1 Deployment for MRCS

The technical specifications and steps for deployment of Talsim-NG as a client-server tool is outlined in the following sub-sections.

3.1.1 Server side

The model transfer is fundamentally based on a few core server pre-requisites, including:

- Availability of a virtual or a physical server based on Microsoft (MS) Windows;
- Accessibility of the server by virtual remote connections with administrative credentials;
- Storage on the server ideally > 100GB to accommodate time series, datasets and possible results for exchange between users;
- Upload and download speed with a minimum of 5 Mbps. The upload rate determines the server's capacity to provide both time series and results;
- Microsoft Access available on the server. If not available, the configuration of the Talsim-NG server database can be completed externally and the final Access database *.mdb copied to the server;
- The server requires the .NET framework 4.8;
- The server requires the Microsoft Windows Communication Foundation (WCF) framework. WCF is usually part of a Microsoft Server installation. It must be activated if not already;
- The installation of the operating system should be English; and
- Installation of Notepad++ as American Standard Code for Information Interchange (ASCII) Editor for editing configuration files.

The Talsim-NG server can work with an encapsulated environment. This means the server does not need any connection to the intranet in which the server is hosted. The only prerequisite is access to Internet. This ensures that no malicious software can enter the host's space.

The requirements for making backups of the Talsim-NG server environment can be based on a simple process of compressing the data repository in regular intervals, ideally on an external hard drive. It is recommended to apply a synchronization tool which saves only changes. Users must also be established on the server side. This requires a) to create the necessary folders for each user to make the server work and b) to add a user in the Talsim-NG server database.

3.1.2 Client side

A Client requires the installation of Talsim-NG Client software (currently version 4, soon version 5). Each Talsim-NG user requires such an installation. The installation requires administrative credentials.

The Client-side prerequisites are:

- Storage on the Client-side is ideally > 100GB to accommodate time series, datasets and results;
- Upload and Download rate with a minimum of 5 Mbps. The upload rate determines the Client's capacity to upload time series and results to the server. The download rate determines the Client's capacity to receive data from the Talsim-NG server;
- The Client requires the .NET framework 4.8;
- The installation of the operating system should be English;
- Installation of Notepad++ as ASCII Editor;

The Client requires a specific date/time format (dd/mm/yyyy hh:mm) and "." as decimal symbol. Note, the American way of writing a date with preceding MM does not work.

3.2 9C-9T data transfer

Both the server and the client have basic hardware requirements. State-of-the-art computers fulfill the needs of Central Processing Unit (CPU) speed, memory, processor. Recommended specifications include 16 GB RAM, 64-bit operating system and >1.5 GHz processor. The Talsim-NG server runs 24/7 and it is recommended to use a server operating system such as MS Server R2016 or later.

3.2.1 Server side

Once all pre-requisites at the server side are fulfilled, the transfer can take place. Transferring the Talsim-NG server and the data is a simple copy-paste process to the server's machine. All required tools that are not Microsoft products are shipped with the package of the Talsim-NG server. The configuration files are Extensible Markup Language (XML)-based formatted ASCII files which can be edited with a standard ASCII Editor like Notepad++.

3.2.2 Client-side

The data repository for the Client is also a simple copy-paste process. However, the amount of data that needs to be transferred is large, especially if all results are copied. Therefore, a link was provided from where the data can be downloaded. In theory, the data can be copied to any place on the Client's hard drive. In practice, a clear structure is recommended to a) ease the configuration process and b) to enable a seamless connection to the Talsim-NG server. The configuration that enables the connection from Client-to-Server depends on the location where Talsim-NG datasets are copied to. If the default path is used, no adaptation of the configuration is needed.

3.3 9C-9T modelling intensive training

A Modelling Intensive training workshop series was conducted for a small group of specialized hydrological modelling staff of MRC. The workshop was carried out in English and led by the developer of the Phase II hydrological model, Dr Hubert Lohr. The aim of the workshop was to install the Talsim-NG 9C-9T model server into the MRC IT environment and to familiarize MRC modelers with the model, in particular outlining opportunities of what the model can offer. In that, the workshop differed from typical hands-on trainings on how to use the model.

The objectives of the hydrological model transfer and training included:

- Deploy the Talsim-NG 9C-9T model on the MRCS server and the client software for MRC staff;
- Provide training on the technical IT elements for hosting both the Talsim-NG Server and Client, including requirements for transferring, installing and hosting the model to the MRC server;
- To develop an understanding of the opportunities of the client-server model architecture of Talsim-NG;
- Identify prerequisites and concepts of hydrological modelling for the 9C-9T sub-basin, including benefits, strength and limitation;
- To develop an understanding of different approaches for applying the software and its post-processing features, including implications for the 9C-9T sub-basin; and

- To develop an understanding of the opportunities of linking the model to the time series data repository of MRC.

The content of the training is listed in Table 1. Further details on the training are provided in Annex 2.

Table 1: 9C-9T hydrological modelling training content

Session	Topic	Participants	Duration	Outcomes
1	• Deployment of Talsim-NG Server on an MRC computer • Configuration of the server • Understanding of the data management • Creating new users	IT staff from Flood and Drought Centre/MRCS HQ	3.5 hrs.	• The server was installed on a virtual machine in the MRC environment with internet access • User administration was explained • Data concept and software architecture was introduced *Comment*: At the time of training, the computer on the MRC server does not yet allow full communication with Talsim-NG clients. One component of WCF communication was not working well and must be checked
2	• Installation of Talsim-NG Client • Configuration • Data management	MRC flood and drought centre modelers	3.5 hrs.	• Installation performed • Clients opened and connection to the server established • Data concept and software architecture was introduced. *Comment*: For the time being, a server on the internet hosted by Sydro is used until the problem is solved (see Session 1)
3	• Training on Talsim-NG Client • Options of how to perform simulations • Using the Client efficiently • Application of additional tools	MRC flood and drought centre modelers	4 hrs.	• Introductory example applied • Data structure explained • Principles of server connection and exchange with other users explained • Wave (time series manager) introduced)
4	• Training on 9C-9T model • Practical use what has been demonstrated in session 3	MRC flood and drought centre modelers	3 hrs.	• Datasets explained • Export of datasets demonstrated • Using datasets in and outside the graphical user interface demonstrated • Practical exercises.
5	• Training on Talsim-NG Client • Practical use what has been demonstrated in session 3, e.g., bring results to GIS, etc.	MRC flood and drought centre modelers	3 hrs.	• Simulation runs in and outside the GUI performed • The concept of using datasets for automation introduced • Practical exercises
6	• Training on 9C-9T model • 9C-9T model	MRC flood and drought centre modelers	3 hrs.	• The 9C-9T model demonstrated • Selecting a sub-set of the 9C-9T model and perform a simulation run • Using add-ons introduced

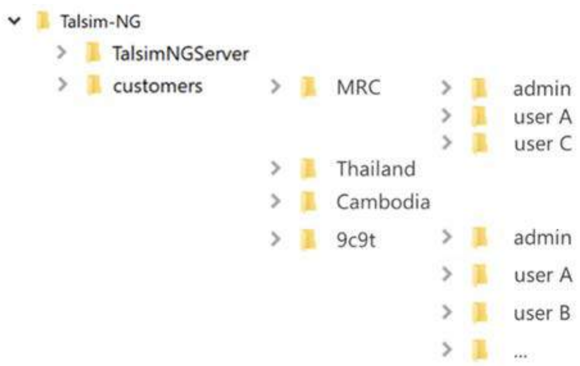
4 MANAGEMENT AND UPDATES OF THE TALSIM-NG SOFTWARE

As introduced above, Talsim-NG is based on a client-server architecture. Data management differs between the server-side and client-side.

4.1 The structure of the server

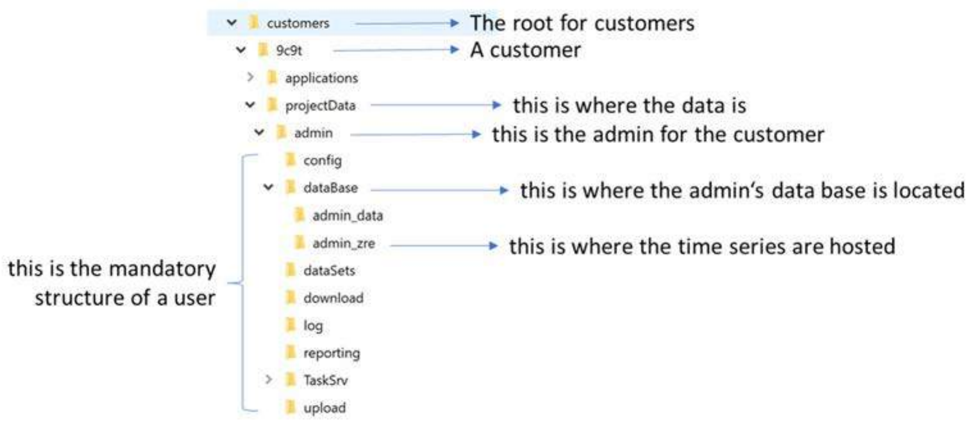
The server is capable of administrating one or more so-called customers. A customer has its own set of time series, long-in information and a group of users. A user can have access to one or more customers. The purpose of having more than one customer is to allow for different time series repositories and user groups in parallel. **The approach is entirely flexible on how many customers a server will host. A use case could be to separate MRC, countries and the 9C-9T watershed, to grant access rights only to specific user groups.**

Figure 6: Customer structure



Again, this is an example and it is 100% customizable. The structure of a customer is organized according to the following layout presented in Figure 3.

Figure 7: User structure



There is one admin per customer. This is the location where the time series repository of a customer is hosted. The data on the server-side for each customer is:

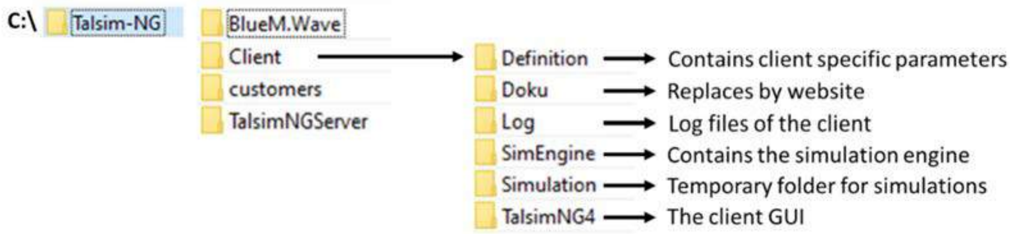
- User and log-in information;
- The time series repository accessible for those who have the credentials to log in to a specific customer; and
- Uploads from a client to make projects/simulations accessible for other users connected to the same customer.

The most important aspect in the day-to-day work is the centralized time series management that enables users logged-in to the same customer, to access always updated time series. Uploads, corrections, extension of timeseries is done once by one designated user and all other users are updated automatically when using this timeseries.

4.2 The structure of the client

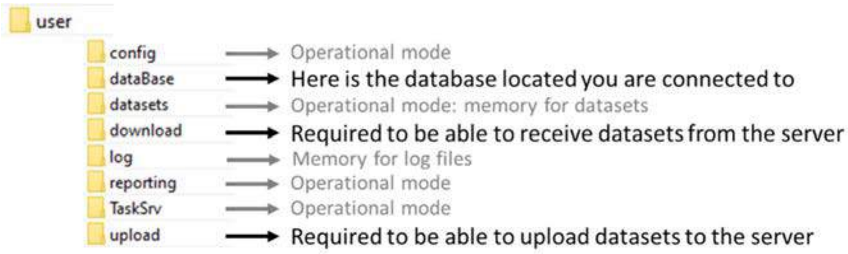
The typical structure of the Talsim-NG client is illustrated in Figure 5.

Figure 8: Talsim-NG client structure



The default installation of a client will create this folder structure where only the software and tools are located. Tools and data are separated. A typical structure of how data is organized is shown below.

Figure 9: Data organisation



Below the root folder "user" the structure is mandatory and automatically created for one user during installation. The client's database is behind the folder database and contains all information for one or more projects and associated simulations. Currently, the database is MS Access but will be replaced by SQLight database in the next update due to performance reasons and due to sometime unwanted interactions with MS Office packages.

When a user connects to the server and requests access to a customer, the client must provide a username and a password.

While working with the client-server architecture, the memory of the client grows, meaning that each time a time series is requested from the server, it is subsequently memorized by the client and stored locally. Before a timeseries is used at the client-side, client and server check whether a new version of the timeseries is available. If yes, the new version is downloaded. If not, the client uses the already available timeseries. This way, the client enhances its memory and access time is minimized.

A user has to decide during the login process which customer he/she wants to be connected to. Once a customer is selected, the user gets access to this time series repository which is associated with the selected customer.

4.3 Installation and deployment of the software

The installation has two components: i) the server and ii) the client software.

4.3.1 Server installation

Installation of the server software is typically done at one location and is a process of unzipping files into a root folder. The default root folder is: *C:\talsim-ng*

If this is not possible or the administrator wants to install the server at another location, the files can be unzipped to any other location. In this case, the XML configuration file *TalsimNGSrv.exe.config* must be adjusted. The config file can be opened by any text editor and the variable "RootDir" must be adjusted and changed from *c:\talsim-ng\customer* to *<new root path>\customer*. It is important to note the "\" at the end.

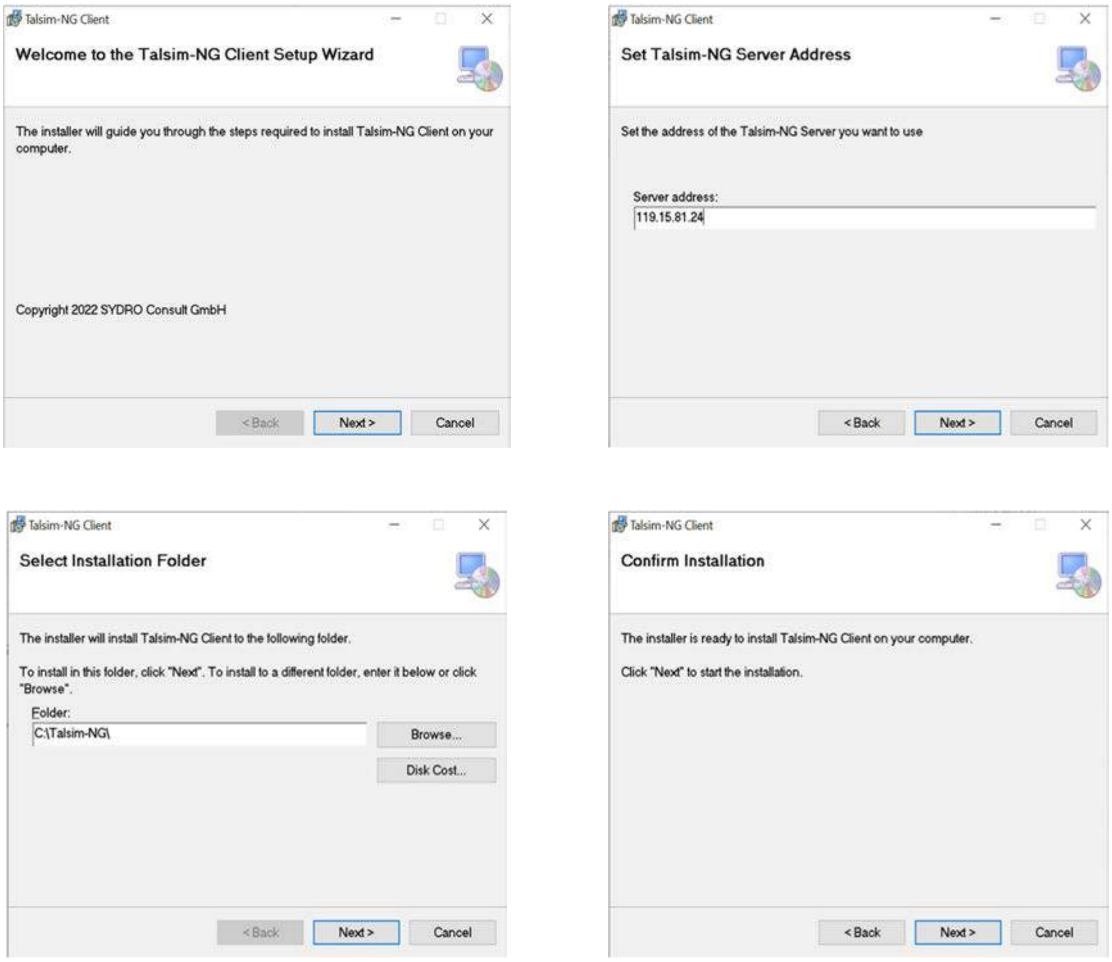
As long as the server and all clients are within the same domain (intranet) no further specifications are needed. However, if the server runs behind a proxy or clients connect via internet (not intranet), then the firewall must be adjusted to allow access to the ports and the proxy must be enabled to let the server communicate without credentials. The current client version cannot connect to the server if proxy authorization is required.

The WCF component must be enabled on the server computer. This is the software that the server uses for communication. WCF is installed on all Window machines and usually active by default. However, it is recommended to check.

4.3.2 *Client installation*

The installation process of a client is guided by an installer. The installer guides the user through all steps and makes adjustments in the configuration automatically according to the user definitions.

Figure 10: Client setup and installation steps

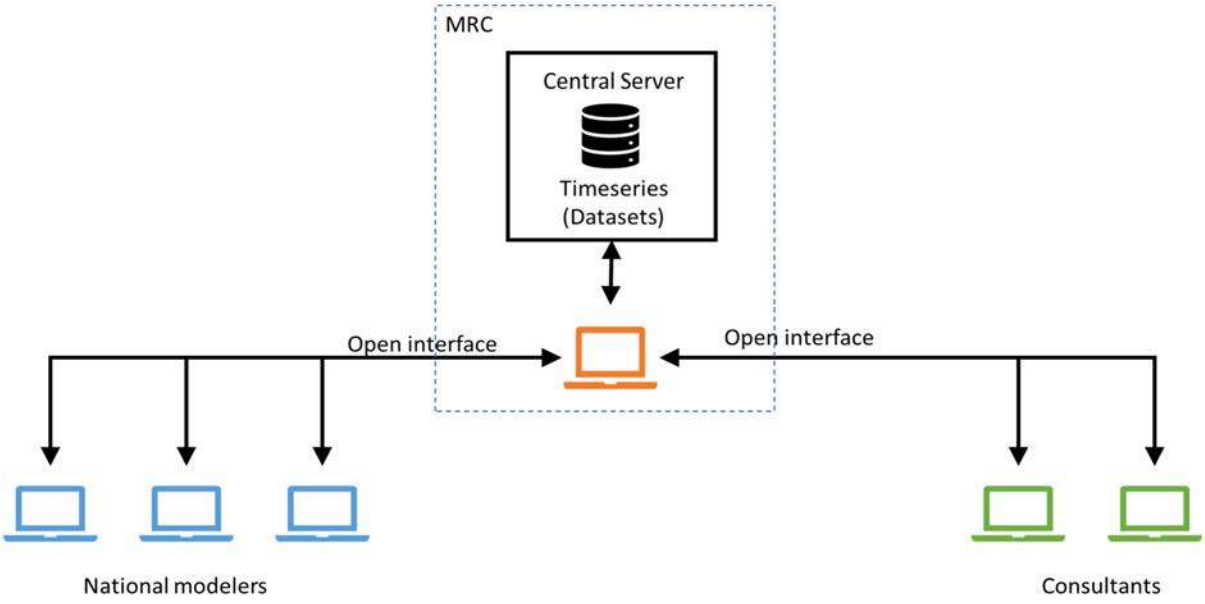


By default, the installer sets the root path to c:\talsim-ng\. The server and the client use the same root but on different machines. This is mentioned to avoid any confusion.

4.3.3 *Visualization of the client and server architecture*

The architecture of server and client is illustrated in Figure 7. In theory, a client can be connected to different servers but only one at the same time. When the client is started, the IP address in its configuration file decides to which server the client should establish a connection. If this IP address is changed, the next time when the client starts, it will try to connect to the new server. This opportunity would enable clients to connect either to MRC or a Talsim-NG server hosted in the respective country.

Figure 11: Server architecture



4.4 Updates

Updates are facilitated through downloadable files for both the server and/or the client. A download is organized so that the user only has to unzip the new content, assuming the first installation process is already finished and the location where the software is installed is clear.

Updating the server is rarely needed, when new endpoints for communication with the Talsim-NG client are required. Data on the server side is not affected during updates. **An update of the server means that the Talsim-NG server is not available during the unzip and copy process.** Since this process usually takes a few seconds, no serious disturbances can be expected.

Updates related to the client can affect the graphical user interface but also the simulation engine. Local datasets and results at the client side are not affected through updates. A backup of the local database is created prior to any update process, so that a history of databases is held at the client's computer automatically. Updates at the client-side cover new parameters and algorithms, new features, bug fixes and performance changes of the simulation engine.

Updates require that a user is subscribed to the Talsim-NG user list. Only subscribed users are informed about news and updates.

4.5 Maintenance and support

Maintenance and support are possible through three main channels:

1. Talsim-NG documentation and PowerPoint presentations through the Talsim homepage www.talsim.de[1];
2. YouTube tutorials accessible through the Talsim-NG homepage; and
3. Direct support through SYDRO Consult (www.sydro.de, developer of Talsim-NG).

Direct Support requires a maintenance contract with SYDRO. Maintenance can come at different levels that are individually determined. The cost of a maintenance contract depends on the hours requested direct support. Currently, one hour of support costs 80 USD.

Talsim-NG virtual meetings are held occasionally. Topics and date are disseminated via the homepage and to all subscribers in advance. Training courses on site are possible on request.

[1] Note, the Talsim-NG documentation will move soon to a new place with a new look and feel and extended information

5 OPPORTUNITIES FOR FUTURE MODEL DEVELOPMENT AND DEPLOYMENT

Talsim-NG is constantly maintained. The change-log of Talsim-NG provides information about new features, changes to existing components or bug-fixes. The change-log is delivered during the installation process.

Recent development of new features comprises more complex options for simulating irrigation, nested modelling, ecohydrological components to model wetlands and a conceptual groundwater module. Planned features include the enhancement of the groundwater module to account for Darcy's law and hydraulic head, better connectivity of deep subsurface flow and groundwater.

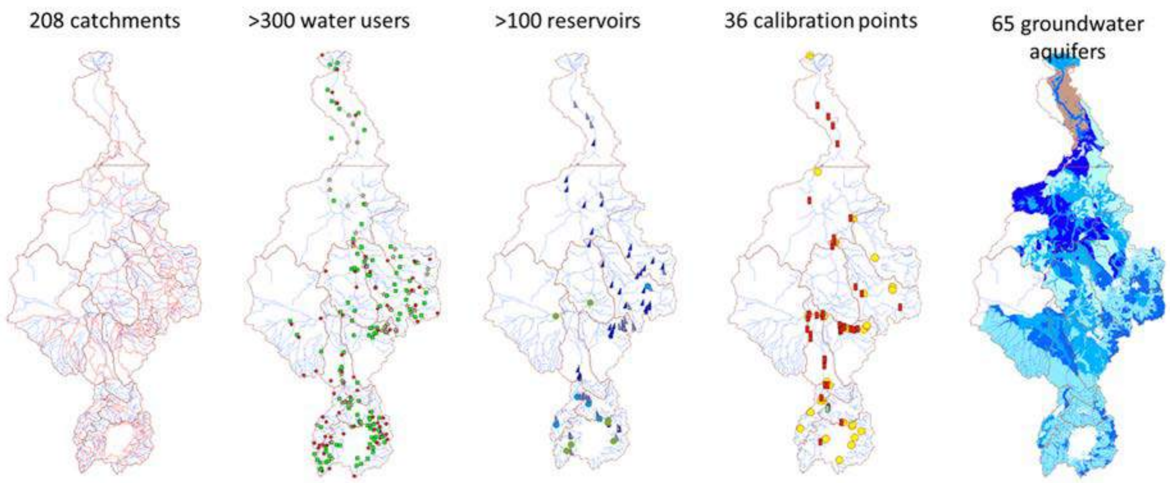
A currently implemented feature is the option to use netcdf as input and output format. The next release will contain this option.

The update from the current version 4.0 to 5.0 as one of the next steps will mark a milestone from the viewpoint of the graphical user interface. Talsim 5.0 comes with a more GIS like view with shapefiles or maps that are accessible through web-services, e.g., Google satellite or similar. In addition, the change to 5.0 will also mark the end of MS Access as database and the introduction of SQLight databases. A separate tool will convert old databases to SQLight if required.

5.1 Examples from other basins

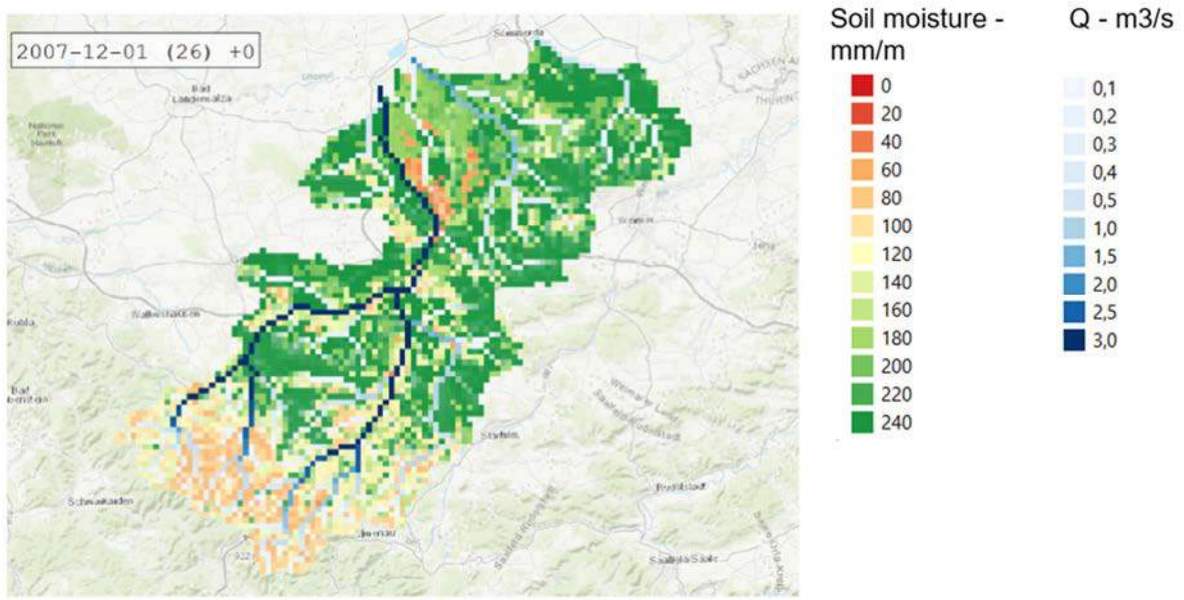
Talsim-NG is widely used for operational purposes but also for studies and assessments. The largest application in terms of the watershed is the Nile Basin. The Nile model includes **rainfall-runoff modelling, flood routing, irrigation, water provision for urban areas, groundwater, reservoirs and reservoir operation**. This model was developed as part of the Strategic Water Resources Analyses of the Nile as a key component to support the Nile Investment Program, scenario development and climate change assessments.

Figure 12: Nile Basin model components



Operational applications comprise early warning systems or forecasting systems such as the model of the Federal State of Thuringia in Germany, the River Werra forecasting model and other catchments where reservoir operators use the tool for early warning and forecasts.

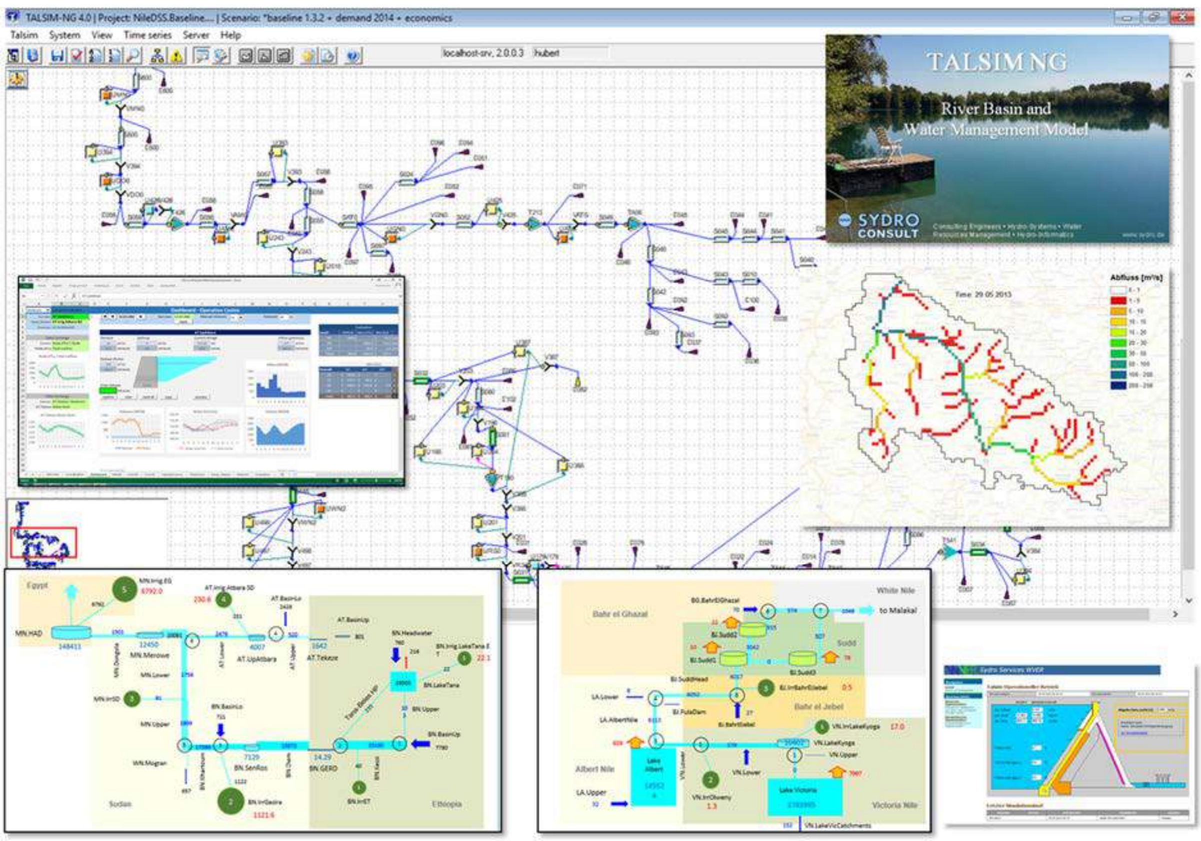
Figure 13: River Werra forecasting model



Talsim-NG can run as stand-alone product or under the Delft-FEWS (C) Deltares software framework. The operational use usually requires the pre- and post-processing toolset of Talsim-NG as well. Talsim-NG must have access to the Internet if satellite rainfall estimates or other internet-based sources are used. The current phase of the 9C-9T has not incorporated satellite rainfall estimates, forecasts or climate change projections.

Depending on the configuration, different views are possible, which are facilitated outside the typical graphical user interface and require configuration in order to be linked to either the Talsim-NG Server or interact with the Talsim-NG engine performing simulations.

Figure 14: Talsim-NG Nile configuration



5.2 Specific opportunities for 9C-9T sub-basin

Specific development related to the 9C-9T could embed the following topics:

- *Connect the Talsim-NG server with the near-real time climate data repository at MRC and facilitate the regular and automatic update of precipitation and temperature time series*

  This would be a useful activity if the use case is to apply Talsim-NG in operational mode as a **forecasting tool**. Since MRC has already developed the work flow to obtain rainfall estimates and forecasts, the 9C-9T Talsim-NG model could be linked to obtain the data from this workflow and enhance its own data repository. Configuring the Talsim-NG environment and connecting it to MRCS flood and drought forecasting data may be possible. MRC predominantly uses standard formats and processes and runs the Delft-FEWS platform, under which Talsim-NG can be integrated, as Talsim has a Delft-FEWS adapter.

- *Perform calibration and validation runs to update, improve and verify the model as new observation data evolves*

  The 9C-9T watershed has very little streamflow observations. Only one station at Sisophon, Cambodia, has a flow timeseries which is available and long enough to be used for calibration. The available time step of one day is sufficient. The review of the calibration process and its expansion to other tributaries within the 9C-9T would bring significant performance improvements. Although the observations at Sisophon are good, there are still many unobserved catchments where results could not be cross-checked and compared with observations.

- *Enhance land use and crop data to obtain crop water requirements with a high spatial resolution*

  The current approach of land use and crops is based on Landsat satellite images. The Landsat land use classification and crop classification does not distinguish much between different crop types and plants. It would be an advantage to enhance the categories of plants and crops by means of updates or through more detailed information. A higher spatial resolution is only meaningful if it comes with additional details about the land use to distinguish different land use types.

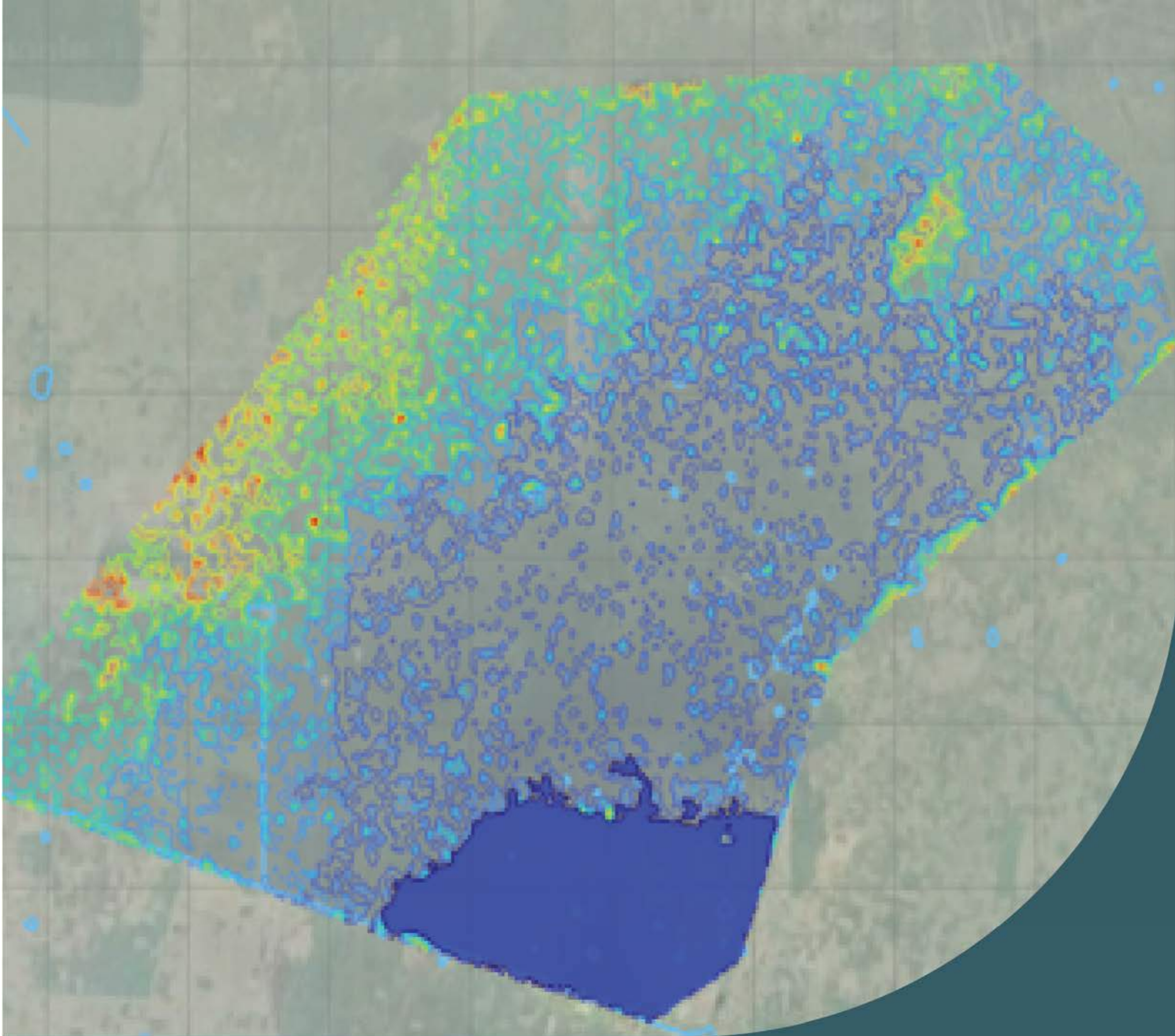
- *Conceive use as a decision support system (DSS) in combination with climate proofing of water infrastructure*

  Long-term simulation runs based on historical and bias-corrected climate change projections could offer a useful strategy to undertake climate proofing for the development of water infrastructure. This is a state-of-the-art approach. Integration into the MRCS DSS depends on the input that is available in the DSS.

- *Reservoir operation*

  Reservoir operation is a further strength of the Talsim-NG model, since it was originally developed for this purpose. A first application could be to undertake a review of existing operation rules. Climate change impacts on reservoir operations are expected and simple rule curves have difficulties coping with increased climate variability. This calls for more complex rules and the integration of mid-term to seasonal forecasts.

If further application of the model within MRC is supported, additional configuration/enhancement would be required to enable operational use, which is currently not within the scope of the 9C-9T Joint Project. This would also require additional training sessions.



ANNEX 1. 9C-9T HYDROLOGICAL MODEL DATA AND CALIBRATION

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

9C-9T hydrological model data and calibration

Data sources

The main sources of data used to set up the 9C-9T hydrological model are presented below:

30x30m SRTM digital elevation model

Land use land cover

Landsat land cover 2017 and 2020 with the following different land cover types:

Soil data from ISRIC (https://maps.isric.org/)

- Bulk density
- Soil texture (sand, silt, clay) for 6 layers

River flow network (ICEM database)

Model load for simulation

Precipitation timeseries (all from MRC)

- RF.130202.Sisophon
- RF.120202.Pailin
- RF.120204.Pon Nam Ron
- RF.130201.Watthana Nakhon
- RF.130204.Aranyaprathet
- RF.130208.Bavel
- RF.130305.Battambang
- RF.440003.Taphaya
- RF.440015.Khok Soong

Temperature

- World Clim

Evapotranspiration

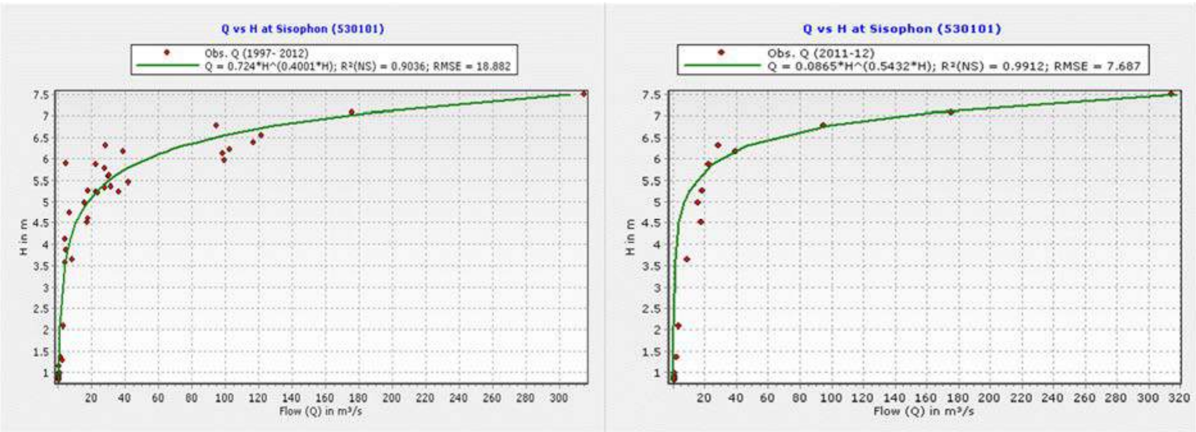
- Calculated with the approach of Blaney-Criddle and Turc and checked against Royal Irrigation Department (2015), Water Allocation Work Manual, Volume no. 7, Determination of Crop Water Requirement

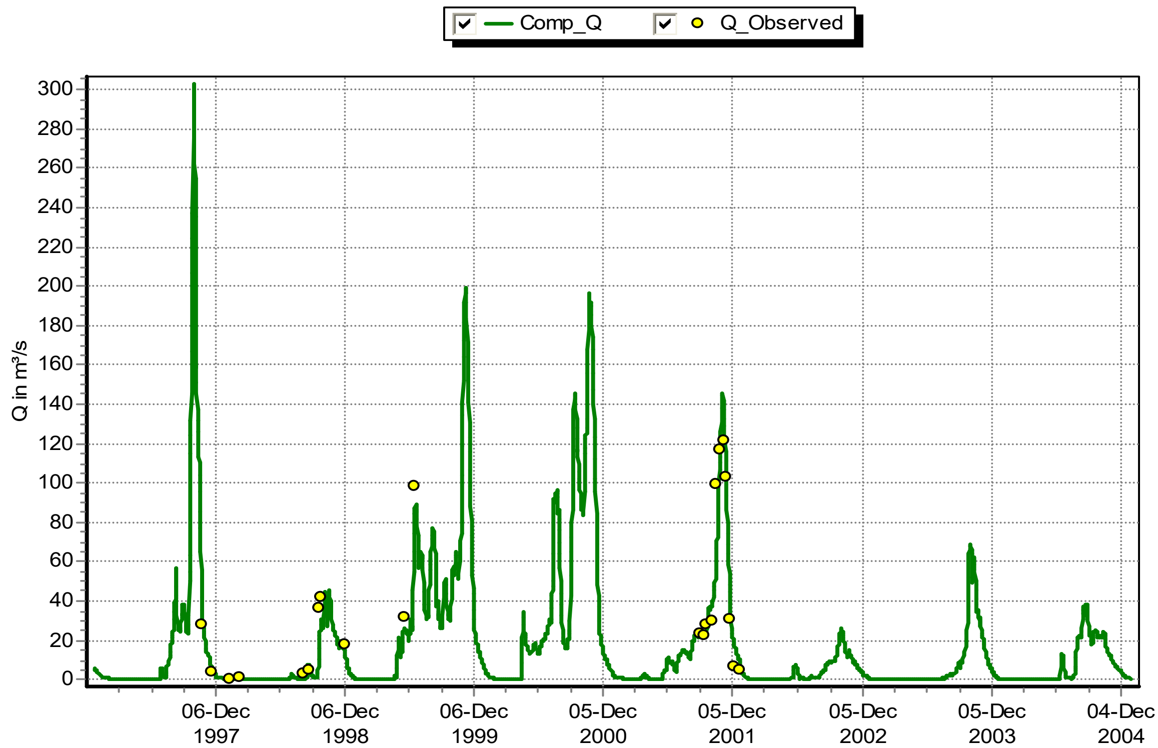
Streamflow

Royal irrigation Department (RID), Thailand

Name	Stream	Local River Basin	Longitude	Latitude	District
TL.1	Huai Phrom Hod	Huai Phrom Hod	102.469	13.72	Aranyaprathet
TL.3	Khlong Pra Put	Khlong Pra Put	102.289	12.968	Pong Nam Ron
TL.4	Khlong Ta Kong	Khlong Pong Nam Ron	102.325	12.916	Pong Nam Ron
TL.5	Khlong Thani	Khlong Pong Nam Ron	102.269	12.896	Pong Nam Ron
TL.6	Khlong Thung Krang	Khlong Pra Put	102.272	13.027	Pong Nam Ron

Mekong River Commission, Sisophon





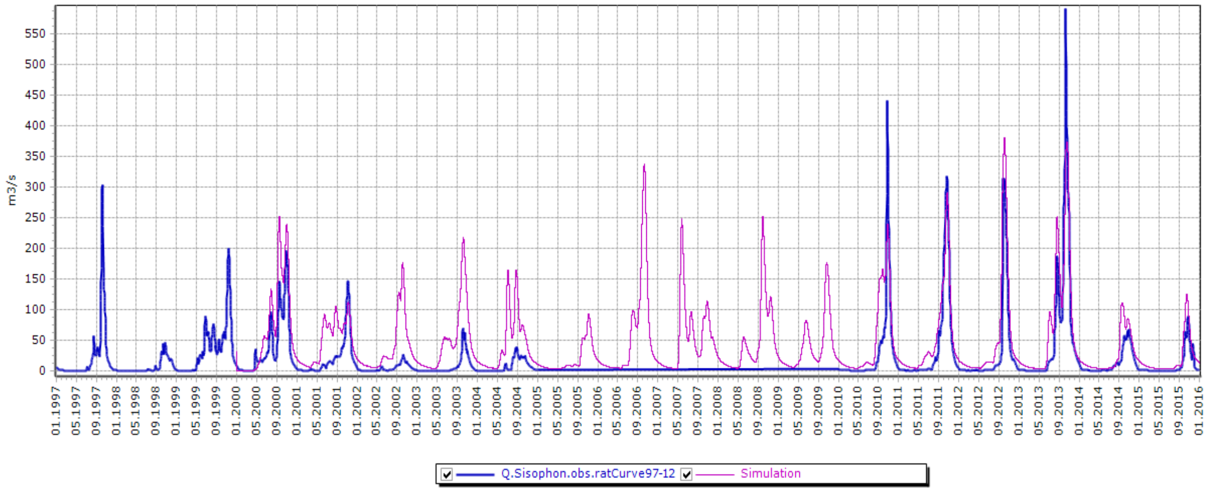
Mekong River Commission, Mongkol Borey

- All records outside the period of rainfall

Calibration

Calibration Sisophon

The streamflow station with long enough overlap with rainfall was Sisophon. The match between observed and simulated flow is illustrated below.



Regionalisation

Regionalisation compares streamflow per unit of area for different sites. In this case the following stations were analysed (see tables for Cambodia and Thailand). Not all stations are fully comparable due to differences in the topography, land use and soil. However, the comparison shows the validity of simulation results as it allows to use and compare all streamflow cells in the 9C-9T.

Cambodia

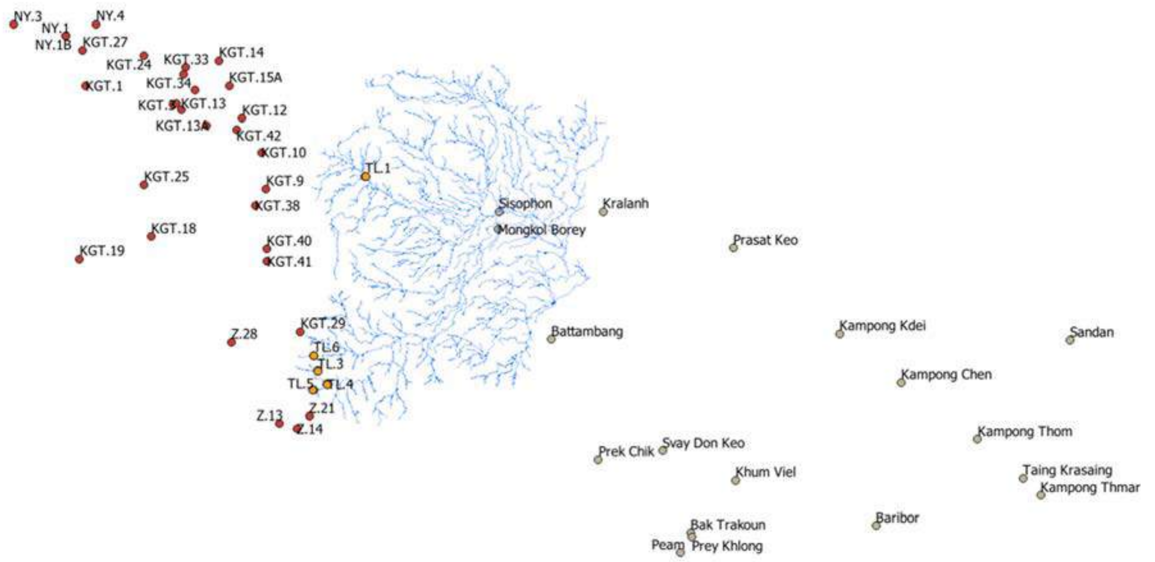
Basin	Province	Station	Years	Ae (km2)	CAM.Max Qmax (m3/s)	spec. Q (m3/s/km)
Tonle Sap Basin		St. Chinit	19	8235	601	0.073
Tonle Sap Basin		St. Sen	21	16341	1476	0.090
Tonle Sap Basin		St. Staung	19	4356	227	0.052
Tonle Sap Basin		St. Chikreng	14	2713	395	0.146
Tonle Sap Basin		St. Siem Reap	14	3618	132	0.036
Tonle Sap Basin		St. Sreng	14	9930	340	0.034
Tonle Sap Basin	Chanthaburi	St. Mongkol Borey	14	10856	303	0.028
Tonle Sap Basin	Chanthaburi	St. Sangke	19	6051	1020	0.169
Tonle Sap Basin	Chanthaburi	St. Dauntri	14	3695	260	0.070
Bangpakong Basin	Prachinburi	St. Pursat	21	5963	1264	0.212
Bangpakong Basin	Prachinburi	St. Bariob	14	7152	287	0.040

Thailand

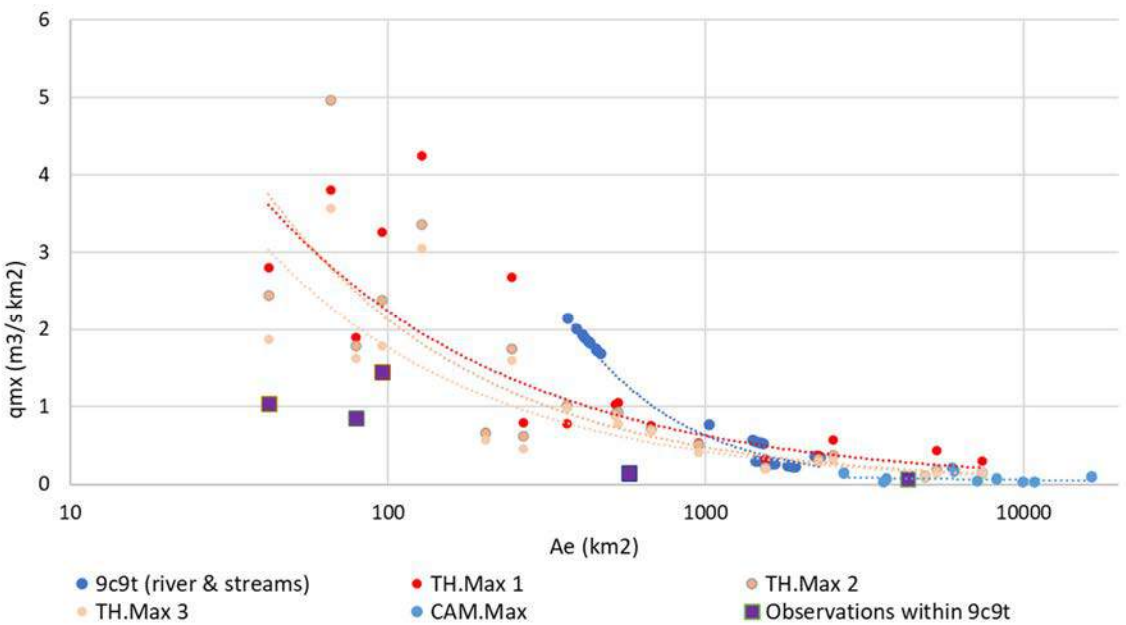
					TH.Max 1		TH.Max 2		TH.Max 3	
Basin	Province	Station	Yrs	Ae (km2)	Qmax (m3/s)	spec. Q (m3/s/km)	Qmax (m3/s)	spec. Q (m3/s/km)	Qmax (m3/s)	spec. Q (m3/s/km)
Bangpakong Basin	Prachinburi	KGT. 1	9	9209	800	0.087	798	0.087	792	0.086
Bangpakong Basin	Prachinburi	KGT. 3	76	7424.5	2220	0.299	1111	0.150	1068	0.144
Bangpakong Basin	Sa Kaeo	KGT. 9	46	2263.6	824	0.364	711	0.314	635	0.281
Bangpakong Basin	Sa Kaeo	KGT. 10	38	2523	1420	0.563	936	0.371	768	0.304
Bangpakong Basin	Sa Kaeo	KGT. 12	53	1540	487	0.316	321	0.208	308	0.200
Tonle Sap Basin	Sa Kaeo	TL.1	7	571	124	0.217	82.1	0.144	67.5	0.118
Tonle Sap Basin	Chanthaburi	TL.3	30	79	150	1.899	141.3	1.789	128.2	1.623
Tonle Sap Basin	Chanthaburi	TL.4	32	96	313	3.260	228.5	2.380	171.4	1.785
Tonle Sap Basin	Chanthaburi	TL.6	31	42	117.6	2.800	102.5	2.440	78.7	1.874
Bangpakong Basin	Prachinburi	KGT. 13	27	5347	2296.5	0.429	966	0.181	751	0.140
Bangpakong Basin	Prachinburi	KGT. 13A	20	4905.7	550.4	0.112	491	0.100	489	0.100
Bangpakong Basin	Prachinburi	KGT. 14	52	366	284.8	0.778	372.8	1.019	359	0.981
Bangpakong Basin	Prachinburi	KGT. 15	11	789	419	0.531	405	0.513	366.5	0.465
Bangpakong Basin	Prachinburi	KGT. 15A	50	530	558	1.053	489.5	0.924	412.1	0.778
Bangpakong Basin	Chachoengsao	KGT. 18	35	951	500	0.526	475	0.499	383	0.403
Bangpakong Basin	Prachinburi	KGT. 24	11	121	280	2.314	188.5	1.558	186	1.537
Bangpakong Basin	Chachoengsao	KGT. 25	12	243	123.9	0.510	107.5	0.442	68	0.280
Bangpakong Basin	Nakom Nayok	KGT. 27	16	45	126.33	2.807	91.05	2.023	89.3	1.984
Bangpakong Basin	Chanthaburi	KGT. 29	12	61	187.88	3.080	86.8	1.423	62	1.016
Bangpakong Basin	Prachinburi	KGT. 33	19	1015	364.4	0.359	353.2	0.348	342.3	0.337
Bangpakong Basin	Prachinburi	KGT. 34	13	1255	613.2	0.489	556	0.443	515.2	0.411
Bangpakong Basin	Sa Kaeo	KGT. 38	9	289	300	1.038	167.5	0.580	111	0.384
Bangpakong Basin	Sa Kaeo	KGT. 40	12	574	590	1.028	350	0.610	255.9	0.446
Bangpakong Basin	Sa Kaeo	KGT. 41	8	123	133.3	1.084	94	0.764	53.3	0.433
Bangpakong Basin	Sa Kaeo	KGT. 42	14	2558	358	0.140	328.1	0.128	297.6	0.116
Bangpakong Basin	Nakom Nayok	NY.1	14	520	776	1.492	576	1.108	525	1.010
Bangpakong Basin	Nakom Nayok	NY.1 B	31	519	535	1.031	468	0.902	452.5	0.872
Bangpakong Basin	Nakom Nayok	NY.3	42	203	134.5	0.663	133	0.655	114.8	0.566

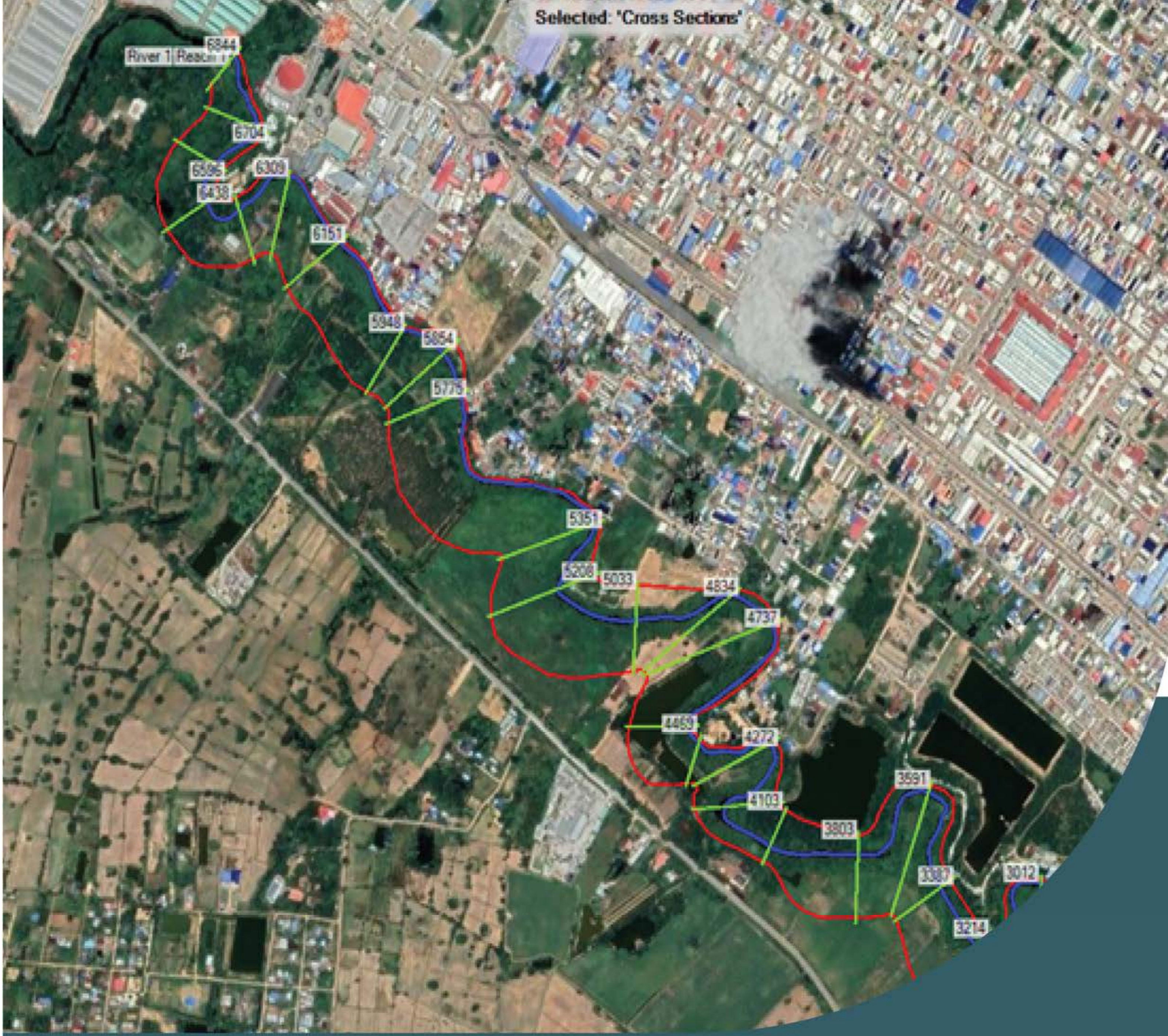
					TH.Max 1		TH.Max 2		TH.Max 3	
Basin	**Province**	**Station**	**Yrs**	**Ae (km2)**	**Qmax (m3/s)**	**spec. Q (m3/s/km)**	**Qmax (m3/s)**	**spec. Q (m3/s/km)**	**Qmax (m3/s)**	**spec. Q (m3/s/km)**
Bangpakong Basin	Nakom Nayok	NY.4	32	128	542.4	4.238	429.2	3.353	390	3.047
Eastern Coast Basin	Chanthaburi	Z.13	49	671	503.6	0.751	471.6	0.703	451	0.672
Eastern Coast Basin	Chanthaburi	Z.14	32	245	654.8	2.673	428	1.747	390.4	1.593
Eastern Coast Basin	Chanthaburi	Z.21	33	66	250.8	3.800	327.5	4.962	235.8	3.573
Eastern Coast Basin	Chanthaburi	Z.28	32	267	211.2	0.791	164.6	0.616	121.7	0.456

The following map illustrated the stations analysed for streamflow per unit of area.



The below graph shows that the 9C-9T is at the upper boundary of streamflow per unit of area, the smaller the catchments are. Small catchments in the 9C-9T are located in the headwater areas, comprising steeper slopes and higher runoff yields. The light blue dots indicate the downstream sections of the 9C-9T, with the extensive flat terrain in Cambodia close to Tonle Sap.





ANNEX 2. REGIONAL HYDROLOGICAL MODEL AND MODELLING INTENSIVE PLAN

german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

Mekong River Commission – Joint Project on Flood and Drought Management

Regional Hydrological Model and Modelling Intensive Plan

Virtual meeting

November 2022

1. Introduction

The Joint Project on transboundary cooperation for flood and drought management in the Cambodian-Thai 9C-9T Sub-basin is currently being implemented with the technical and financial support of MRCS and the German Cooperation implemented by GIZ. ICEM, COT and PPIC are providing the technical backing for the project. Based on the priorities identified in Phase I and Phase II of the Joint Project, Phase III includes a component on capacity building for the members of the National Working Group. The 1st National Working Group (NWG) meeting in September 2020 provided input on the technical topics to be covered within the Capacity Building Programme for Phase II which was subsequently endorsed in-principle by the 2nd regional Steering Committee (SC) meeting held on 3rd November 2020.

1.1. Hydrological model transfer and training

A Modelling Intensive training workshop series is now proposed, that will comprise a small group of specialized hydrological modelling staff, to further progress expertise in the 9C-9T hydrological model that has been developed using the Talsim-NG package during Phase II of the Joint Project. This will build on the previous Modelling Intensive sessions conducted across four afternoon sessions in late October/early November 2021.

The workshops will comprise a series of interactive training events conducted in English and led by the developer of the Phase II hydrological model, Dr Hubert Lohr. These will be conducted over multiple days in November 2022, with the aim to install the Talsim-NG 9C-9T model. The workshops will also familiarize MRC with the model, including outlining opportunities of what the model can offer, before it is more widely disseminated to line agencies or national committees at a later date.

Prior to any prospective model dissemination by MRC, future model deployment objective will need to be discussed and aligned with MRC priorities, activities, tools and hydrological developments. As such, it is important to note that these workshops will not provide a detailed deep dive and step-by-step guidance into the analysis and application of the model for different users in the 9C-9T sub-basin and Mekong Basin more widely.

This plan sets out the proposed approach to deploy the Talsim-NG 9C-9T hydrological model for MRCS and build familiarity around the model, and specifically outlines:

1. The objectives of the hydrological model transfer and training;
2. An overview of the Talsim-NG model, including its deployment for the 9C-9T and future opportunities of the model through MRC;
3. An overview of the hydrological modelling intensive approach, including proposed participants;
4. An overview of the workshop agenda and content; and
5. A summary of the pre-requisites to enable model transfer to the MRCS server.

1.2. Objectives of hydrological model transfer and training

The objectives of the hydrological modelling intensive are to:

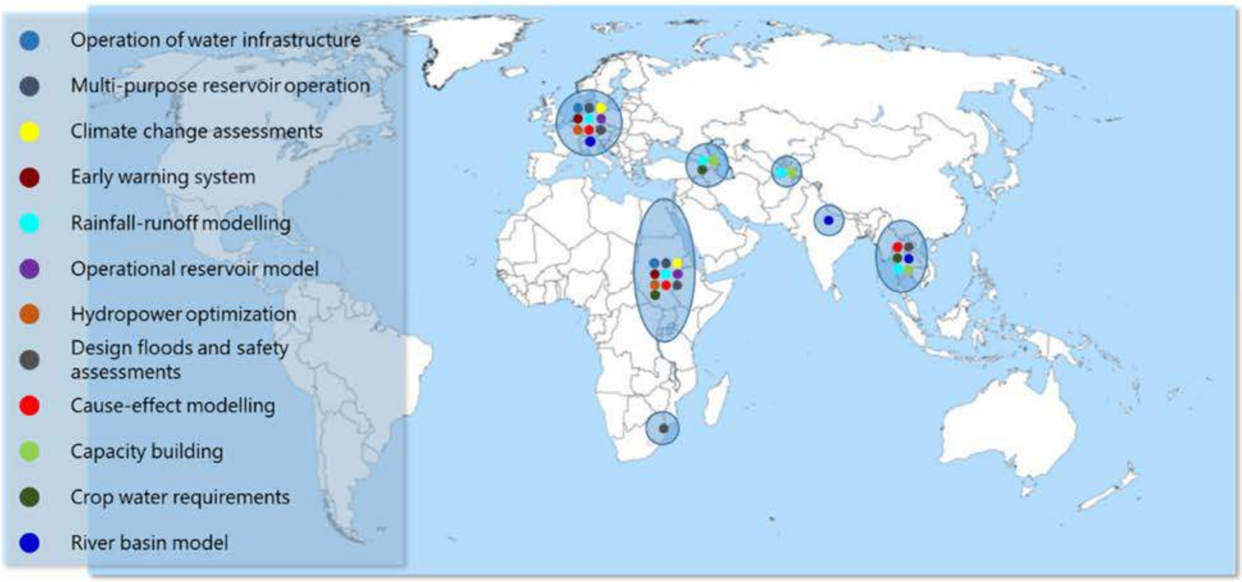
1. Deploy the Talsim-NG 9C-9T model on the MRCS server and the client software for MRC staff;
2. Provide training on the technical IT elements for hosting both the Talsim-NG Server and Client, including requirements for transferring, installing and hosting the model to the MRC server;
3. To develop an understanding of the opportunities of the client-server model architecture of Talsim-NG;
4. Identify prerequisites and concepts of hydrological modelling for the 9C-9T sub-basin, including benefits, strength and limitation;
5. To develop an understanding of different approaches for applying the software and its post-processing features, including implications for the 9C-9T sub-basin; and
6. To develop an understanding of the opportunities of linking the model to the time series data repository of MRC.

2. Overview of Talsim-NG 9C-9T hydrological model

2.1. The Talsim-NG software package

The Talsim-NG software has a wide range of applications for flood and drought management, supporting a wide range of possible modelling modules, which offer opportunities for various applications. For projects in South-East Asia, this includes capacity building, rainfall-runoff modelling, river basin modelling, crop water requirements, design floods and safety assessments and cause-effect modelling (Figure 1). The software package can be used for both baseline desktop studies and also for operational use.

Figure 1: Talsim-NG software applications and locations



2.2. History of model development in Phase II

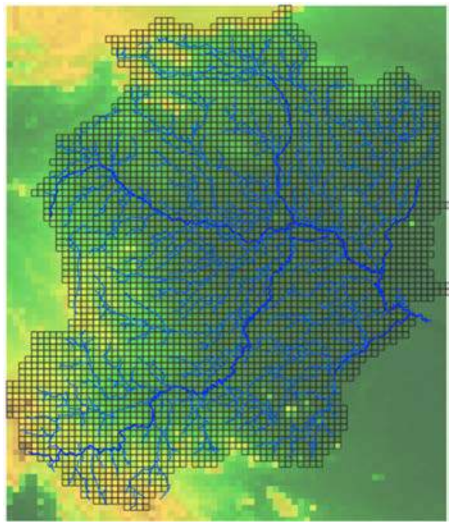
The development of the 9C-9T hydrological model arose within the Joint Project Phase II, based on the following aspects:

- Support the basin characterisation of the 9C-9T sub-basin in Phase II (2020-2021);
- Identify hot-spots of flood and drought;
- Help to support the conceptualisation of flood and drought mitigation measures;
- Support other aspects, if possible, that were determined in Phase I and were continued in Phase II such as;
    - Identification of suitable locations for hydromet and flood warning improvements;
    - River Basin Master Plan.

Detailed modelling exercises were carried out in the Phase I of the 9C-9T Joint Project. The hydrological model developed in Phase I was coarse (48 catchments) and was not sufficient for the requirements of Phase II. Therefore, a raster-based model with 4298 catchments (using 2x2 km grid resolution) was established as part of Phase III.

Hydrological model resolution Phase I

Hydrological model resolution Phase II

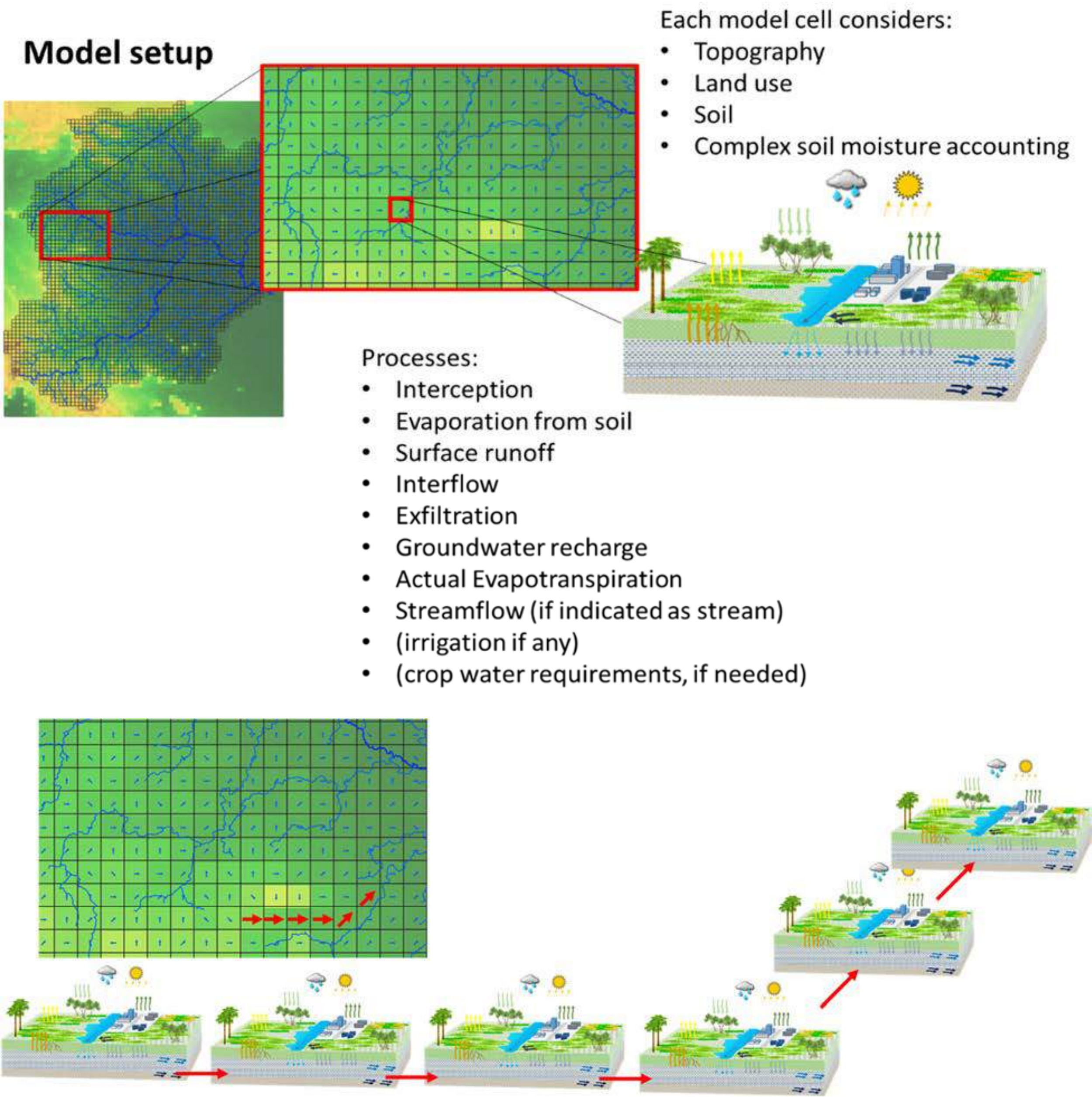


2.3. The Phase II hydrological model of the 9C-9T sub-basin

The main Talsim-NG hydrological model features for the 9C-9T sub-basin are summarized below (Figure 2 illustrates the model setup):

- Spatial resolution with 2x2 km grid with 4298 catchments;
- Temporal resolution (time step is 24h);
- Soil texture from the International Soil Reference and Information Centre (ISRIC) platform with six soil horizons;
- Soil texture data translated to physical soil properties, including wiling point, field capacity, saturation and permeability;
- Land use data from Landsat 2020;
- Integrated crop water requirement calculations, following the FAO approach; and
- Interlinked surface and sub-surface flow between catchments.

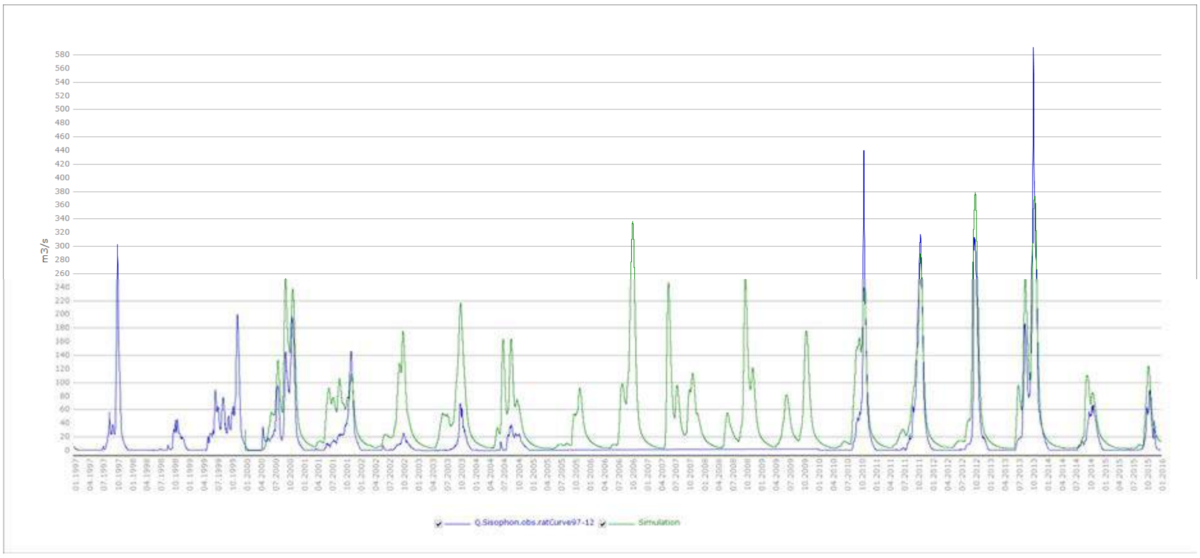
Figure 2: Talsim-NG model setup



Flow components between catchments (cells) are interconnected. If soil downstream is saturated, flow from the upstream cell is impeded causing backwater effects. Surface flow accumulates from cell to cell.

Calibration was performed based on the flow time series obtained from MRC (see Figure 3 below). The longest time series for calibration was available at the Sisophon station, where the temporal resolution was via a daily time step.

Figure 3: Sisophon station flow time series



2.4. Training intensives conducted in Phase II

Training intensives on hydrological modelling were conducted in a sequence of virtual meetings in Phase II, with training participants from MRCS and agencies of Cambodia and Thailand. The meetings focused on hydrological modelling in general. They also provided a short introduction to the 9C-9T model, including a practical exercise based on the Talsim-NG light model based on MS Excel. The Talsim-NG light model used an excerpt of the full 9C-9T hydrological model dataset. The full 9C-9T sub-basin hydrological model was not applied due to complexity and time constraints.

2.5. Future opportunities for the 9C-9T sub-basin

A number of opportunities exist for future use of the Talsim-NG server hosted by MRCS, which would require further review and discussion beyond the proposed training intensive. These include:

- Connect the Talsim-NG server with the near-real time climate data repository at MRC and facilitate the regular and automatic update of precipitation and temperature time series;
- Run the model regularly with 'hot-starts' to update the state of the 9C-9T sub-basin;
- Perform more regular calibration and validation runs to improve and verify the model;
- Enhance land use and crop data to obtain crop water requirements with a high spatial resolution; and
- Add forecasts for precipitation to deploy the model as a forecasting tool.

The above listed steps would enable the model to be embedded into the modelling framework and toolset of MRC for forecasting and flood and drought management, including for use as a detailed tool for flash flooding and as a predictive tool for stream flow.

If further application of the model within MRC is supported, additional configuration/enhancement would be required to enable operational use, which is currently not within the scope of the 9C-9T Joint Project. This would also require additional training sessions (Stages 2 and 3 in table below). The entire process could therefore be seen as a three-staged process:

Stage	Objectives	Outcome
Stage 1: Introduction *This training session*	• Introducing software to MRC and installation of Talsim-NG Server; • Installation of the client-software on computers of MRC staff; • Introducing opportunities of the model; and • Concept of the existing 9C-9T hydrological model, features, benefits, limitations and constraints.	Installation and knowledge enhancement on the product as prerequisite for future model use

Stage	Objectives	Outcome
Stage 2: Discussion and decision making	• Discussion on further use of the model; • Options for integration into the data repository of MRC; • Options for operational use; and • Options to link users in the countries to the Talsim-NG server hosted by MRC.	Options for decision making
Stage 3: Implementation *If Stage 2 is successful*	• Work plan and Terms of Reference; • Configuration; • Testing; • Outreach to stakeholders; • Training intensives following options determined in Stage 2.	Application of the model

3. Hydrological Model transfer to MRC

A number of prerequisites have been identified that require clarification prior to the training exercises, as identified in Section 6. These need to be in place prior to any training taking place.

4. Hydrological modelling intensive

4.1. Type of the training

This training stage is conceived as introduction to the Talsim-NG model for MRCS, in order to get sufficient knowledge about the model and its opportunities. In addition, this will provide an opportunity to discuss possible further use of the model by MRC.

The training combines presentations and practical sessions. The presentations aim to providing the background that is needed to execute the practical session. Participants will be provided with training tools and materials to download prior to the event, including the Talsim-NG Client installation and the Talsim-NG server installation for those who want to run the Talsim-NG server. While the Talsim-NG server training is very specific and only useful for those who intent to provide the Talsim-NG server functionality, the training on the Client is useful for a wider community.

The first session is dedicated to reviewing the installation process and performing the installation; one session for the Server and one session for the Client. The server installation session will cover the "how to" dedicated to the server. This enables the administrator to understand the mechanisms for how the server responds to Client requests, the steps needed for server operation and how to manage new users.

One session will be dedicated to the Client installation and related processes, to facilitate an understanding of possible options for using the Client. It is important to note there is a range of options for using the Client and all of these cannot be addressed in one session. The most important options, however, will be covered.

All other sessions will relate to the 9C-9T dataset including time series updates.

4.2. Required background for participants

The event is targeted at those technical staff with a high level of background expertise in modelling of water resources, who use hydrological models on a regular basis for their work, and who are expected to support in the implementation of Joint Project activities.

They should be technical staff with strong background in:

- IT and data management;
- Hydrological modelling;
- Planning and management of water resources and water infrastructure;
- Flood and drought management, monitoring and early warning; and
- Watershed management and rehabilitation.

At this introductory stage, it is not intended to invite experts from Project countries (Cambodia and Thailand) or from line agencies to this intensive.

4.3. Suggested participants

Prior the commencement of the training workshop, the names and details of the proposed model users participating in the meeting will need to be established. Proposed training participants include:

- 7 staff from the MRC Regional Flood and Drought Management Centre, including;
  - 3 forecasters;
  - 1 meteorologist;
  - 1 GIS expert;
  - 1 database expert;
  - 1 IT expert;
- 1-2 staff from the MRC Technical/IT Division.

4.4. Other attendees

In addition, the following individuals and agencies would participate:

- GIZ representatives, including
  - Nike Hestermann, Development Advisor, MRC-GIZ.
- ICEM/COT/PPIC team, including
  - Hubert Lohr, International Expert;
  - Harvey Rich, ICEM Project Manager; and
  - Nguyen Thi Phuong Thao, ICEM Project Coordinator.

5. Overview of proposed training workshops

A proposed agenda and session overview is presented below, followed by a detailed agenda for each workshop day.

It should be noted that a preparatory meeting has been held to discuss the pre-requisite items outlined below, as well as the suggested participants listed above.

Session	Topic	Participants	Duration
1) 1 November	Deployment of Talsim-NG Server on an MRC computer • Configuration of the server • Understanding of the data management • Creating new users	IT staff from Flood and Drought Centre/ MRCS HQ (*depending on where server is hosted*)	3.5 hrs.
2) 16 November	Installation of Talsim-NG Client on one (or more) MRC computers • Installation • Configuration • Data management	IT staff from Flood and Drought Centre/ MRCS HQ (*depending on where server is hosted*) MRC flood and drought centre staff	3.5 hrs. *(depending on the number of computers)*
3) 21 November	Training on Talsim-NG Client • Options of how to perform simulations • Using the Client efficiently • Application of additional tools	MRC flood and drought centre staff	4 hrs.
4) 23 November	Training on 9C-9T model • Practical use what has been demonstrated in session 3	MRC flood and drought centre staff	3 hrs.
5) 24 November	Training on Talsim-NG Client • Practical use what has been demonstrated in session 3, including bringing results to GIS	MRC flood and drought centre staff	3 hrs.
6) 25 November	*Training on 9C-9T model (optional)* • *9C-9T model*	*MRC flood and drought centre staff*	*3 hrs.*
	Total number of hrs.: 20 (2.5 days), 6 sessions		

Modelling Intensive Day 1: Deployment of Talsim-NG Server on an MRC computer

This session will be focused on the deployment of Talsim-NG Server on an MRC computer, ideally a server in MRC Environment, for IT staff with MRC admin credentials.

Time	Activities	Presenter/Facilitator
14:00 – 14:10 (10 min)	Welcome and introductions	MRC representative
14:10 – 15:10 (60 min)	Deployment / installation	ICEM team
15:10 – 15:40 (30 min)	Configuration of the server	All participants
15:40 – 15:55 (15 min)	*Afternoon tea break*	
15:55 – 16:55 (60 min)	Understanding the data management	ICEM team
16:55 – 17:20 (25 min)	Creating new users	Participants with support of ICEM team
17:20 – 17:30 (10 min)	Wrap up day 1	All participants

Modelling Intensive Day 2: Installation of Talsim-NG Client on one (or more) MRC computers

This session will be focused around the installation of Talsim-NG Client on one (or more) MRC computers, for IT staff with MRC admin credentials.

Time	Activities	Presenter/Facilitator
14:00 – 14:10 (10 min)	Welcome and check of pre-requisites	Nominated participant
14:10 – 15:45 (95 min)	Installation	ICEM team
15:45 – 16:00 (15 min)	*Afternoon tea break*	
16:00 – 16:30 (30 min)	Configuration	Participants with support of ICEM team
16:30 – 17:20 (50 min)	Data management	Participants with support of ICEM team
17:20 – 17:30 (10 min)	Wrap up day 2	ICEM team

Modelling Intensive Day 3: Training on Talsim-NG Client

Time	Activities	Presenter/Facilitator
13:30 – 13:40 (10 min)	Welcome and recap of day 2	Nominated participant
13:40 – 14:25 (45 min)	Options on how to perform simulations	ICEM team
14:25 – 15:25 (60 min)	Using the Client efficiently (1)	All participants
15:25 – 15:40 (15 min)	*Afternoon tea break*	
15:40 – 16:40 (60 min)	Using the Client efficiently (2)	Participants with support of ICEM team
16:40 – 17:20 (40 min)	Application of additional tools	Participants with support of ICEM team
17:20 – 17:30 (10 min)	Wrap up day 3	ICEM team

Modelling Intensive Day 4: Training on Talsim-NG Client

Time	Activities	Presenter/Facilitator
14:00 – 14:10 (10 min)	Welcome and recap of day 3	Nominated participant
14:10 – 15:00 (50 min)	Introduction of the 9C-9T system	ICEM team
15:00 – 15:15 (15 min)	*Afternoon tea break*	
15:15 – 16:05 (50 min)	Understanding the 9C-9T system and dataset	ICEM team
16:05 – 16:50 (45 min)	Use and change the dataset and perform simulation runs	All participants
16:50 – 17:00 (10 min)	Wrap up day 4	ICEM team

Modelling Intensive Day 5: Training on Talsim-NG Client

Time	Activities	Presenter/Facilitator
14:00 – 14:10 (10 min)	Welcome and recap of day 4	Nominated participant
14:10 – 14:55 (45 min)	Using GIS through post-processing tools of the software package Talsim-NG	ICEM team
14:55 – 15:10 (15 min)	*Afternoon tea break*	
15:10 – 16:10 (60 min)	Practical session: Use the Talsim-NG Grid tool to bring results to GIS	All participants
16:10 – 16:50 (40 min)	Interaction client and server, server API	All participants
16:50 – 17:00 (10 min)	Wrap up day 5	ICEM team

Modelling Intensive Day 6: Training on Talsim-NG Client (optional)

Time	Activities	Presenter/Facilitator
14:00 – 14:10 (10 min)	Welcome and recap of day 5	Nominated participant
14:10 – 16:00 (110 min)	Q & A, details on demand	ICEM team
16:00 – 16:15 (15 min)	*Afternoon tea break*	
16:15 – 17:00 (45 min)	Workshop wrap up, comments and questions	All participants

6. HYDROLOGICAL MODEL TRANSFER TO MRC

Pre-requisite for model transfer

A number of prerequisites have been identified that require clarification prior to the training exercises – these need to be in place prior to any training taking place.

Server side:

The model transfer and associated training is fundamentally based on a few core pre-requisites, including:

- Availability of a virtual or a physical server based on Microsoft Windows;
- Accessibility of the server by virtual remote connections with administrative credentials;
- Storage on the server ideally > 100GB to accommodate time series, datasets and possible results for exchange between users;
- Upload and download speed with a minimum of 5 Mbps. The upload rate determines the server's capacity to provide both time series and results;
- Ideally, Microsoft Access is available on the server. If not available, the configuration of the Talsim-NG server database is can be completed externally and the final *.mdb copied to the server;
- The server requires the .NET framework 4.8;
- The server requires the Microsoft Windows Communication Foundation (WCF) framework. WCF is usually part of a Microsoft Server installation. It must be activated if not already;
- The installation of the operating system should be English; and
- Installation of Notepad++ as ASCII Editor.

The Talsim-NG server can work in an encapsulated environment. This means that the server does not need any connections to the intranet on which the server is hosted. The only pre-requisite is access to the Internet. This ensures that no malicious software can enter the host's space.

The requirements for making backups of the Talsim-NG server environment can be based on a simple process of compressing the data repository in regular intervals, ideally on an external hard drive. It is recommended to apply a synchronization tool which safes only changes. Users must also be established on the server side. This requires a) to create the necessary folders that come to make the server work with a user and b) to enter the user in the Talsim-NG server database.

Client-side:

A Client requires the installation of the Talsim-NG Client software. Each Talsim-NG user requires such an installation. The installation requires administrative credentials. The Client-side pre-requisites are:

- Storage on the Client-side is ideally > 100GB to accommodate time series, datasets and results;
- Upload and Download rate with a minimum of 5 Mbps. The upload rate determines the Client's capacity to upload time series and results to the server. The download rate determines the Client's capacity to receive data from the Talsim-NG server;
- The Client requires the .NET framework 4.8;
- The installation of the operating system should be English;
- Installation of Notepad++ as ASCII Editor; and
- The Client requires a specific date/time format (dd/mm/yyyy hh:mm) and "." as decimal symbol. Note the American way of writing a date with preceding MM does not work.

Process for model transfer

Server side:

Having all pre-requisites at the server side fulfilled, the transfer can take place. Transferring the Talsim-NG server and the data is a simple copy-paste process to the server's machine. All required tools that are not Microsoft products are shipped with the package of the Talsim-NG server.

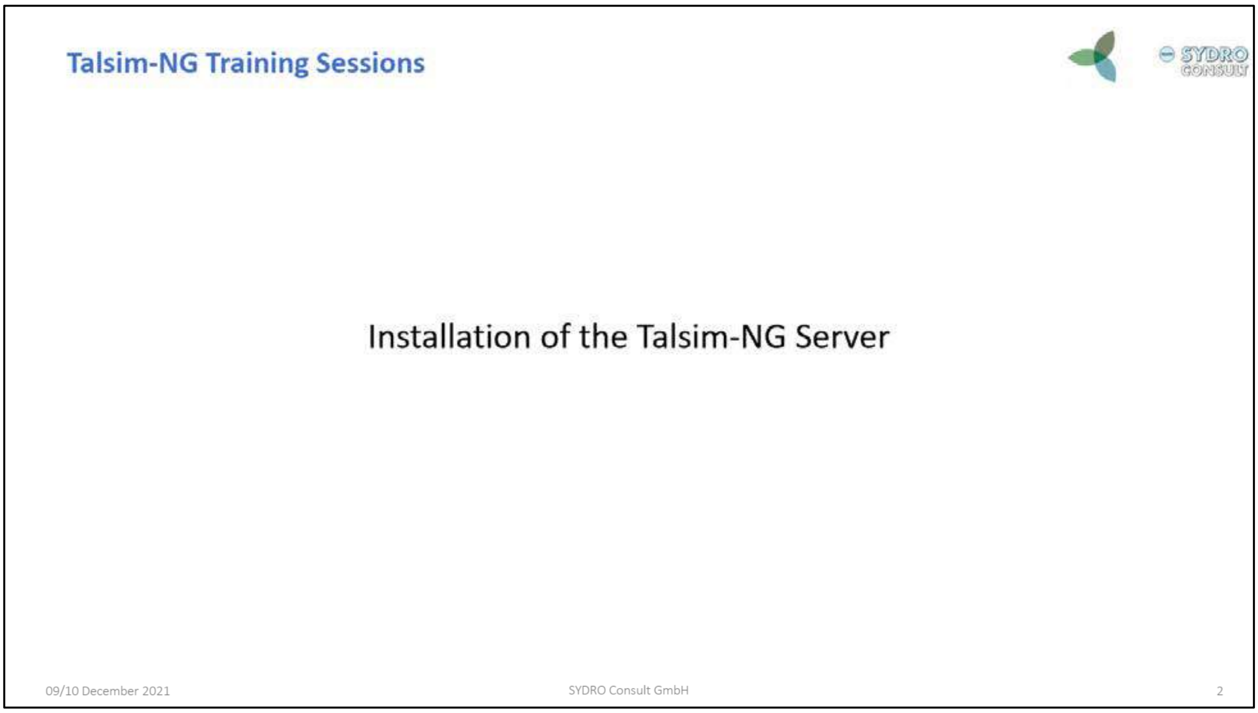
The configuration files are XML-based formatted ASCII files which can be edited with a standard ASCII Editor like Notepad++.

Client-side:

The data repository for the Client is also a simple copy-paste process. However, the MB that needs to be transferred is high, especially if all results are copied. It is recommended to provide a link from where the data can be downloaded. In theory, the data can be copied to any place on the Client's hard drive. In practice, a clear structure is recommended to a) ease the configuration process and b) to enable a seamless connection to the Talsim-NG server.

The configuration that enables the connection from Client-to-server depends on the location where Talsim-NG datasets are copied to. If the default path is used, no adaptation of the configuration is needed.


icem
9c9t Joint Project
Talsim-NG
Training sessions
Installation
Virtual Meeting, 01 - November 2022
Dr. Hubert Lohr


Talsim-NG Training Sessions
Installation of the Talsim-NG Server
09/10 December 2021
SYDRO Consult GmbH
2

Talsim-NG Training Sessions

Installation

Prerequisites:

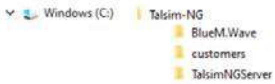
- Ensure the Date setting is **dd/MM/yyyy**
- The American style with the month first won't work!

Defaults:

The default root path is **c:\Talsim-NG**

Unzip the **Talsim-NG.Server.9c9tdata.zip** file to this folder. All is done.

The structure should look like this:



If the default root path is not possible, go to the next page.

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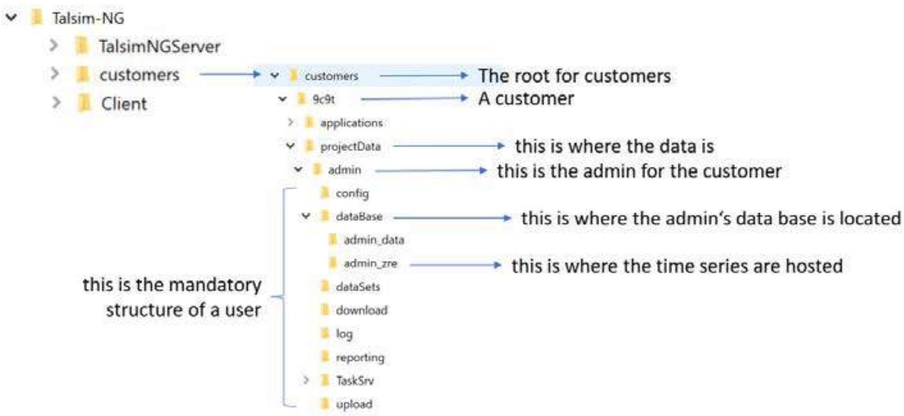
Talsim-NG Training Sessions

Installation

Folder structure:



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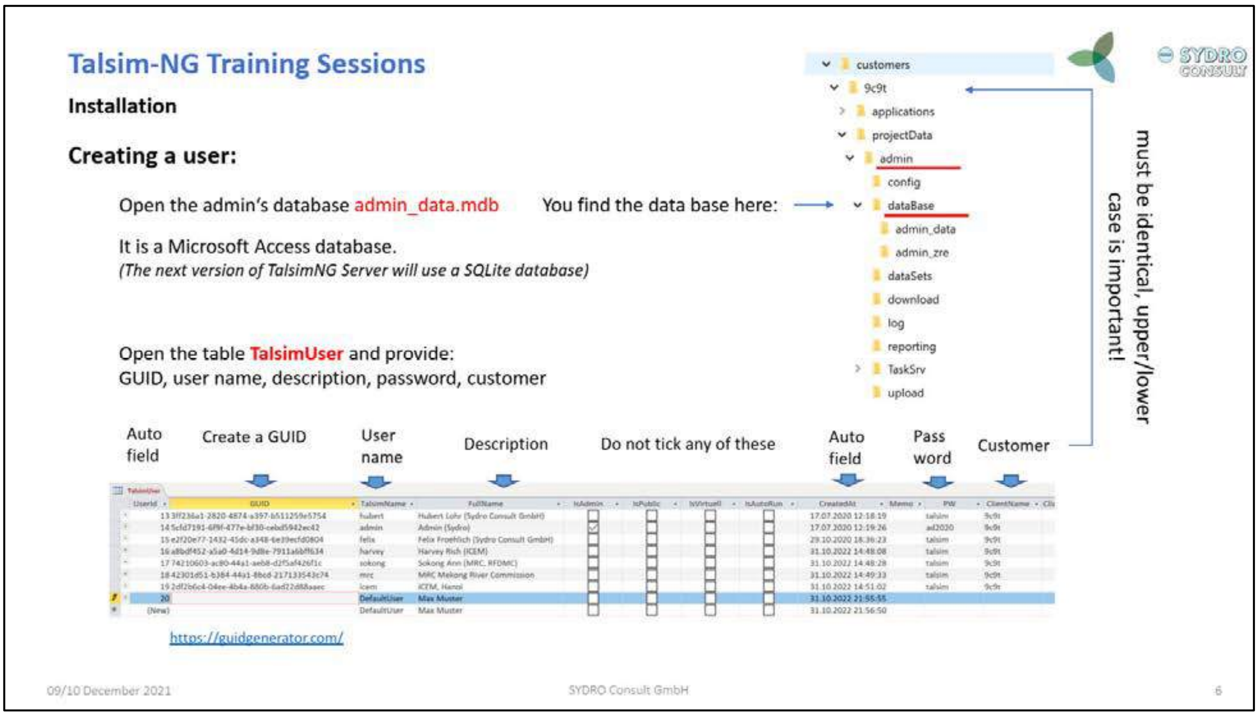
Talsim-NG Training Sessions
Installation
Creating a user:
Open the admin's database admin_data.mdb
You find the data base here:
It is a Microsoft Access database.
(The next version of TalsimNG Server will use a SQLite database)
Open the table TalsimUser and provide:
GUID, user name, description, password, customer
customers
9c9t
applications
projectData
admin
config
dataBase
admin_data
admin_zre
dataSets
download
log
reporting
TaskSrv
upload
must be identical, upper/lower case is important!
Auto field
Create a GUID
User name
Description
Do not tick any of these
Auto field
Pass word
Customer
https://guidgenerator.com/
09/10 December 2021
SYDRO Consult GmbH
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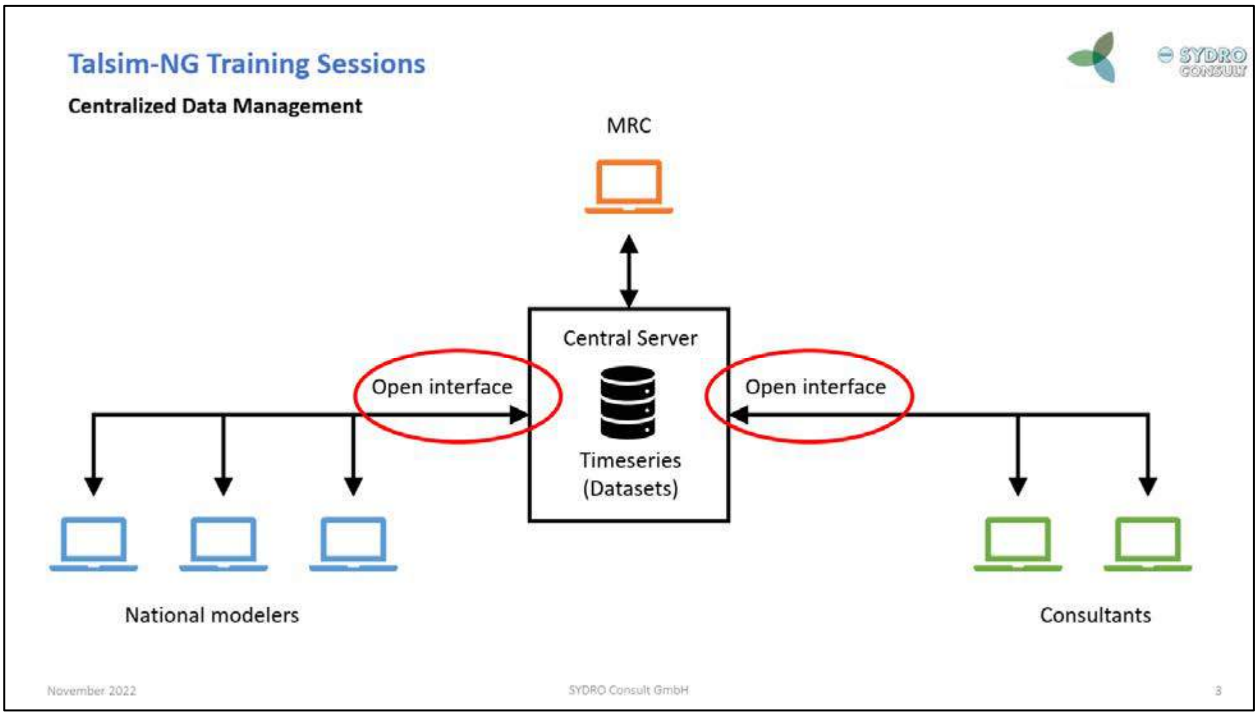
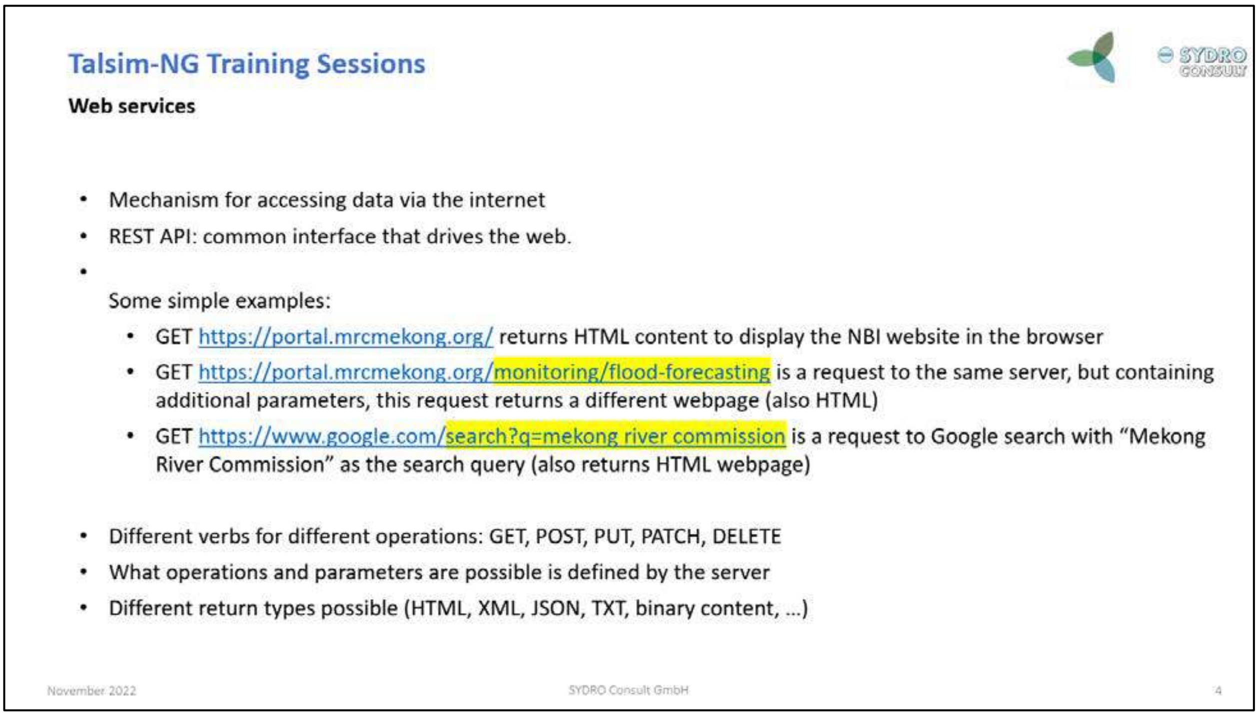
Talsim-NG Training Sessions

SYDRO CONSULT

Centralized time series management
Technical background

November 2022 SYDRO Consult GmbH 2


Talsim-NG Training Sessions
Centralized Data Management
MRC
Central Server
Open interface
Open interface
Timeseries
(Datasets)
National modelers
Consultants
November 2022
SYDRO Consult GmbH
3


Talsim-NG Training Sessions
Web services
• Mechanism for accessing data via the internet
• REST API: common interface that drives the web.
•
Some simple examples:
• GET https://portal.mrcmekong.org/ returns HTML content to display the NBI website in the browser
• GET https://portal.mrcmekong.org/monitoring/flood-forecasting is a request to the same server, but containing additional parameters, this request returns a different webpage (also HTML)
• GET https://www.google.com/search?q=mekong river commission is a request to Google search with "Mekong River Commission" as the search query (also returns HTML webpage)
• Different verbs for different operations: GET, POST, PUT, PATCH, DELETE
• What operations and parameters are possible is defined by the server
• Different return types possible (HTML, XML, JSON, TXT, binary content, ...)
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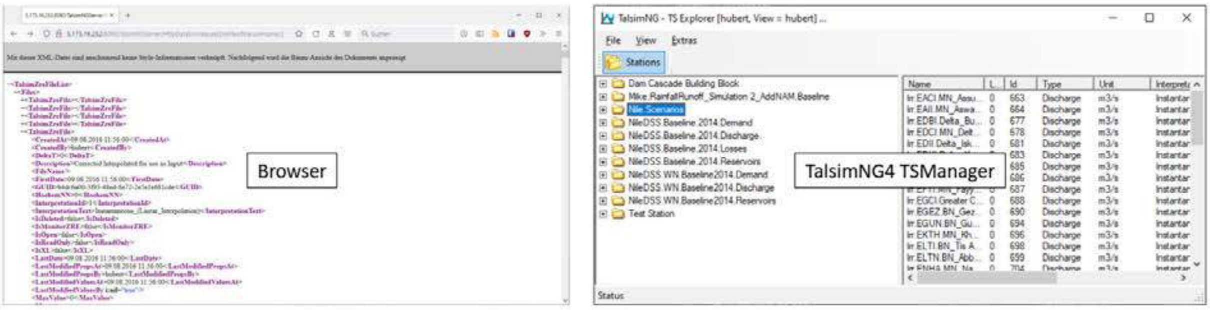
Talsim-NG Training Sessions

Talsim-NG Server

- Server address: http://5.175.16.252
- Sample request:
- GET http://5.175.16.252:8090/TalsimNGServer/HttpDataSrv/requestZreFiles/9c9t,harvey,0
- Returns the list of all available time series (XML)



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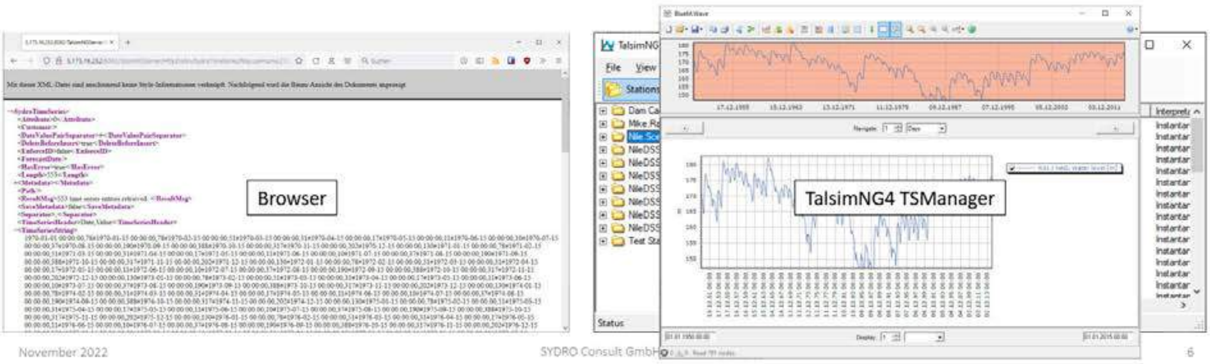
Talsim-NG Training Sessions

Talsim-NG Server

- Sample request:
- GET http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/9c9t,sokong,1502
- Returns the data of one time series (XML)



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Talsim-NG Training Sessions

Talsim-NG Server

- Sample request:
- GET http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/ASCII?customer=9c9t&user=sokong&id=1502
- Returns the data of one time series (TXT)


```
P.150mm.6h.StormEvent.,mm,55 time series entries retrieved.  (request: customer=9c9t,user=sokong,time series id=1502)
2000-01-01T00:00:00+01:00,0
2000-07-02T00:00:00+02:00,0
2000-07-02T00:15:00+02:00,3.333
2000-07-02T00:30:00+02:00,3.333
2000-07-02T00:45:00+02:00,3.833
2000-07-02T01:00:00+02:00,4.167
2000-07-02T01:15:00+02:00,4.333
2000-07-02T01:30:00+02:00,5
2000-07-02T01:45:00+02:00,5
2000-07-02T02:00:00+02:00,13.5
2000-07-02T02:15:00+02:00,15.625
2000-07-02T02:30:00+02:00,15.625
2000-07-02T02:45:00+02:00,15.625
2000-07-02T03:00:00+02:00,15.625
2000-07-02T03:15:00+02:00,5.25
2000-07-02T03:30:00+02:00,5.25
2000-07-02T03:45:00+02:00,4.8
2000-07-02T04:00:00+02:00,4.5
2000-07-02T04:15:00+02:00,4.35
2000-07-02T04:30:00+02:00,3.75
2000-07-02T04:45:00+02:00,3.75
2000-07-02T05:00:00+02:00,3.15
2000-07-02T05:15:00+02:00,3
2000-07-02T05:30:00+02:00,2.7
2000-07-02T05:45:00+02:00,2.25
2000-07-02T06:00:00+02:00,2.25
2000-07-02T06:15:00+02:00,0
2000-07-02T06:30:00+02:00,0
```

Browser

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Talsim-NG Training Sessions

Talsim-NG Server

The REST API can be consumed by any program, provided it knows the appropriate requests/parameters and can understand the responses:

- Browser
- Desktop applications
- Web applications
- Excel
- Scripting languages
- …

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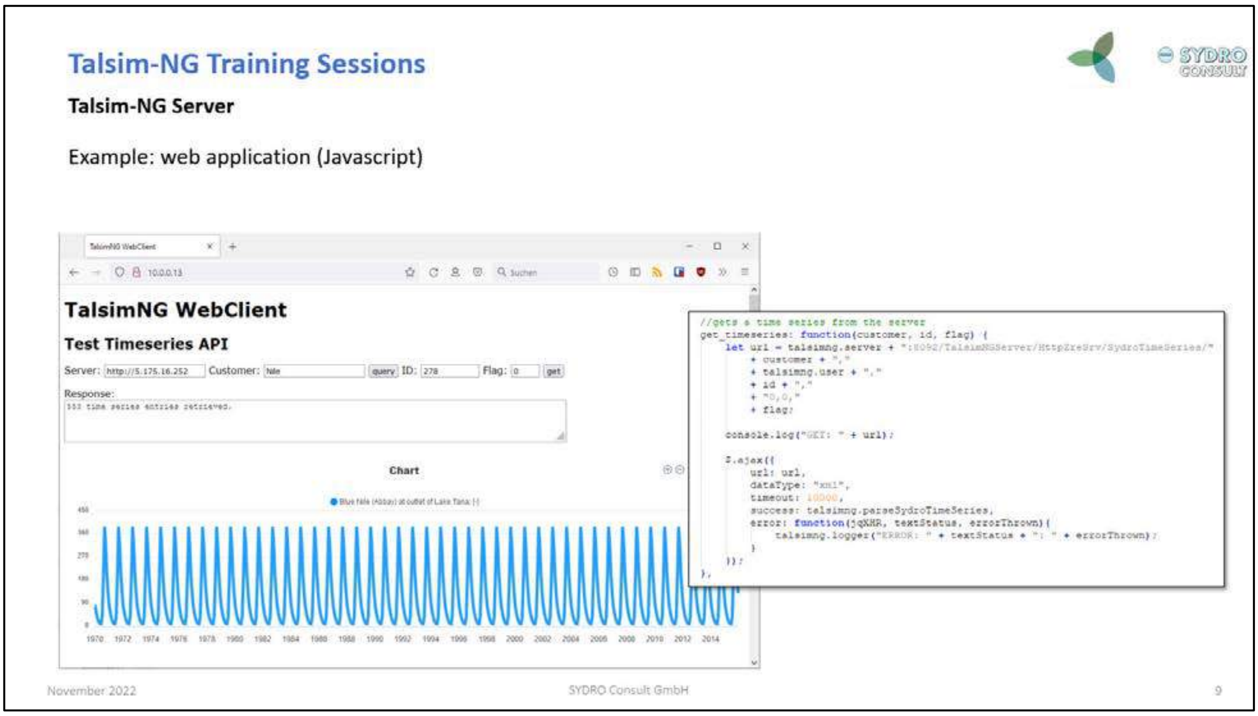
Talsim-NG Training Sessions
Talsim-NG Server
Example: web application (Javascript)
TalsimNG WebClient
Test Timeseries API
Server:
Customer:
query
ID:
Flag:
get
Response:
Chart
//gets a time series from the server
get_timeseries: function(customer, id, flag) {
let url = talsimng.server + ":8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/"
+ customer + ","
+ talsimng.user + ","
+ id + ","
+ "0,0,"
+ flag;
console.log("GET: " + url);
$.ajax({
url: url,
dataType: "xml",
timeout: 10000,
success: talsimng.parseSydroTimeSeries,
error: function(jqXHR, textStatus, errorThrown){
talsimng.logger("ERROR: " + textStatus + ": " + errorThrown);
}
});
},
November 2022
SYDRO Consult GmbH
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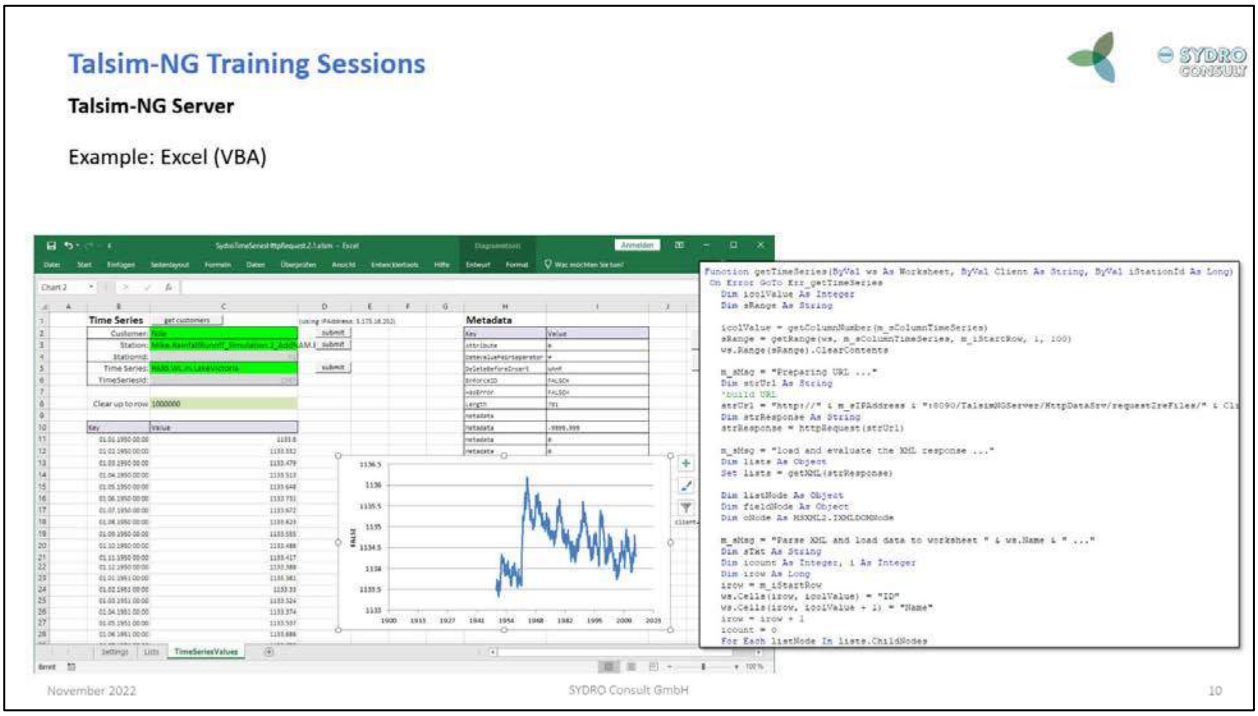
Talsim-NG Training Sessions
Talsim-NG Server
Example: Excel (VBA)
Time Series
Metadata
Function getTimeSeries(ByVal ws As Worksheet, ByVal Client As String, ByVal iStationId As Long)
On Error GoTo Err_getTimeSeries
Dim icolValue As Integer
Dim sRange As String
icolValue = getColumnNumber(m_sColumnTimeSeries)
sRange = getRange(ws, m_sColumnTimeSeries, m_iStartRow, 1, 100)
ws.Range(sRange).ClearContents
m_sMsg = "Preparing URL ..."
Dim strUrl As String
'build URL
Dim strResponse As String
strResponse = httpRequest(strUrl)
m_sMsg = "load and evaluate the XML response ..."
Dim liste As Object
Set liste = getXML(strResponse)
Dim listNode As Object
Dim fieldNode As Object
Dim cNode As MSXML2.IXMLDOMNode
m_sMsg = "Parse XML and load data to worksheet " & ws.Name & " ..."
Dim sTxt As String
Dim icount As Integer, i As Integer
Dim irow As Long
irow = m_iStartRow
ws.Cells(irow, icolValue) = "ID"
ws.Cells(irow, icolValue + 1) = "Name"
irow = irow + 1
icount = 0
For Each listNode In liste.ChildNodes
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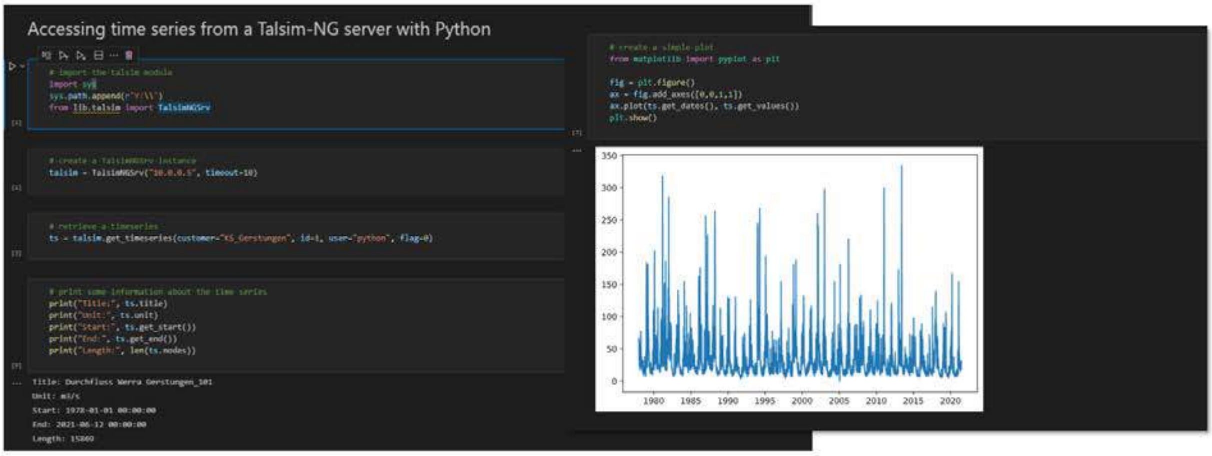
Talsim-NG Training Sessions

Talsim-NG Server

Example: Python script



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Talsim-NG Training Sessions

REST API

- Open interface for accessing (also storing and updating) time series
- Can be used programmatically using any program/script
- Useful for operational applications (e.g. reservoir operation, forecasting)
- Useful for automatic (batch) data retrieval
- Useful for automatic updates (recording observations)

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Examples using the SYDRO internet server:

http://5.175.16.252:8090/TalsimNGServer/HttpDataSrv/requestZreDirectories/9c9t,|

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/ASCII?customer=9c9t&user=sokong&id=1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/ASCII?customer=9c9t&user=sokong&id=1512&startdate=1980-01-01&enddate=2000-01-01

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/9c9t,sokong,1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/attributes/9c9t,harvey,1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/attributes/fieldnames/9c9t,harvey,1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/fieldnames/9c9t,hubert,1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/SydroTimeSeries/flags/9c9t,hubert,1512

http://5.175.16.252:8092/TalsimNGServer/HttpZreSrv/stations
(returns JSON file)

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Time Series Manager - Preparation and Login

1) For accessing and downloading time series make sure there is a connection to the internet
2) Unzip „TalsimNG4TSManager.zip" in a folder where you have **read/write** access
3) Double click on „TalsimNG4TS.exe" (the tool tries to connect to the server)
4) Log in with „username" and „password"

User Name:
your first name (small letters) or mrc or icem
Password: talsim

5) Time series files will be located in the directory „..\work\"

Download the tools from here:
https://www.dropbox.com/s/i9214ohd1np5ai8/TalsimNG4TSManager.zip?dl=0

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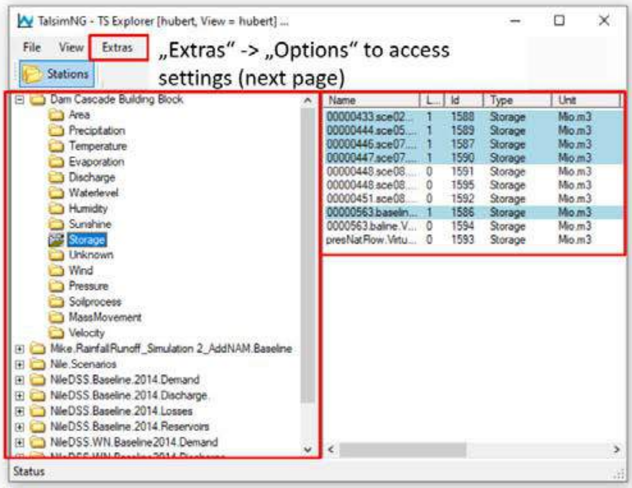
Time Series Manager – Main Window

Tree View (Stations)

- Shows all accessible stations
- Each station contains sub directories (area, precipitation etc.)
- With right click on sub directory -> „Refresh" to show new time series



If you run into problems during downloading/displaying time series, make sure your antivirus program doesnt block Wave (tool to display time series). Wave.exe is located in the same folder as the Time Series Manager.

Time Series Files

- Shows all accessible time series
- With right click on time series -> „Edit Time Series" to edit meta data „Load" -> „Time Series" to download and display time series in Wave
- Blue highlighted files indicate already downloaded time series

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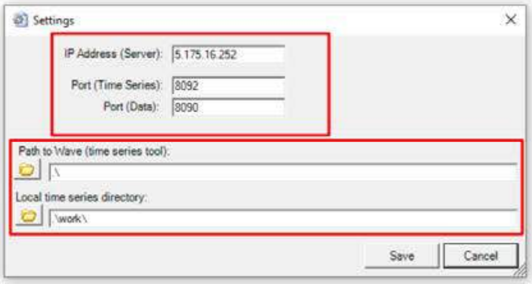
Time Series Manager – Settings

Server Settings

- Settings to access the server
- No changes have to be made



Directory Settings

- Relative path to the time series tool (Wave)
- Relative path to the local time series directory

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Talsim-NG Training Sessions

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BlueM.Wave
A tool for displaying, analyzing and importing and exporting time series

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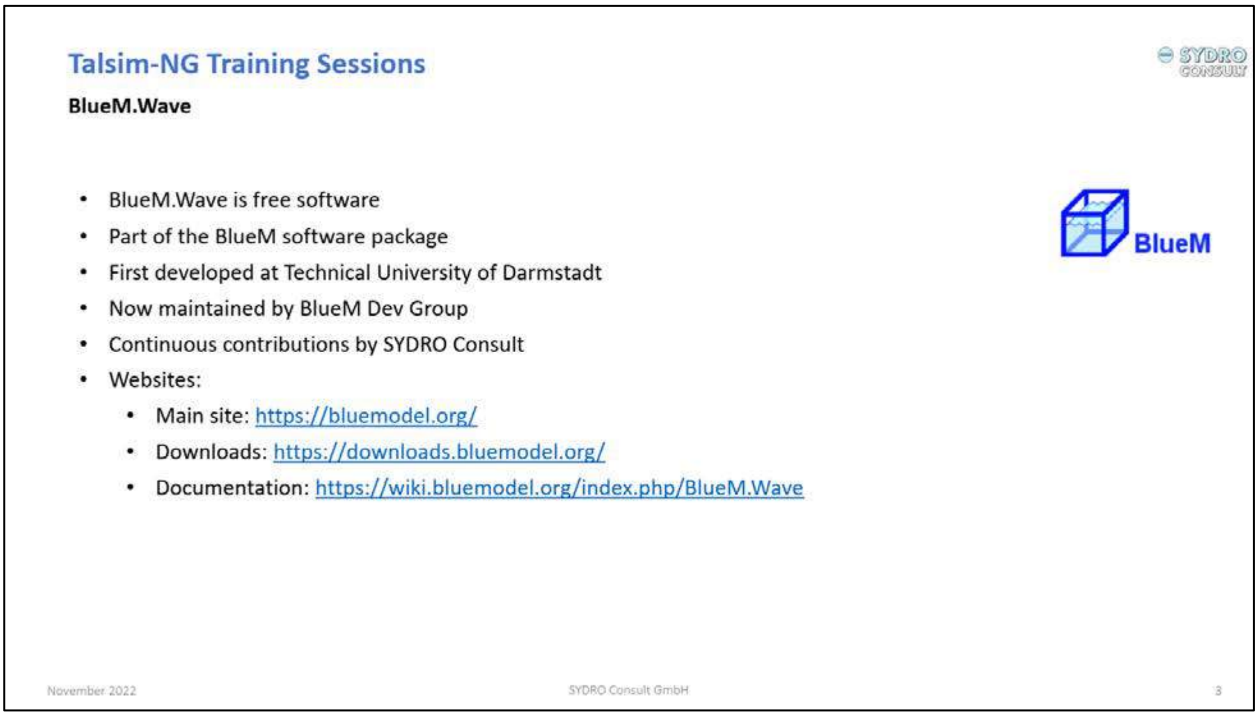
Talsim-NG Training Sessions
BlueM.Wave
BlueM.Wave is free software
Part of the BlueM software package
First developed at Technical University of Darmstadt
Now maintained by BlueM Dev Group
Continuous contributions by SYDRO Consult
Websites:
Main site: https://bluemodel.org/
Downloads: https://downloads.bluemodel.org/
Documentation: https://wiki.bluemodel.org/index.php/BlueM.Wave
BlueM
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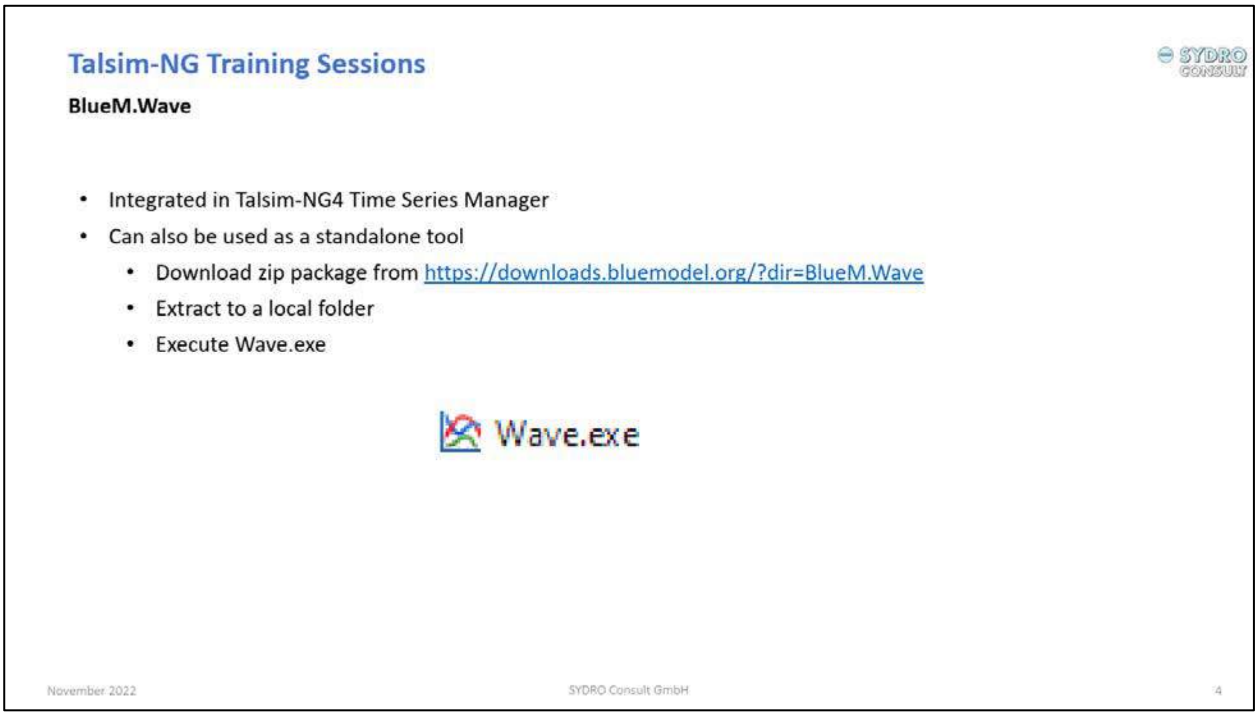
Talsim-NG Training Sessions
BlueM.Wave
Integrated in Talsim-NG4 Time Series Manager
Can also be used as a standalone tool
Download zip package from https://downloads.bluemodel.org/?dir=BlueM.Wave
Extract to a local folder
Execute Wave.exe
Wave.exe
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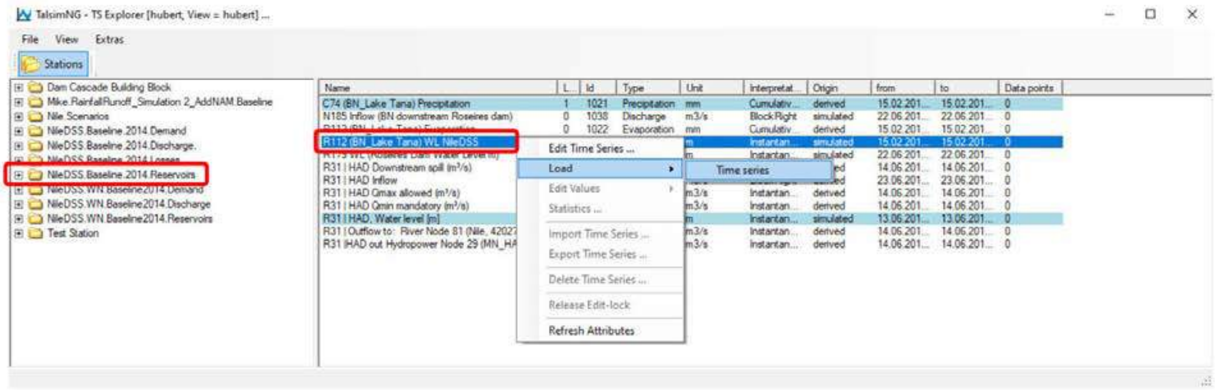
Talsim-NG Training Sessions

BlueM.Wave

Exercise

- Open the Talsim-NG4 Time Series Manager
- Load a time series



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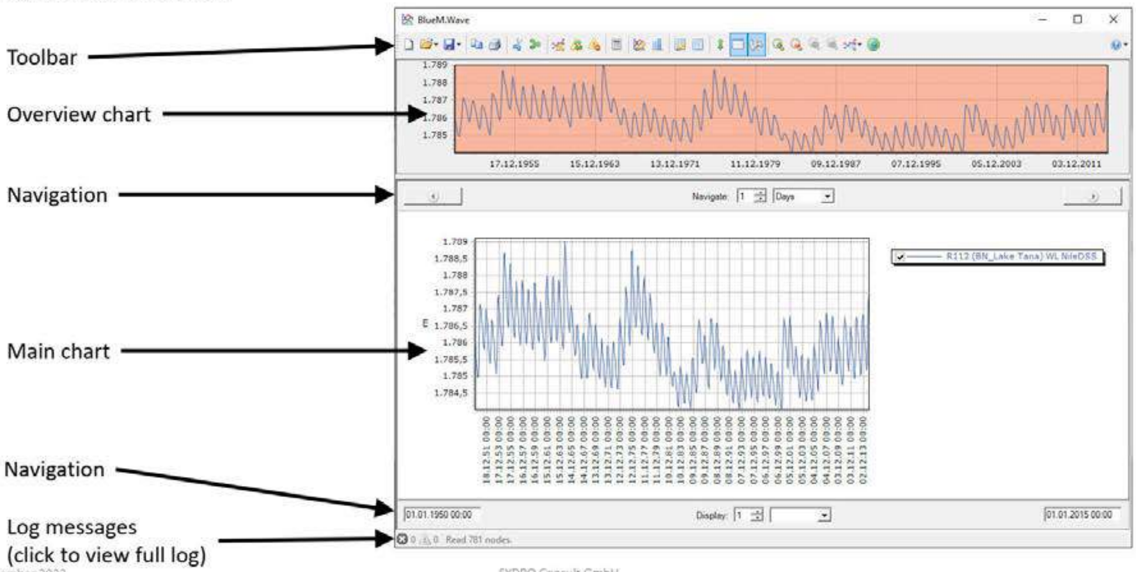
Talsim-NG Training Sessions

BlueM.Wave: Overview



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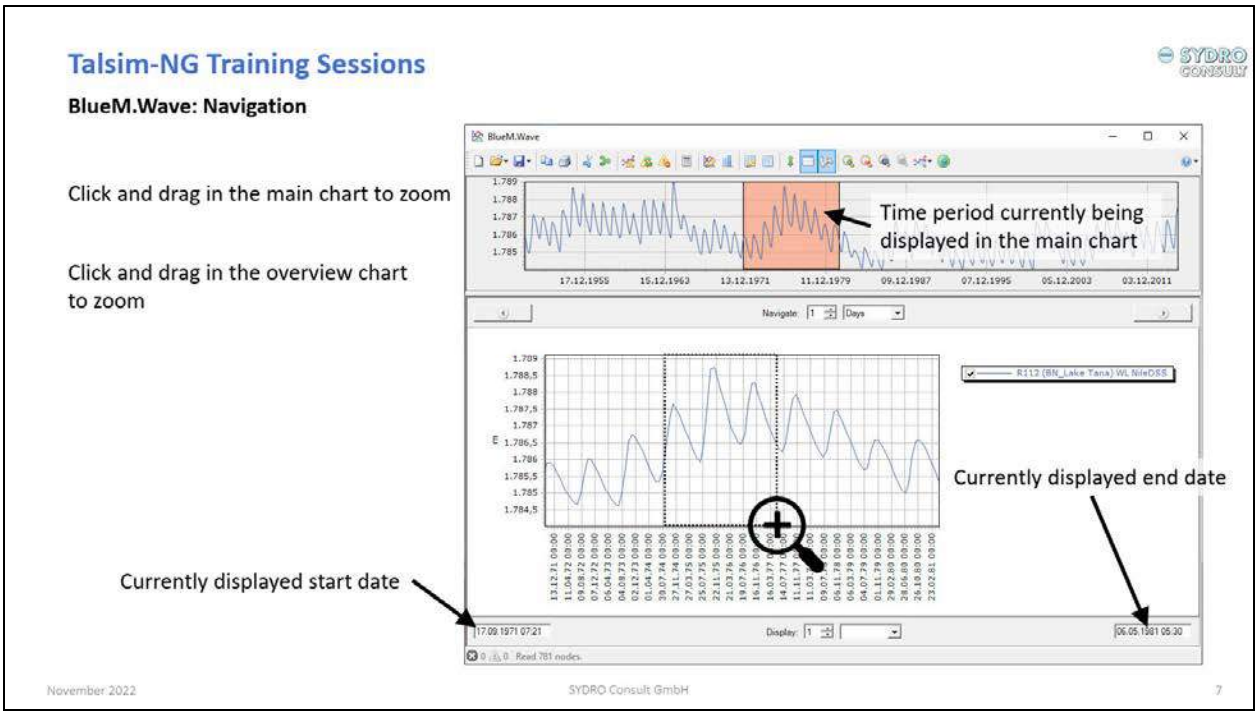
Talsim-NG Training Sessions
BlueM.Wave: Navigation
Click and drag in the main chart to zoom
Click and drag in the overview chart to zoom
Time period currently being displayed in the main chart
Currently displayed end date
Currently displayed start date
BlueM.Wave
17.09.1971 07:21
06.05.1981 05:30
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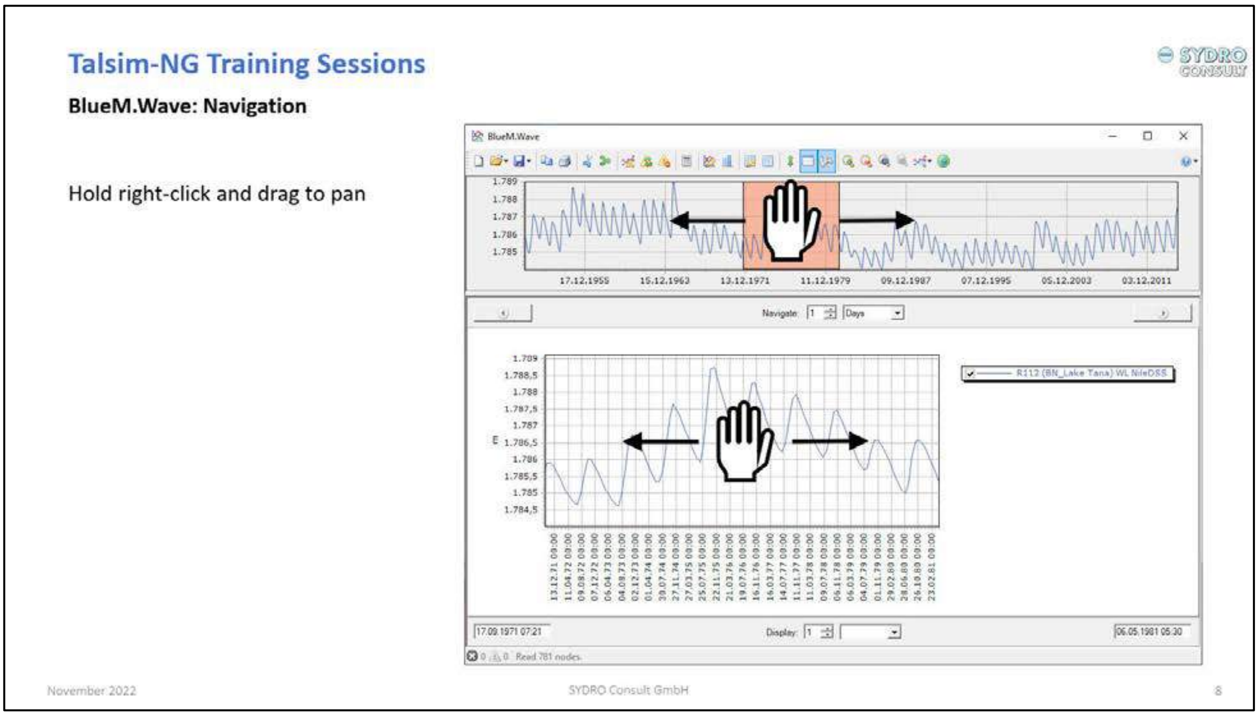
Talsim-NG Training Sessions
BlueM.Wave: Navigation
Hold right-click and drag to pan
BlueM.Wave
17.09.1971 07:21
06.05.1981 05:30
November 2022
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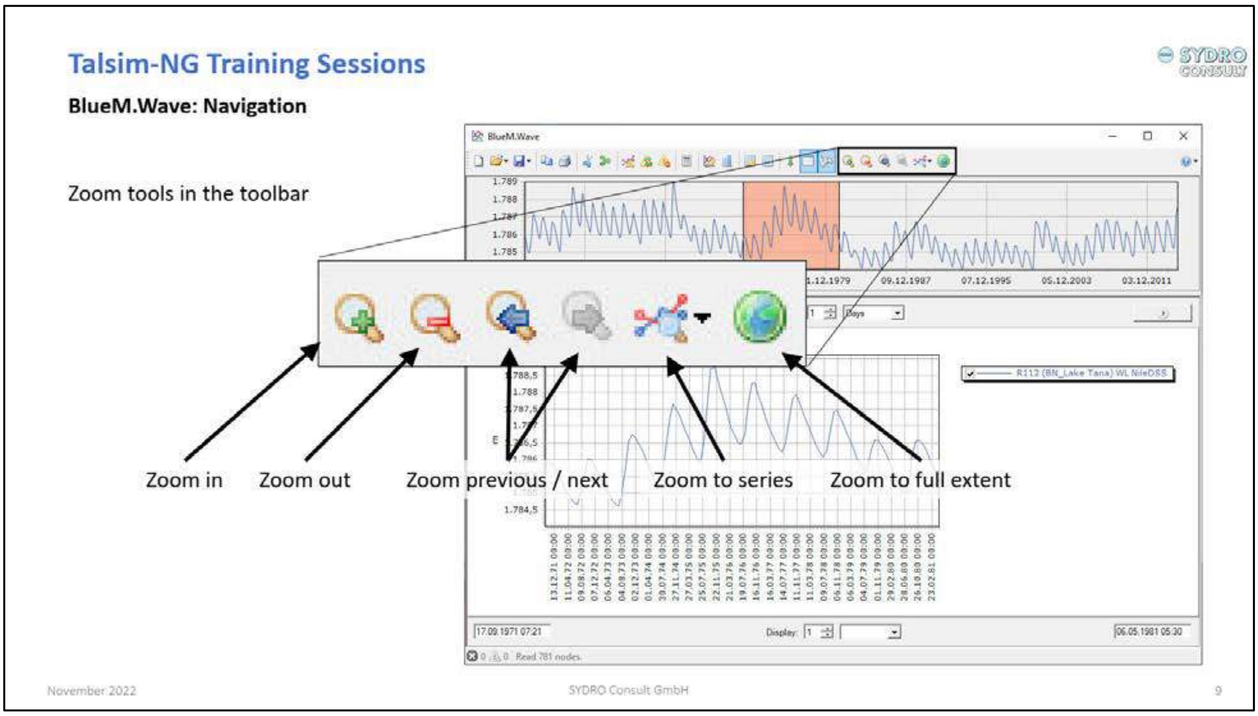
Talsim-NG Training Sessions
BlueM.Wave: Navigation
Zoom tools in the toolbar
Zoom in
Zoom out
Zoom previous / next
Zoom to series
Zoom to full extent
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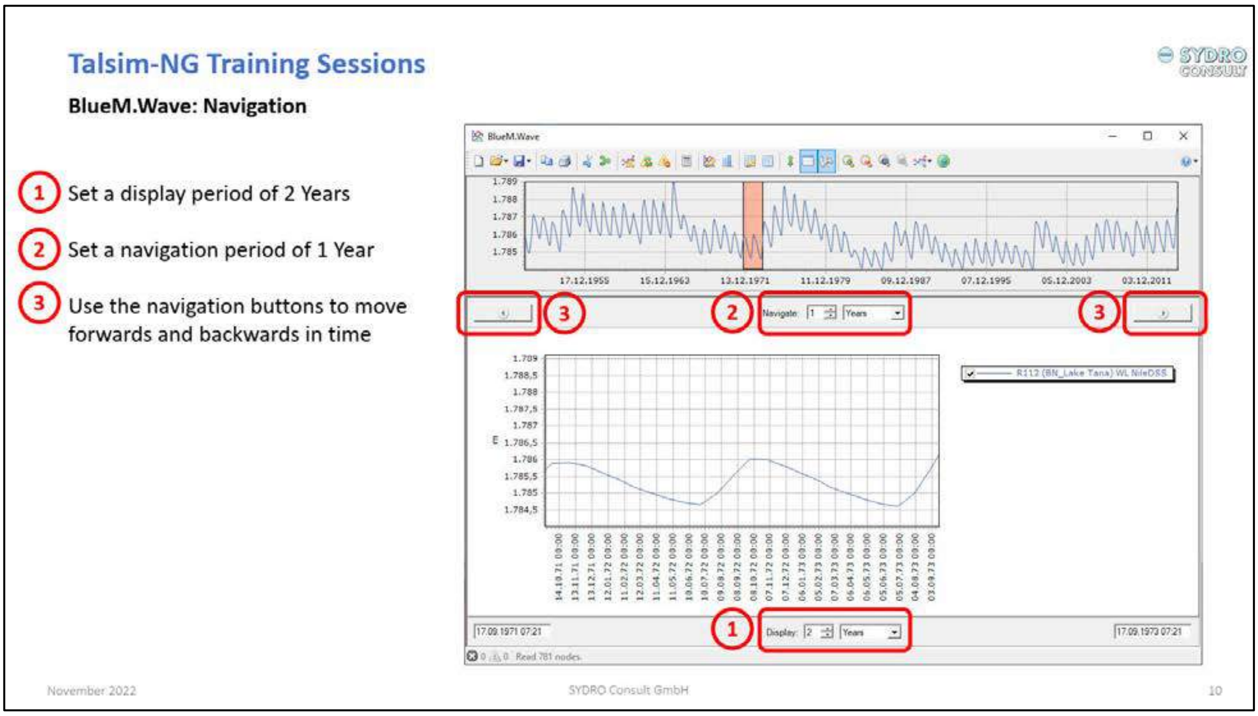
Talsim-NG Training Sessions
BlueM.Wave: Navigation
1 Set a display period of 2 Years
2 Set a navigation period of 1 Year
3 Use the navigation buttons to move forwards and backwards in time
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Talsim-NG Training Sessions

BlueM.Wave: Time Series Management

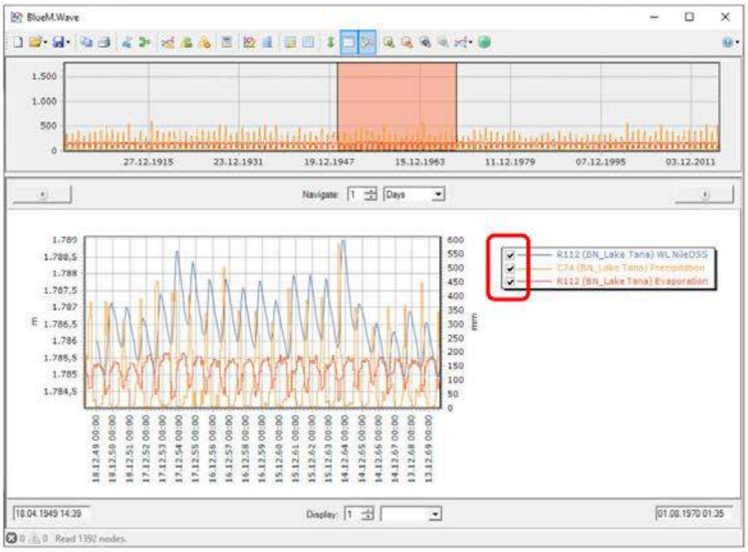
Load additional time series using the Talsim-NG4 Time Series Manager:

- Load another time series

Notice:

- New series added to legend
- New axis for unit "mm"

Use the checkboxes in the legend to switch individual series on or off



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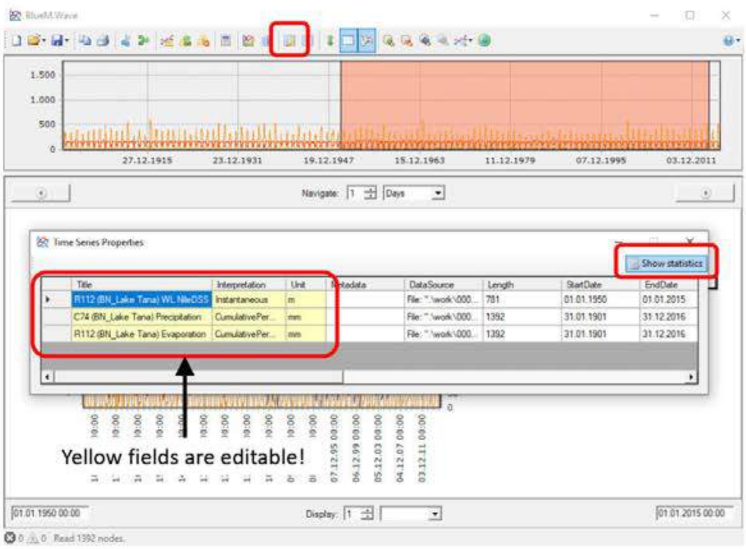
Talsim-NG Training Sessions

BlueM.Wave: Time Series Management

Click the toolbar button „Show time series properties"

Click on "Show statistics" to display general statistics

Select a row and press the Delete key on your keyboard to delete a series



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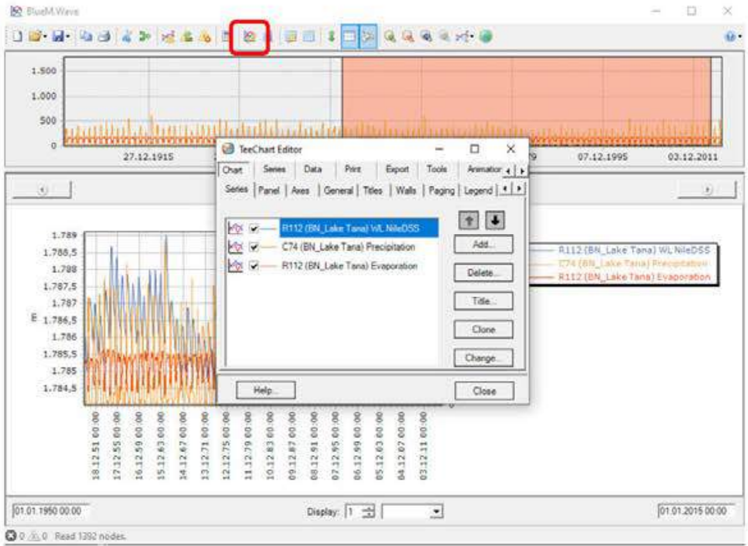
Talsim-NG Training Sessions

BlueM.Wave: Chart Formatting

Click the toolbar button „Edit chart"

Use the "TeeChart Editor" to adjust any chart settings you like

- Line colors
- Line thickness
- Axis settings
- Legend settings
- ...



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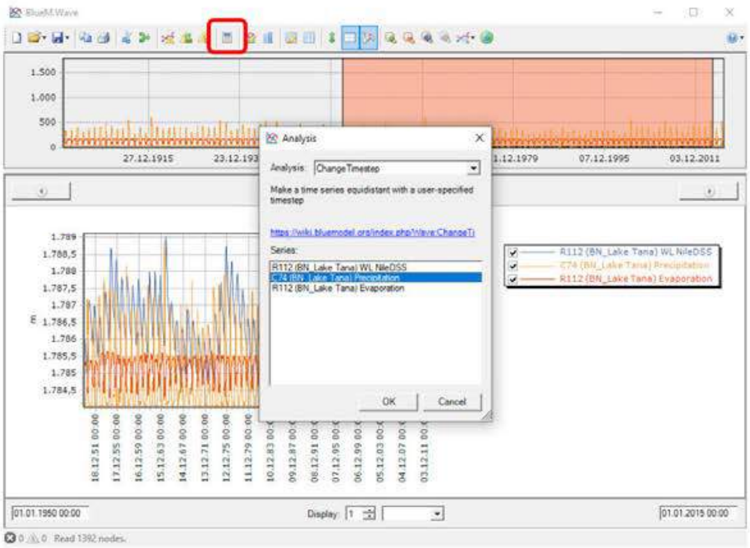
Talsim-NG Training Sessions

BlueM.Wave: Analysis

Click the toolbar button „Analysis"

List of available analysis functions:

- Annual statistics: Compute various statistical parameters (min, max, average) of a time series
- Calculator: Performs a mathematical operation on one or more time series
- ChangeTimestep: Make a time series equidistant with a user-specified timestep
- Comparison: Plot two time series against each other and compute a linear regression line
- Cumulative: Compute a new time series that contains the cumulative values of the original series
- Double sum curve
- Goodness of fit (volume error, sum of squares error, Nash-Sutcliffe efficiency, etc.)
- Histogram
- Monthly statistics
- Timestep analysis: Calculate the timestep between nodes in a user-specified unit



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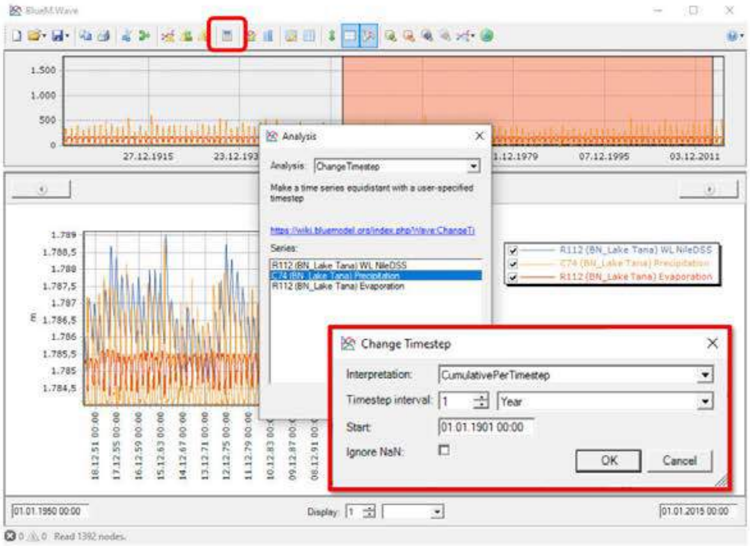
Talsim-NG Training Sessions

BlueM.Wave: Analysis

Click the toolbar button „Analysis“

Try „ChangeTimestep“ for the precipitation time series



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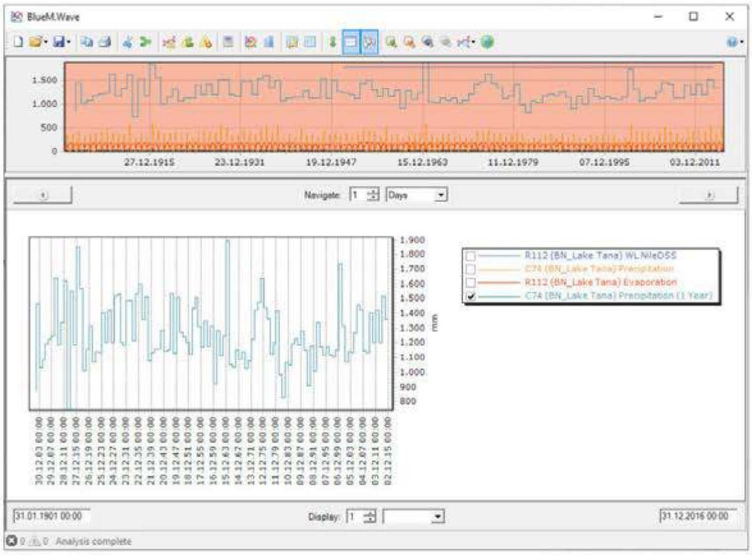
Talsim-NG Training Sessions

BlueM.Wave: Analysis

Click the toolbar button „Analysis“

Try „ChangeTimestep“ for the precipitation time series

Result:
A new time series with yearly precipitation values [mm/year]



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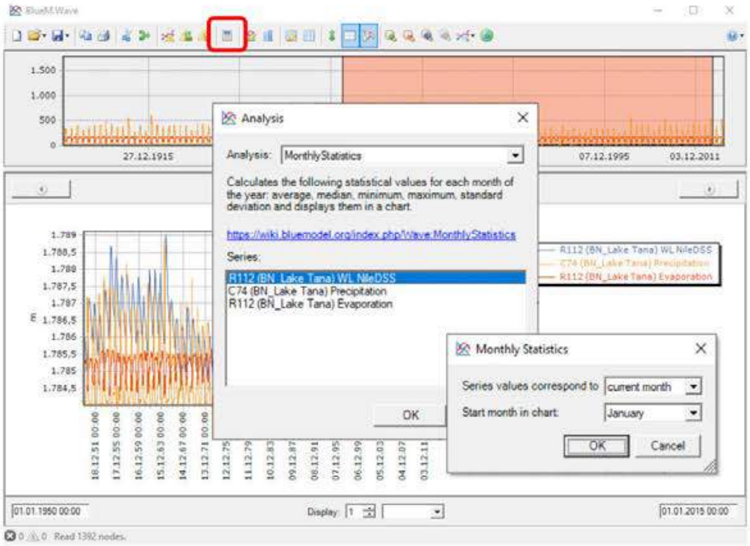
Talsim-NG Training Sessions

BlueM.Wave: Analysis

Click the toolbar button „Analysis"

Try „Monthly Statistics" for the water level

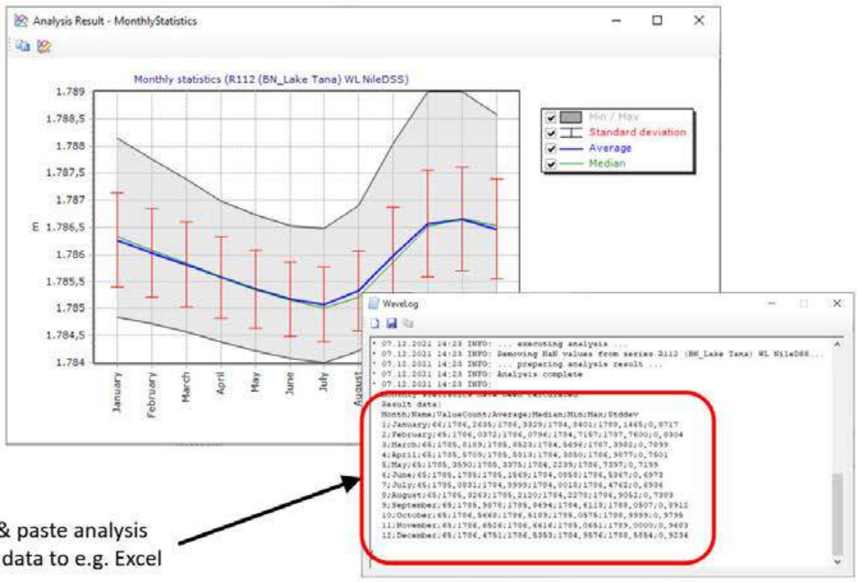


Talsim-NG Training Sessions

BlueM.Wave: Analysis

Analysis results may consist of:

- A separate diagram/chart
- Text & figures in the log
- A new time series in the main chart



Copy & paste analysis result data to e.g. Excel

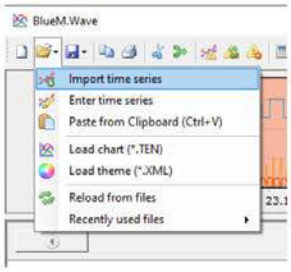
Talsim-NG Training Sessions

BlueM.Wave: Import & Export

Supported import formats:

- WEL (BlueM, GISMO, **TALSIM**, Hystem-Extran)
- ASC
- **BIN** (SYDRO binary format)
- HYDRO_AS-2D result files
- **DFS0** (DHI MIKE Dfs0 format)
- OUT (SWMM)
- PRMS result files
- REG (SMUSI and Hystem-Extran)
- SMB
- TXT (SWMM routing interface files)
- UVF (Universelles Variables Format)
- ZRE
- ZRXP (ZXRP format)
- and generic text files (e.g. **CSV**)

Or copy & paste data from **Excel** (treated as CSV)



Or just drag & drop time series file on Wave window

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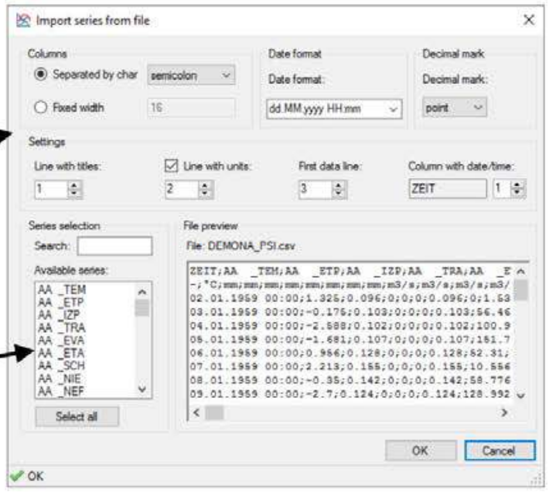
Talsim-NG Training Sessions

BlueM.Wave: Import & Export

File import dialog
(as shown for CSV data)

Import settings

Series selection



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Talsim-NG Training Sessions

BlueM.Wave: Import & Export

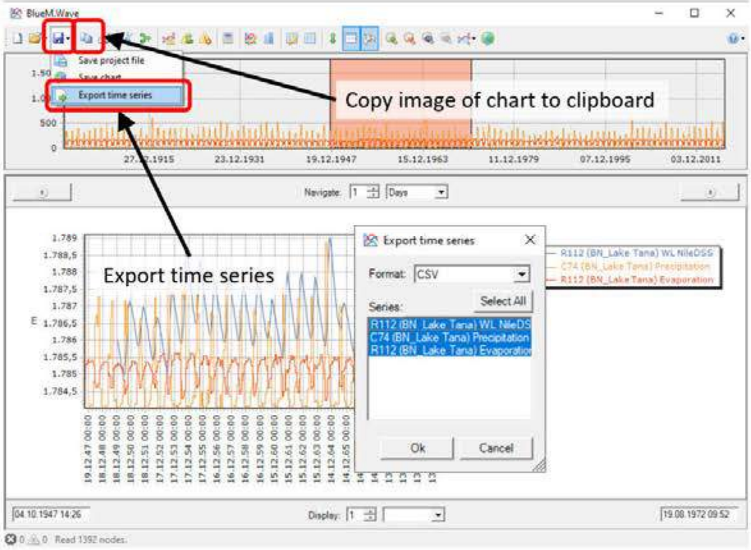
Image export

Time series export
Formats:

- **CSV**
- **BIN** (SYDRO binary format)
- ZRE
- ZRXP (ZXRP format)
- UVF (Universelles Variables Format)
- ...

Save chart (native format)
*.TEN

Save project file
*.wvp



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For the installation process, we need

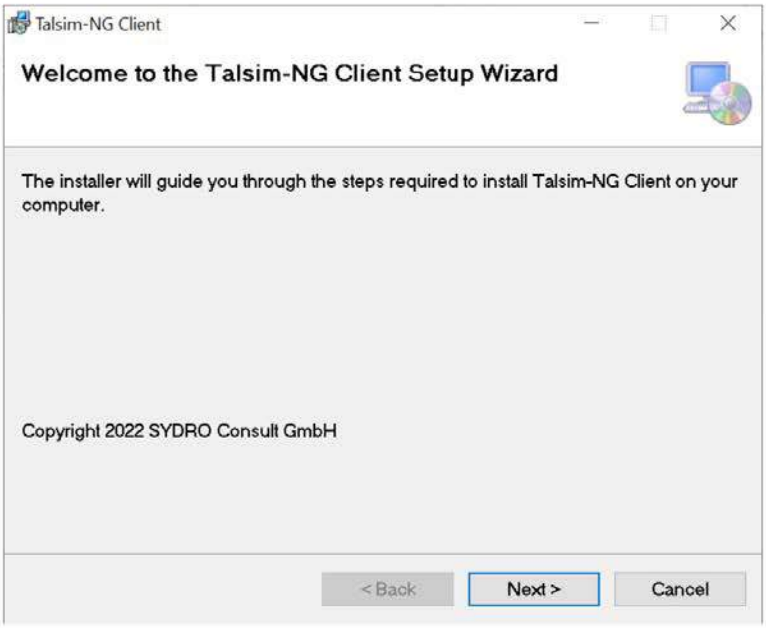
Admininstrator credentials
Microsoft Windows Operating System (>Windows 7)
English Language

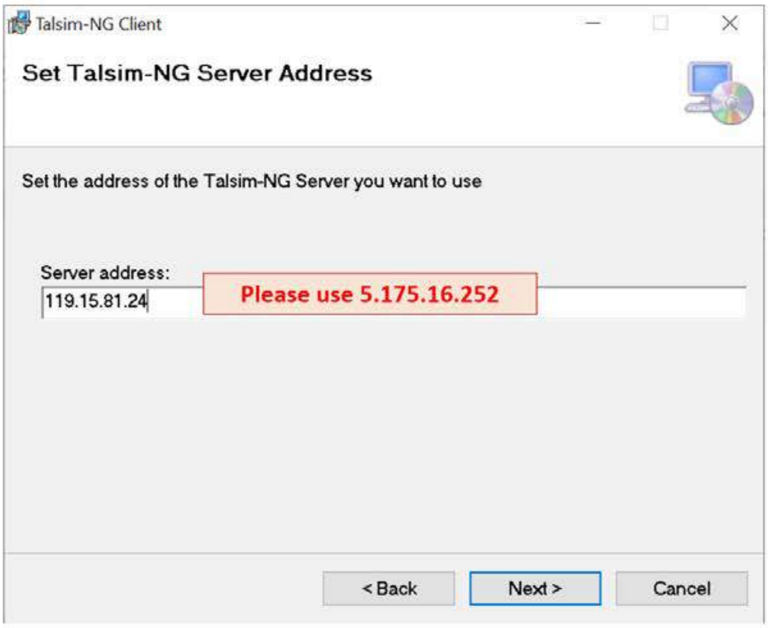
Microsoft .NET Framework 4.8 Runtime:
https://dotnet.microsoft.com/download/dotnet-framework/net48

The installation file can be downloaded from here: https://twk.pm/1trp959zf7

Documentation: http://www.talsim.de/docs/

(remark: we are changing our provider and the Talsim page might be down time and again in the coming weeks)

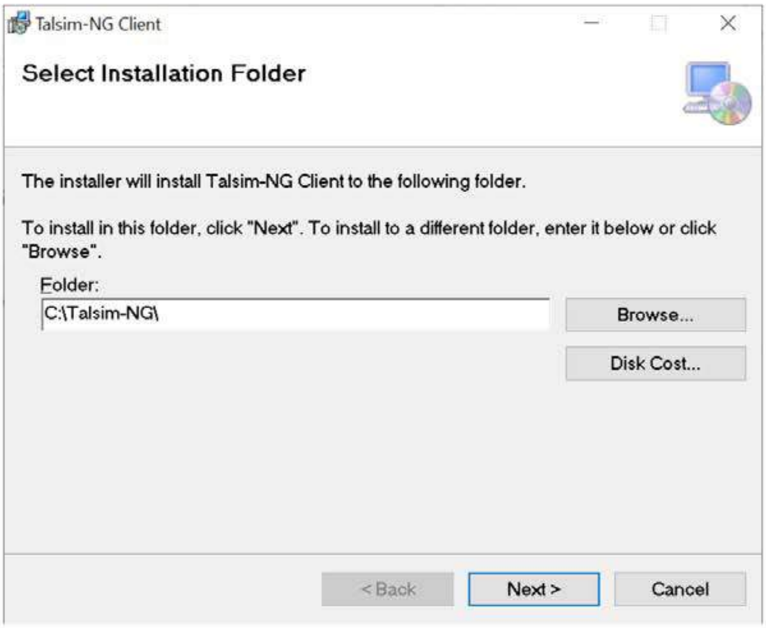


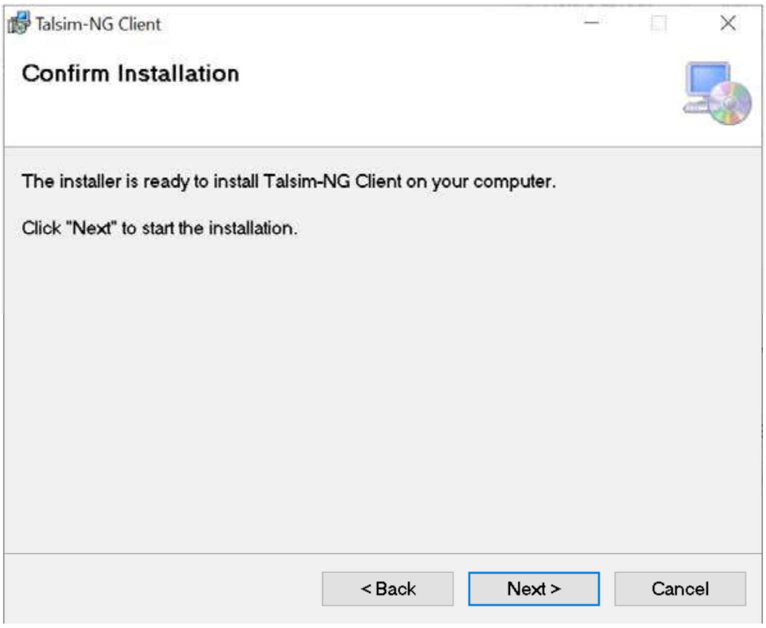


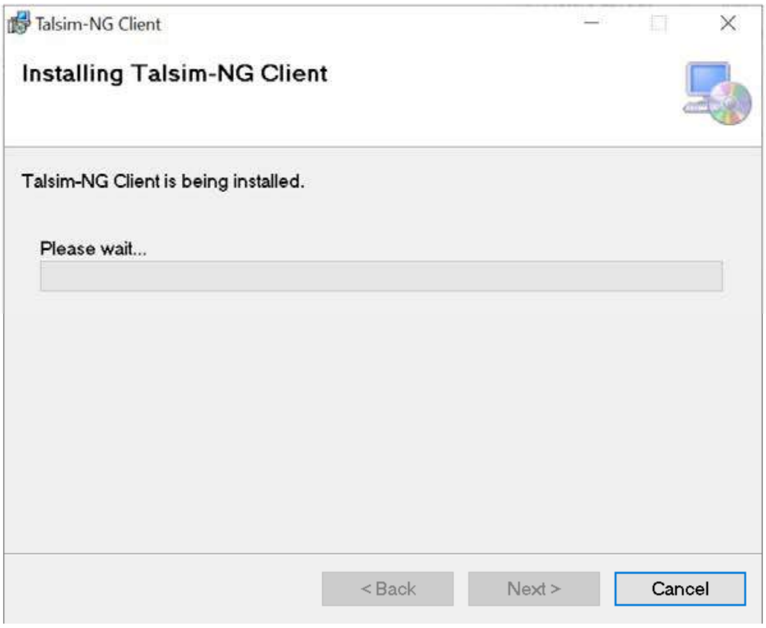
MRC Tasim-NG Server:
IP Address = 119.15.81.24
(for the future)

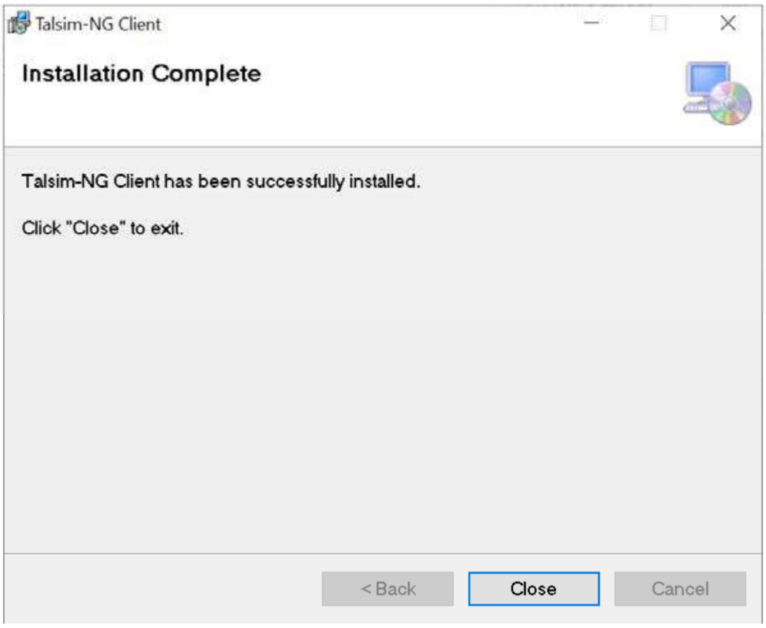
SYDRO Internet-Server:
IP Address = 5.175.16.252
(for now)

Local server:
IP Address = localhost
(if you don't have internet)


Talsim-NG Client
Select Installation Folder
The installer will install Talsim-NG Client to the following folder.
To install in this folder, click "Next". To install to a different folder, enter it below or click "Browse".
Folder:
C:\Talsim-NG\
Browse...
Disk Cost...
< Back
Next >
Cancel


Talsim-NG Client
Confirm Installation
The installer is ready to install Talsim-NG Client on your computer.
Click "Next" to start the installation.
< Back
Next >
Cancel


Talsim-NG Client
Installing Talsim-NG Client
Talsim-NG Client is being installed.
Please wait...
< Back
Next >
Cancel

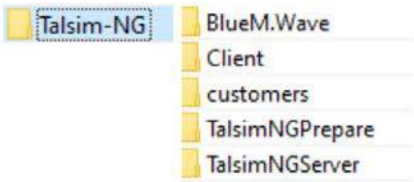

Talsim-NG Client
Installation Complete
Talsim-NG Client has been successfully installed.
Click "Close" to exit.
< Back
Close
Cancel

Download Server, Data and Tools from here: https://twk.pm/5a9j2vpdtc
You will receive this file: TalsimNGServerDataTools.zip

Copy the TalsimNGServerDataTools.zip to the root folder of the application
Default root folder: C:\talsim-ng\

Unzip the file

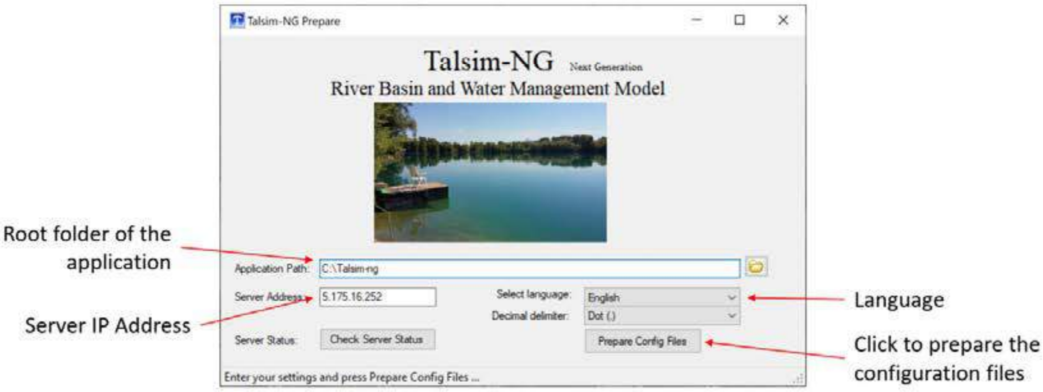
The result should look like this:



Preparation of the Client:
This step is necessary if

- You want to change the language
- You want to connect to a different Talsim-NG server

Double-Click on this file:
C:\Talsim-NG\TalsimNGPrepare\TalsimNGRun.exe



Starting the Client:

Double-Click on this file:
C:\Talsim-ng\Client\TalsimNG\TalsimNG4\TalsimNG.exe

Log in with „username“ and „password“

Select Demo

Introduction to Talsim-NG 4

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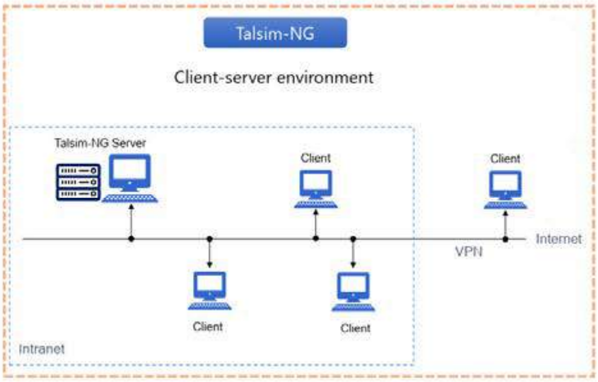

This configuration uses a TalsimNGServer in the Internet and keeps users of Talsim connected. The big advantages are consistent input time series and easy exchange between users.

This configuration uses the local TalsimNGServer, no internet connection is required, but not all time series might be available.

Introduction to Talsim-NG 4

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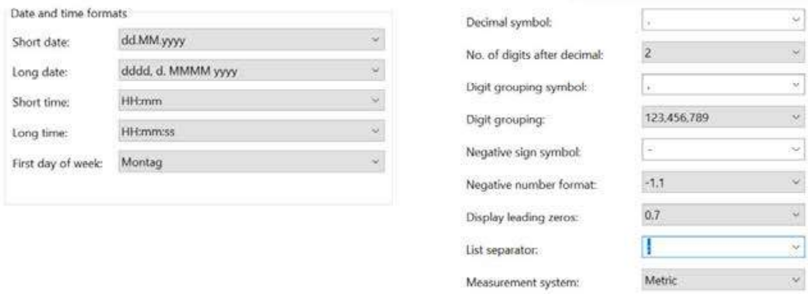
Before we start !

Settings:
- Decimal delimiter = „." (dot)
- Date / Time Settings = dd/MM/yyyy or dd.MM.yyyy



Introduction to Talsim-NG 4

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Running the software

! The local Talsim-NG Server must be started first before you start the client software

You find your local sever here:
C:\Talsim-ng\TalsimNGServer\TalsimNGSrv.exe

Startmenu and look up Talsim-NG Server 

Or

Create a shortcut on your desktop 

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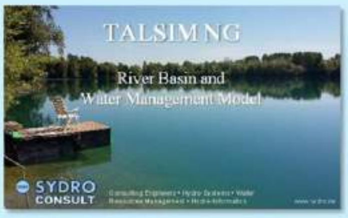

Talsim-NG - River Basin and Water Management Model

Structure of the client, database, datasets and simulation

Dr. Hubert Lohr, Felix Froehlich, Nada Abdelwahab, Emanuel Döser, Kai Sonntag

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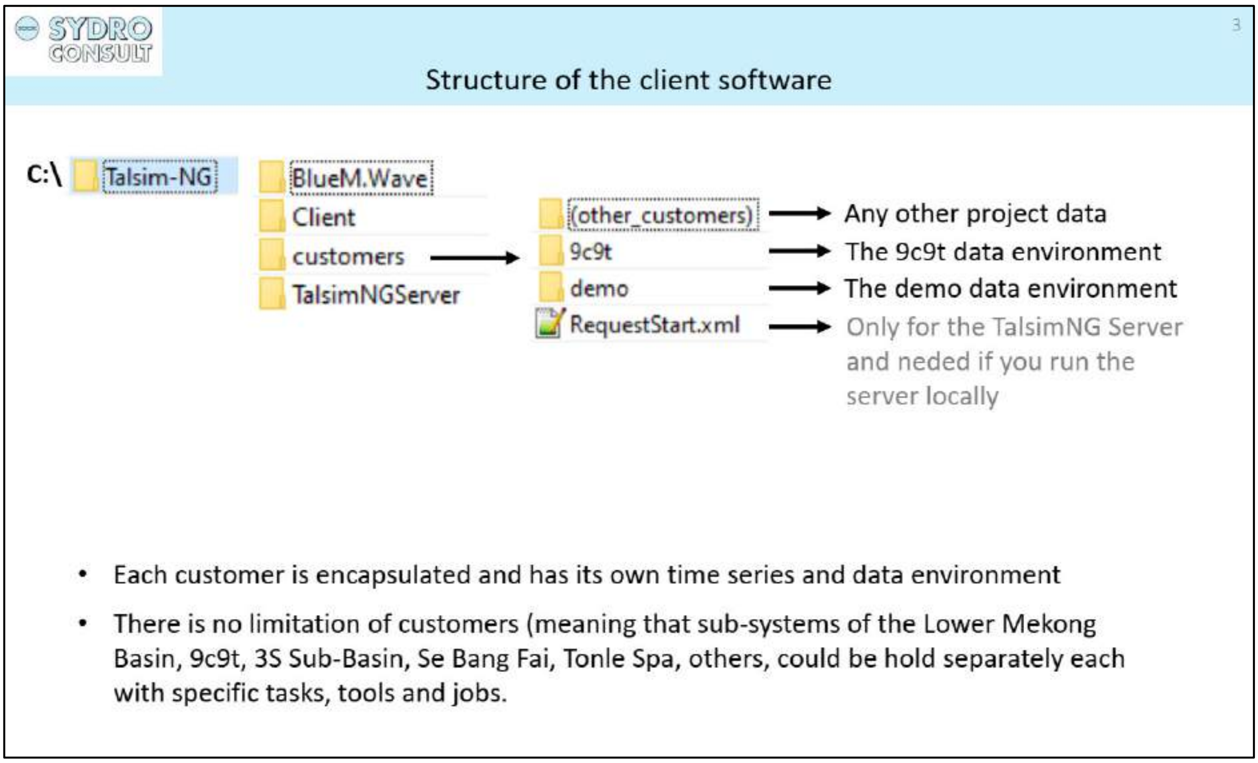
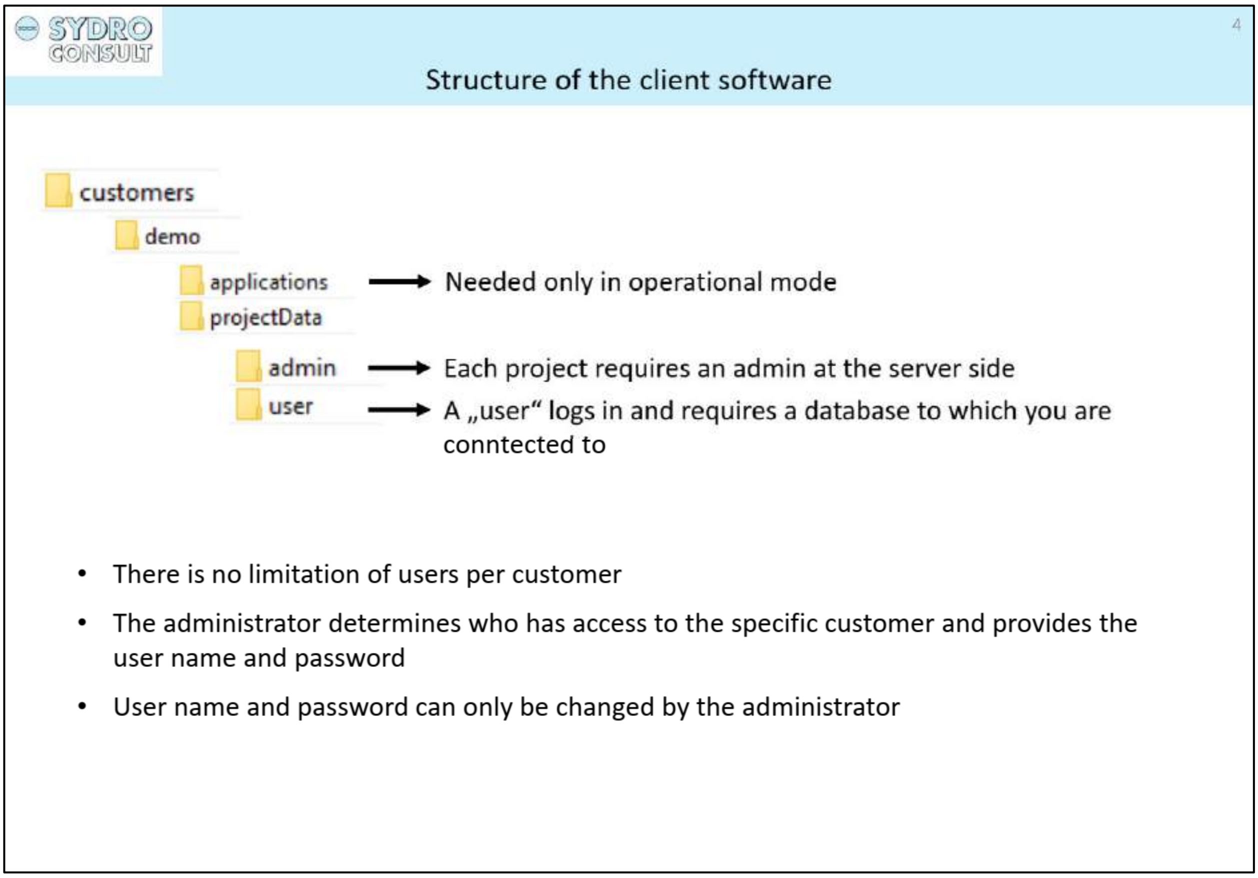
Structure of the client software

C:\ Talsim-NG

- BlueM.Wave
- Client →
  - Definition → Contains client specific parameters
  - Doku → Replaces by website
  - Log → Log files of the client
  - SimEngine → Contains the simulation engine
  - Simulation → Temporary folder for simulations
  - TalsimNG4 → The client GUI
- customers
- TalsimNGServer


SYDRO CONSULT
3
Structure of the client software
C:\
Talsim-NG
BlueM.Wave
Client
customers
TalsimNGServer
(other_customers)
9c9t
demo
RequestStart.xml
Any other project data
The 9c9t data environment
The demo data environment
Only for the TalsimNG Server and neded if you run the server locally
• Each customer is encapsulated and has its own time series and data environment
• There is no limitation of customers (meaning that sub-systems of the Lower Mekong Basin, 9c9t, 3S Sub-Basin, Se Bang Fai, Tonle Spa, others, could be hold separately each with specific tasks, tools and jobs.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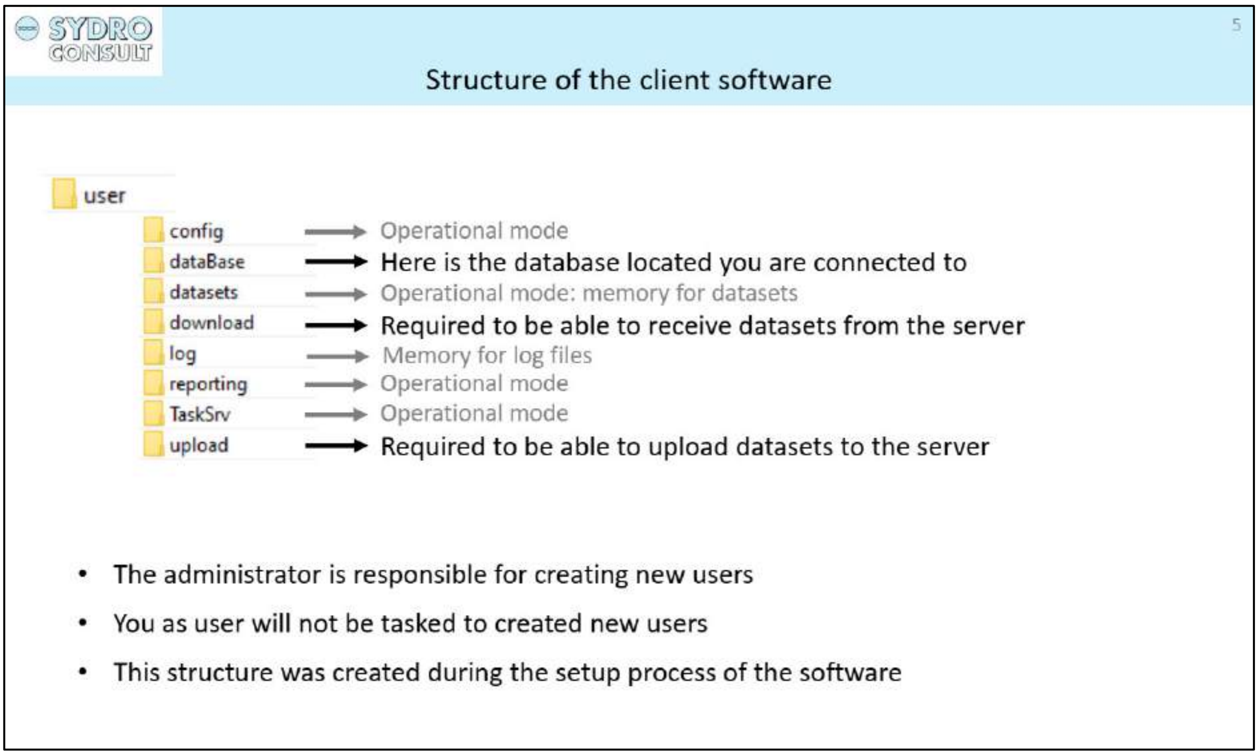
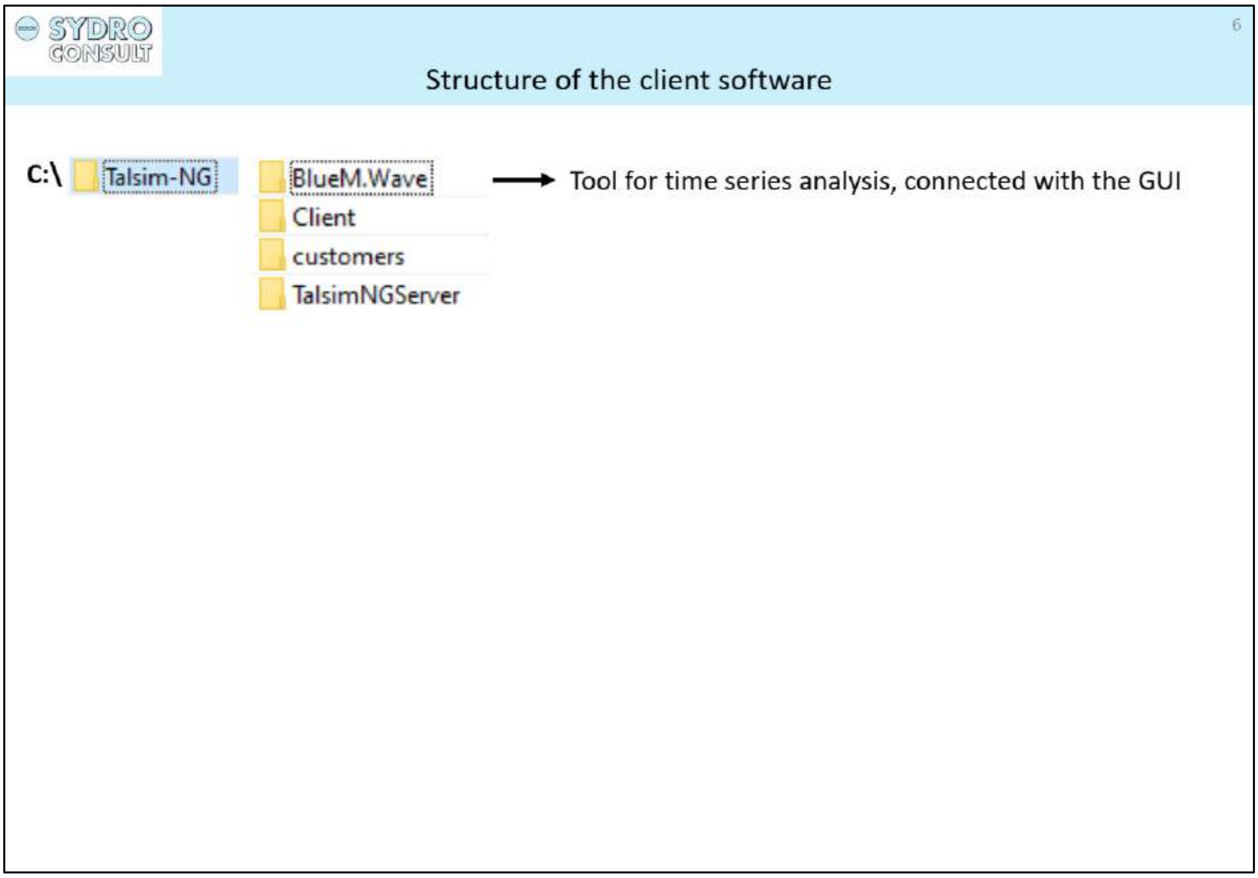
4
Structure of the client software
customers
demo
applications
projectData
admin
user
Needed only in operational mode
Each project requires an admin at the server side
A „user" logs in and requires a database to which you are conntected to
• There is no limitation of users per customer
• The administrator determines who has access to the specific customer and provides the user name and password
• User name and password can only be changed by the administrator


SYDRO CONSULT
5
Structure of the client software
user
config
dataBase
datasets
download
log
reporting
TaskSrv
upload
Operational mode
Here is the database located you are connected to
Operational mode: memory for datasets
Required to be able to receive datasets from the server
Memory for log files
Operational mode
Operational mode
Required to be able to upload datasets to the server
• The administrator is responsible for creating new users
• You as user will not be tasked to created new users
• This structure was created during the setup process of the software


SYDRO CONSULT
6
Structure of the client software
C:\
Talsim-NG
BlueM.Wave
Client
customers
TalsimNGServer
Tool for time series analysis, connected with the GUI

SYDRO CONSULT 7

Structure of the client software

C:\ Talsim-NG
- Client
  - Definition
  - Doku
  - Log
  - SimEngine
  - Simulation
  - TalsimNG4

When a user starts a simulation run:

1. A dataset is exported to the **Simulation** folder
2. The configuration file is prepared for the talsim simulation engine
3. The simulation engine is started in the **SimEngine** folder

- A TalsimNG Dataset consists of different files all located in one folder.
- If a dataset is exported to the memory of datasets, it can be manipulated by other tools, for instance the optimisation tool BlueM.Opt.
- Tasks-jobs and scripts can be configured to perform simulations, optimizations, forecasts, etc. including pre- and post-processing!

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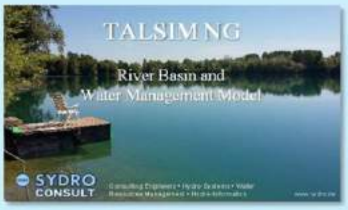
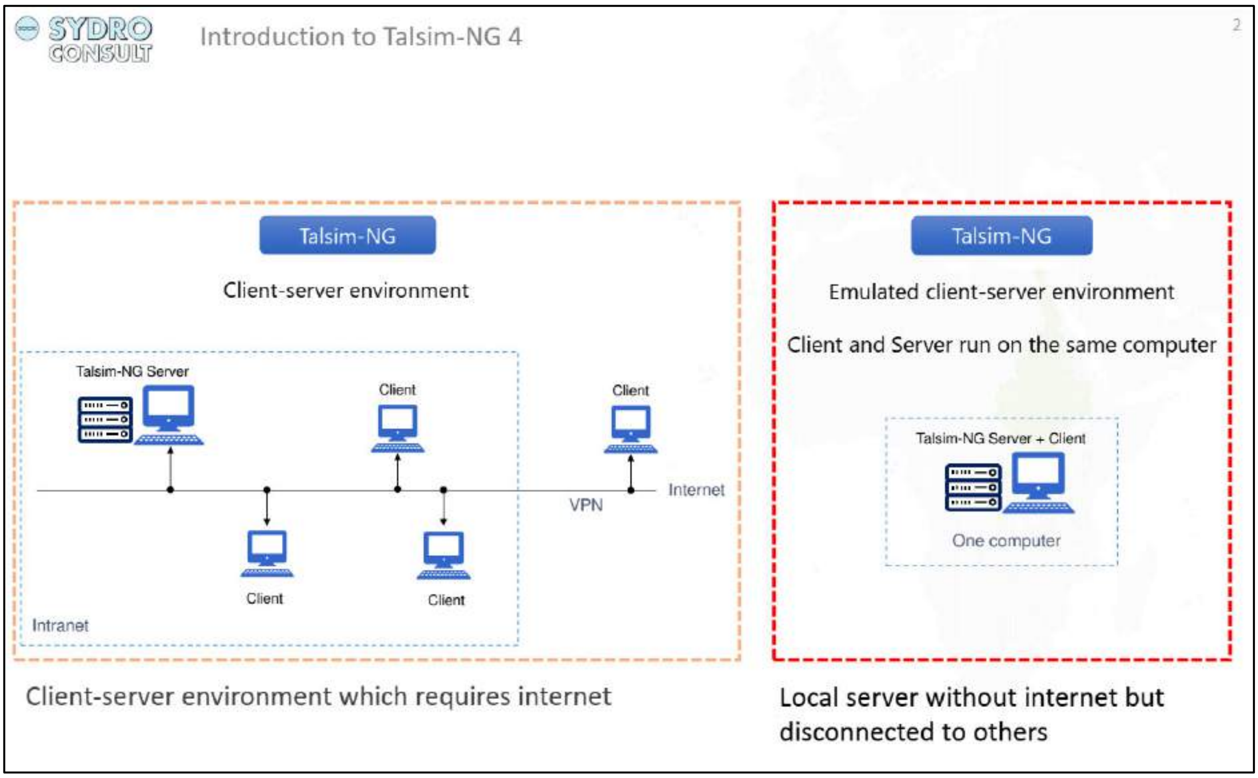
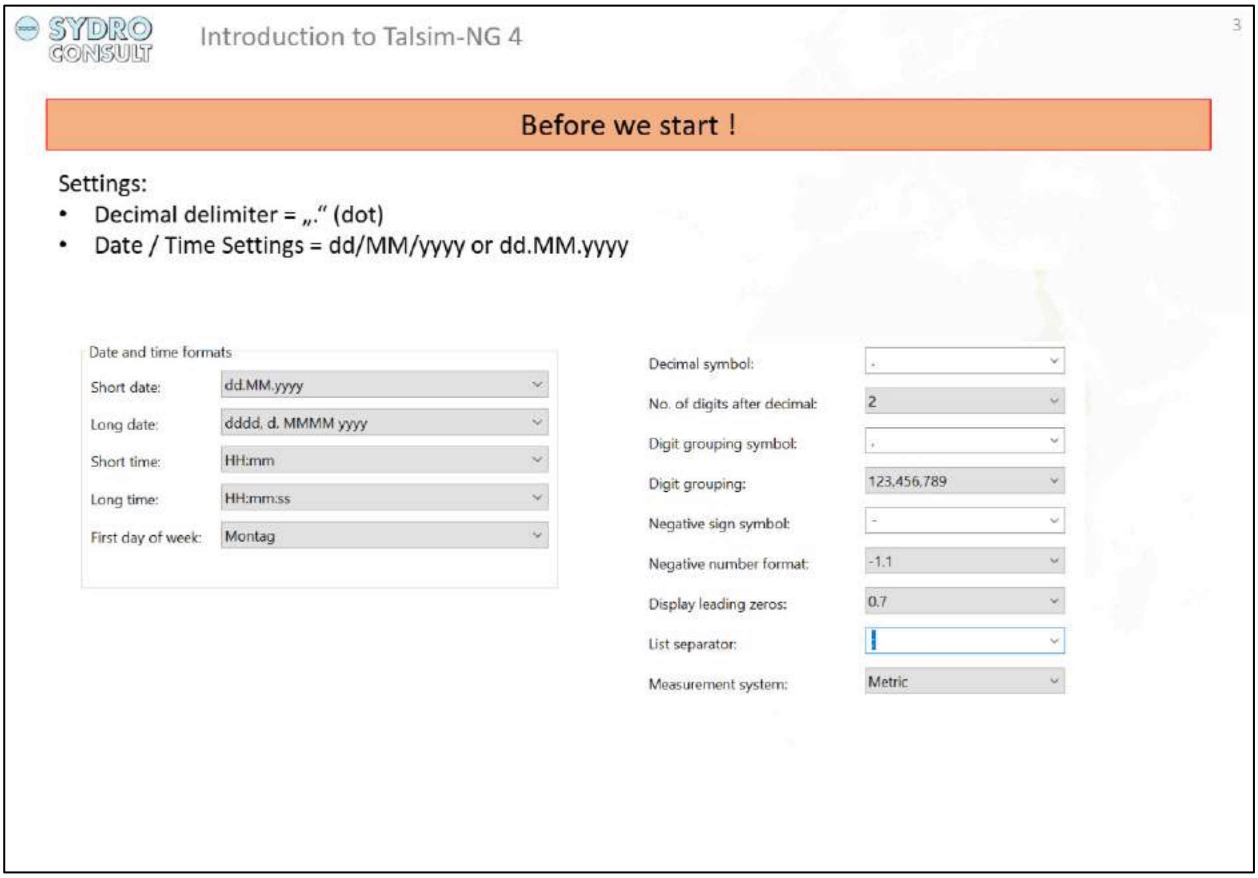


Talsim-NG - River Basin and Water Management Model

Introduction to Talsim-NG

Dr. Hubert Lohr, Felix Froehlich, Nada Abdelwahab, Emanuel Döser, Kai Sonntag


SYDRO CONSULT
Introduction to Talsim-NG 4
2
Talsim-NG
Client-server environment
Talsim-NG Server
Client
Client
Internet
VPN
Client
Client
Intranet
Talsim-NG
Emulated client-server environment
Client and Server run on the same computer
Talsim-NG Server + Client
One computer
Client-server environment which requires internet
Local server without internet but disconnected to others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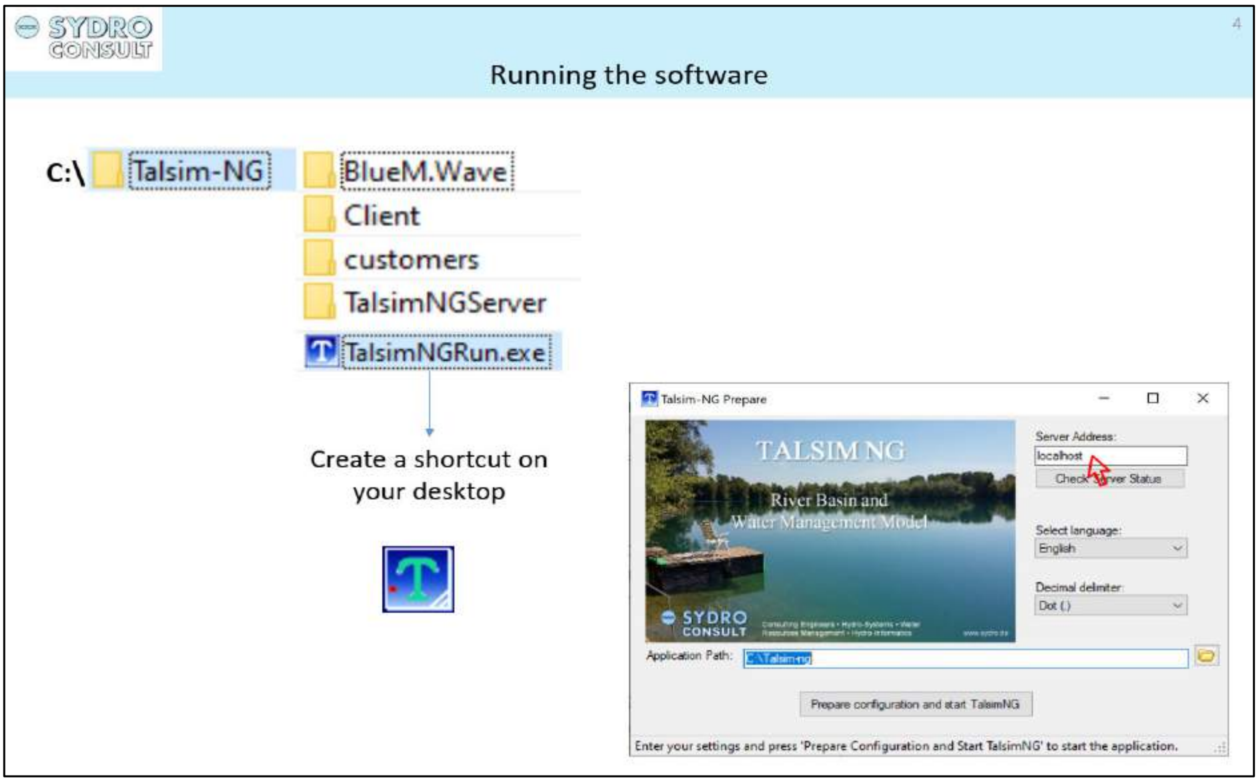
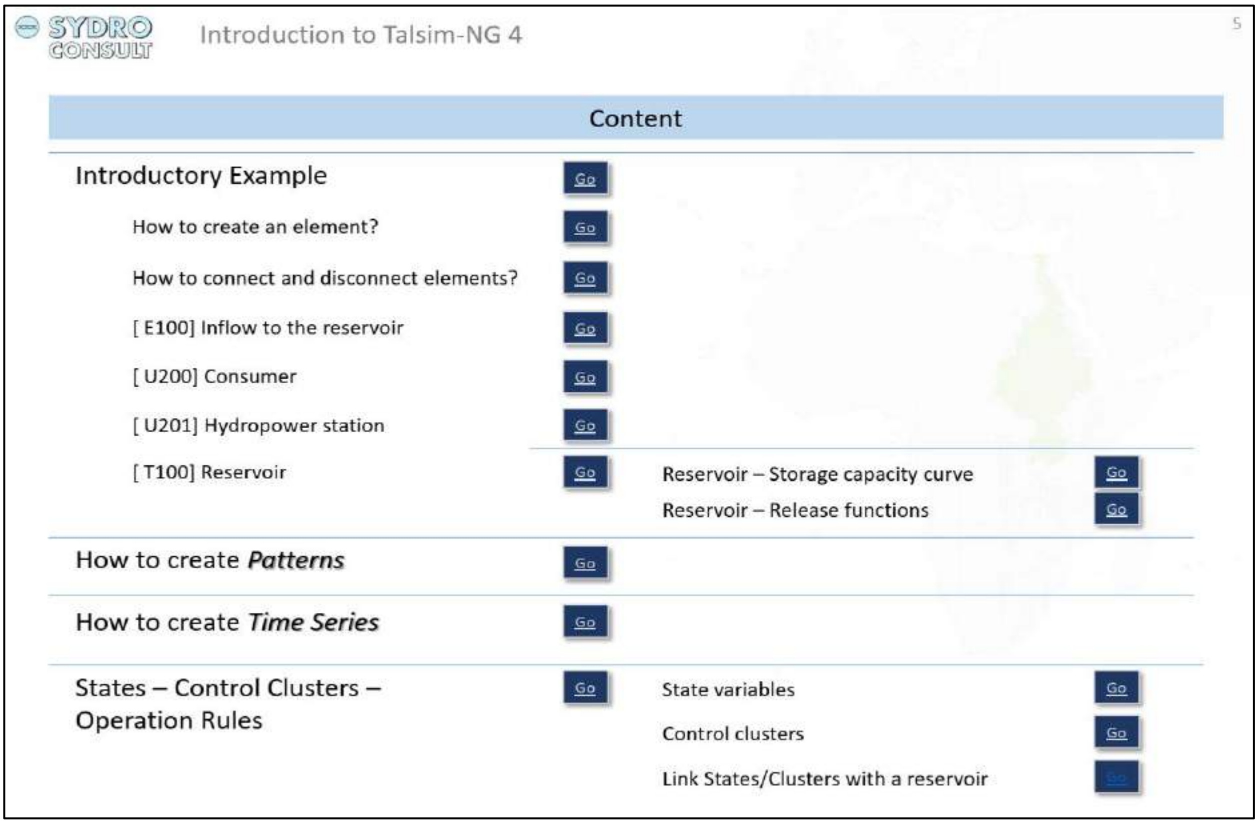
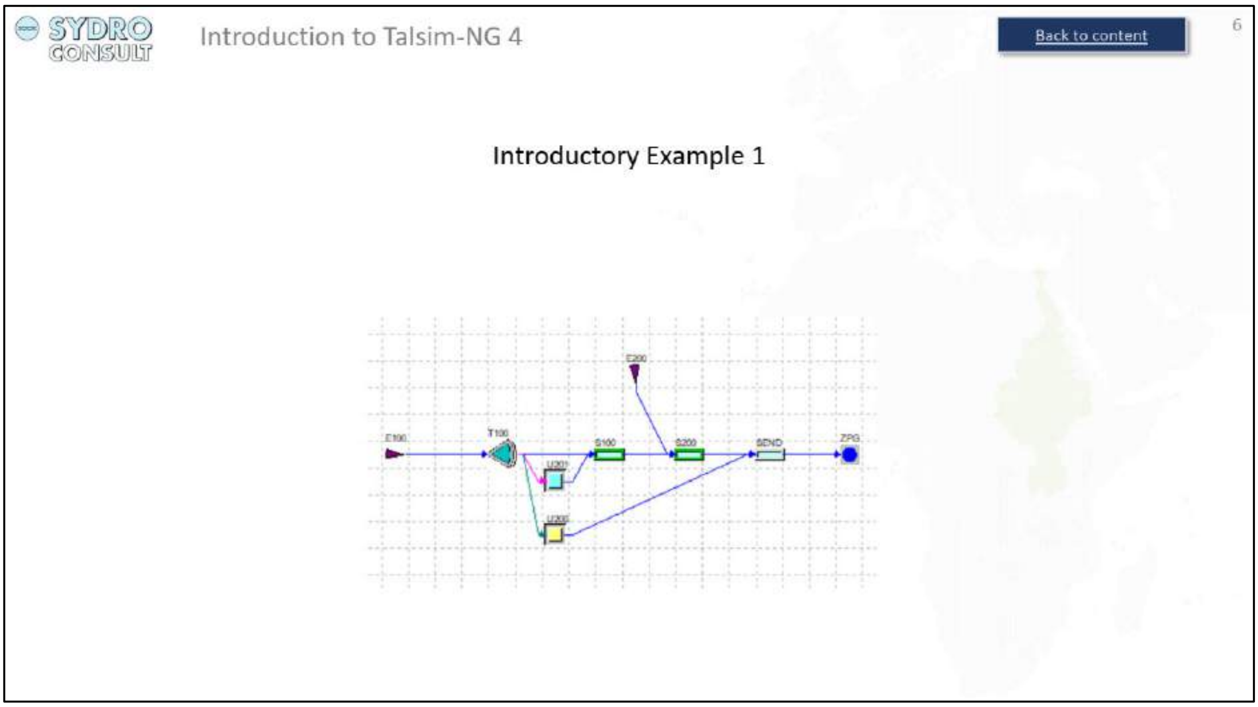
Introduction to Talsim-NG 4
3
Before we start !
Settings:
Decimal delimiter = „.“ (dot)
Date / Time Settings = dd/MM/yyyy or dd.MM.yyyy
Date and time formats
Short date: dd.MM.yyyy
Long date: dddd, d. MMMM yyyy
Short time: HH:mm
Long time: HH:mm:ss
First day of week: Montag
Decimal symbol: .
No. of digits after decimal: 2
Digit grouping symbol: ,
Digit grouping: 123,456,789
Negative sign symbol: -
Negative number format: -1.1
Display leading zeros: 0.7
List separator:
Measurement system: Metric


SYDRO CONSULT
4
Running the software
C:\ Talsim-NG
BlueM.Wave
Client
customers
TalsimNGServer
TalsimNGRun.exe
Create a shortcut on your desktop
Talsim-NG Prepare
TALSIM NG
River Basin and Water Management Model
SYDRO CONSULT
Server Address:
localhost
Check Server Status
Select language:
English
Decimal delimiter:
Dot (.)
Application Path:
C:\Talsim-ng
Prepare configuration and start TalsimNG
Enter your settings and press 'Prepare Configuration and Start TalsimNG' to start the application.


SYDRO CONSULT
Introduction to Talsim-NG 4
5
Content
Introductory Example Go
How to create an element? Go
How to connect and disconnect elements? Go
[E100] Inflow to the reservoir Go
[U200] Consumer Go
[U201] Hydropower station Go
[T100] Reservoir Go
Reservoir – Storage capacity curve Go
Reservoir – Release functions Go
How to create Patterns Go
How to create Time Series Go
States – Control Clusters – Operation Rules Go
State variables Go
Control clusters Go
Link States/Clusters with a reservoir


SYDRO CONSULT
Introduction to Talsim-NG 4
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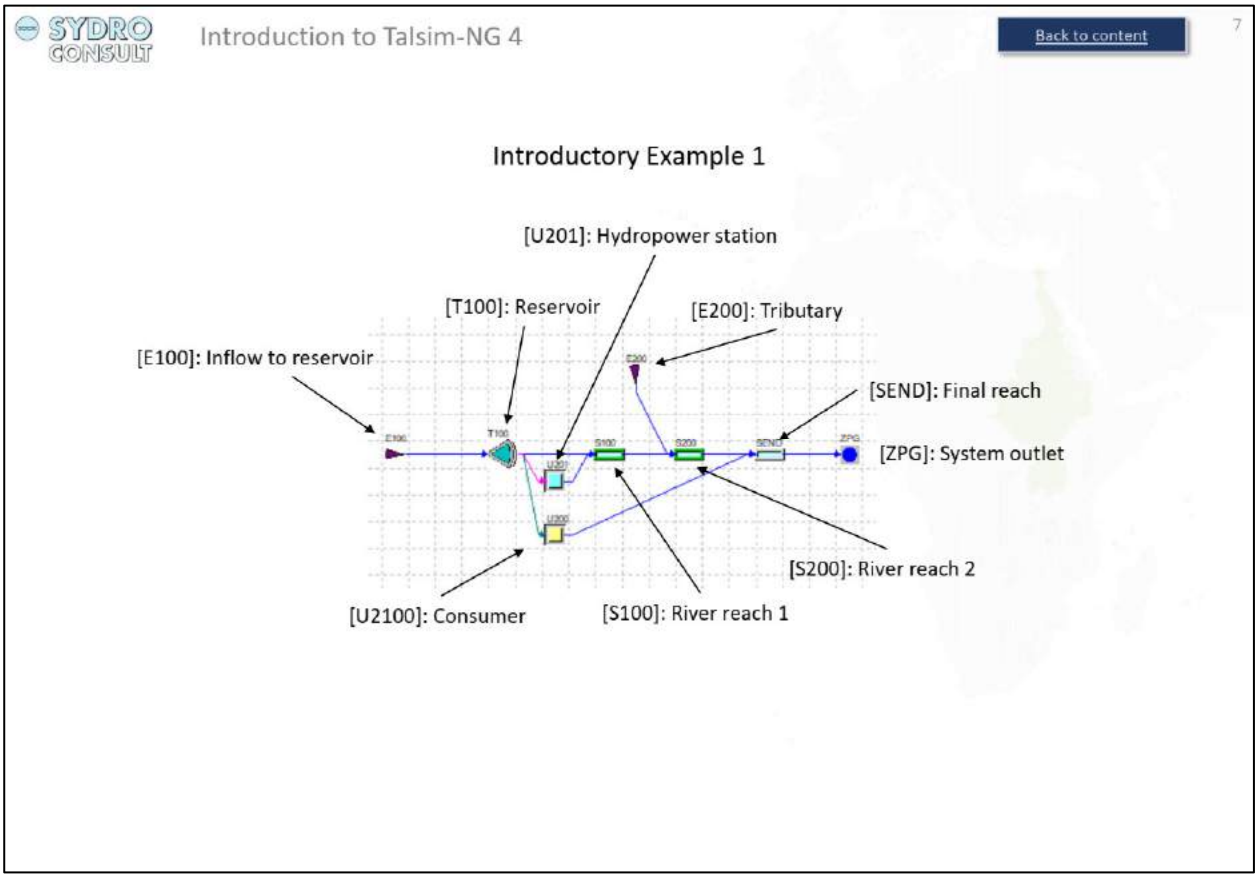
6
Introductory Example 1


SYDRO CONSULT
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Introductory Example 1
[U201]: Hydropower station
[T100]: Reservoir
[E200]: Tributary
[E100]: Inflow to reservoir
[SEND]: Final reach
[ZPG]: System outlet
[S200]: River reach 2
[U2100]: Consumer
[S100]: River reach 1

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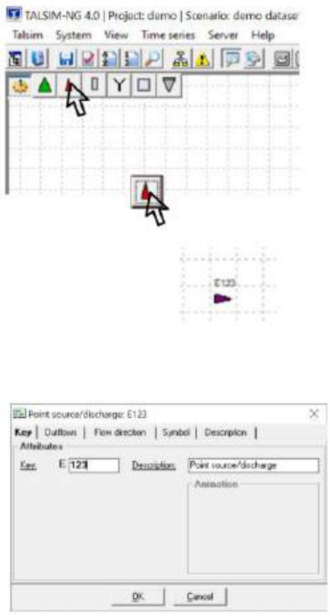
How to create an element?



1. Select the element type you want to be generated
2. Drag and drop the element to a location
3. Drop the element
4. Provide a unique key and meaningful short description

Repeat the process to generate other elements

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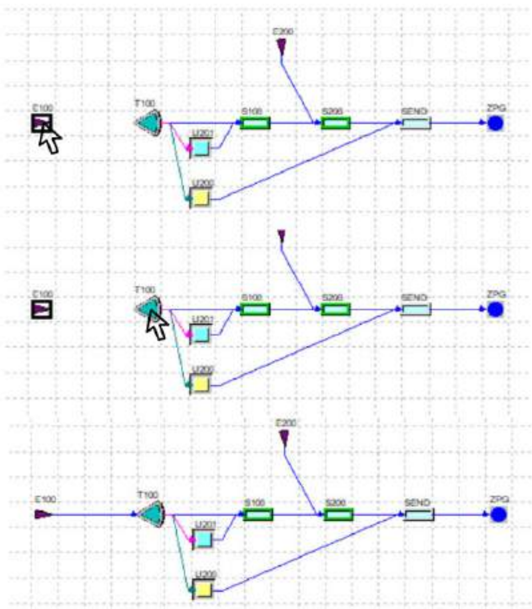
How to connect and disconnect elements?



Connect elements

1. Connect two elements by holding down the CTRL key and dragging the element on top of another element.
2. Drop the element on top of your target element and a flow arrow is generated.

Disconnect elements

Repeating the process for an existing connection removes the connection.

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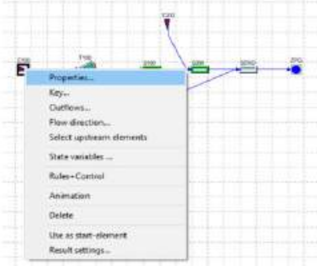
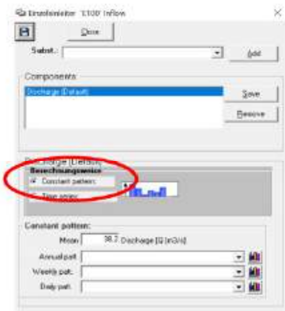
[E100]: Inflow to reservoir

1. Click on E100
2. Right mouse click
3. Select Properties



Calculation options

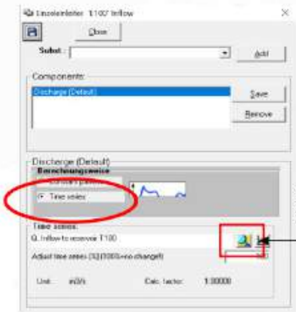
Constant pattern



Selection of monthly, weekly or daily values or a combination thereof is possible.
A pattern must be generated before they can be selected.

How to generate Patterns see section ***Patterns***.

Time series



Click to open the time series manager

Selection of a time series from the time series manager is possible. You can remove an already selected time series by selecting the time series name and pressing „Remove".

How to generate a time series see section ***Time series***.

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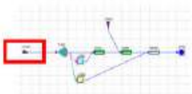
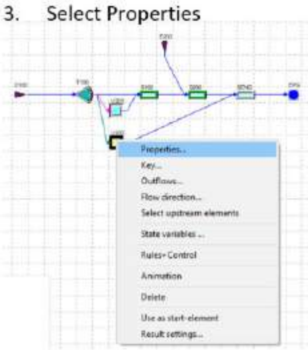


[U200]: Consumer

1. Click on U200
2. Right mouse click
3. Select Properties



Behaviour

A consumer has a ***Behaviour*** describing how inflow is returned to the system and has options for water demand and possible water supply. While ***Behaviour*** is mandatory, demand and supply are optional.

Behaviour:

Retention describes the time lag of return flow as storage coefficient in hours.

The calculation mode determines how much inflow is returned. For example, a percentage of 0 means no return flow at all.

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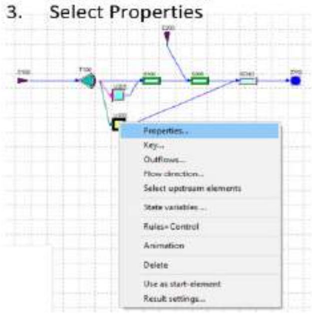
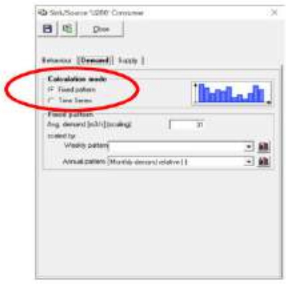
[U200]: Consumer

1. Click on U200
2. Right mouse click
3. Select Properties



Demand

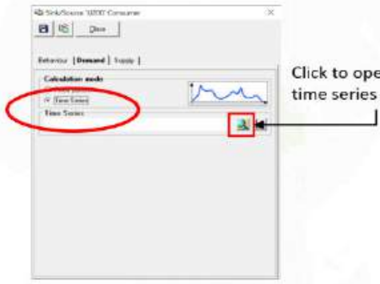
Constant pattern



Selection of monthly or weekly values or combination thereof is possible.
A pattern must be generated before it can be selected.

How to generate patterns see section ***Patterns***.

Time series



Selection of a time series from the time series manager is possible. You can remove an already selected time series by selecting the time series name and pressing „Delete" on your keyboard.

How to generate a time series

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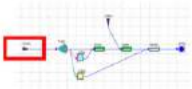
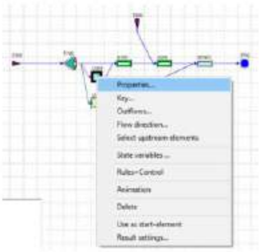


[U201]: Hydropower station

1. Click on U201
2. Right mouse click
3. Select Properties



Behaviour

The ***Behaviour*** of U201 should be consistent with a turbine station. In this case we assume no losses and 100% of inflow goes back into the system.
There is no considerable time lag between inflow and outflow, therefore, Retention in [h] is very small.

Behaviour:

Use percentage. 100% of inflow goes back into the system.

Demand:

none

Supply:

none

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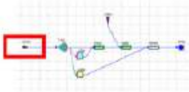
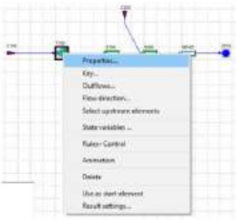


[T100]: Reservoir

1. Click on T100
2. Right mouse click
3. Select Properties



General Properties

The ***General properties*** determine the basic data of a reservoir. The first time a new reservoir is accessed, this window pops up. Once the data is filled the default reservoir window appears.

Max. storage and max. elevation refers to either the crest level or to a fictitious maximum level that is only used as a ceiling for calculation.

The spillway level is an informative value and has no meaning for the calculation. The real spillway is determined as a release function and is described here.

The bottom level is used as the lowest possible elevation and allows validity checks when the user enters values.

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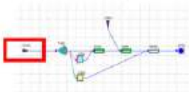
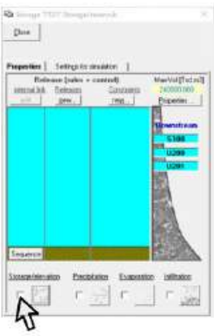


[T100]: Reservoir

Storage-Elevation-Surface relationship

The ***Storage-Elevation-Surface*** relationship is mandatory. All eventually created release functions must be defined within the min-max range of the ***Storage-Elevation-Surface*** relationship.

1. Tick Storage/elevation and confirm.



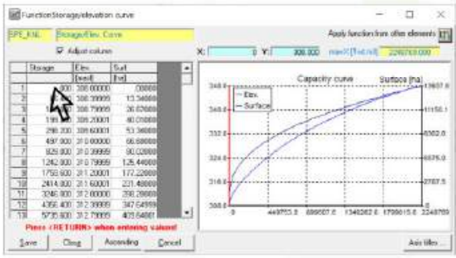
2. Prepare three columns:
   1) Storage [Tm³]
   2) Elevation [masl]
   3) Surface [ha]

   and copy it with CTRL+C

Storage capacity curve

Storage	Elevation	Surface
Tm3	masl	ha
0	308	0.00
66.4	308.4	13.34
132.8	308.8	26.67
199.2	309.2	40.01
298.2	309.6	53.34
497	310	66.68
829	310.4	80.02
1242	310.8	125.44
1759.6	311.2	177.22
2414	311.6	231.48
3246	312	288.28
4356.4	312.4	347.65
5735.6	312.8	409.64
7417.6	313.2	474.28
9451	313.6	541.61

3. Select the utmost left cells and paste CTRL+V



!

Min. storage must be 0!
Max. storage must be consistent to what was given in the ***General Properties*** (see here)

Min. and max. Elevation must be consistent to what was given in the ***General Properties*** (see here)

Min. Surface must be 0!

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[T100]: Reservoir

Creating a release function

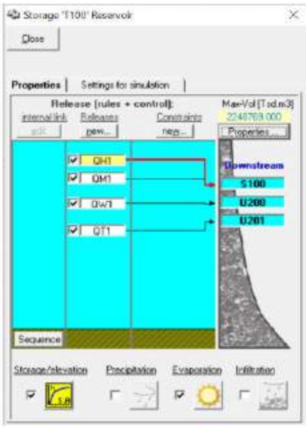
A ***Release function*** is the general term used for all kinds of releases from the reservoir. The requirement for a release function is its dependency on the storage volume. Usually, a ***spillway*** is a release function, driven by hydraulic parameters or by a functional relationship as Release = function(Storage).
It is recommended to determine separate release functions for each purpose, e.g. one for water supply, one for flood response, one for hydropower, one for minimum flow and so on. In so doing, operating rules can be assigned individually.

QH1 = Spillway

QM1 = Minimum flow

QW1 = Water supply

QT1 = Turbine



Goto General Properties of the reservoir

Shows the connected elements

Can be used to create Rainfall, Evaporation from the reservoir surface or Leakage into the underground.

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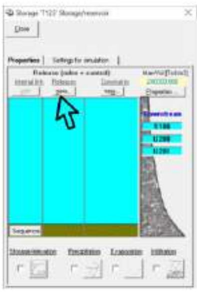
[T100]: Reservoir

Creating a release function

1. Click ***New*** below Releases

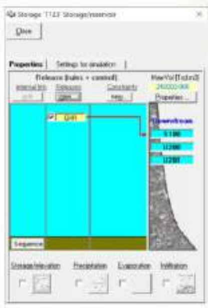


2. Select from the list

NOTE: the most flexible one is ***Release*** while other types have restrictions on how to define operation rules.

2. Link the Release to an outlet

NOTE: An outlet is created by connecting the reservoir with other elements (see here). It is recommended to connect and save elements before defining releases.



1. Select the release
2. Drag and drop it on top of an outlet.

A line will be drawn showing to which outlet the water will flow.

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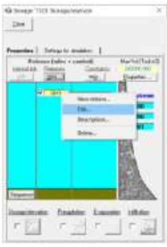
[T100]: Reservoir

Creating a release function

4. Right mouse click on the release and select *Edit* opens the ***Release Editor***



5. Editing a release

Provide a meaningful name with max. 50 characters.
Enter the elevation of the outlet.

Select the calculation mode:

Function (Rule): Default, Requires a function of the storage volume that is scaled by a combination of a static factor and patterns (patterns see here).

Function + file: Requires a function of the storage volume that will be scaled by values from a time series.

Weir hydraulics: Determines releases by means of a hydraulic function.

Pipeline: Determines releases by means of hydraulic parameters describing pressure flow in pipes.

Turbine: Determines releases by using a turbine efficiency curve.
NOTE: hydropower generation can be incorporated much more flexible by means of States + Clusters + Operation Rules.

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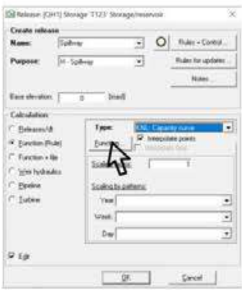
[T100]: Reservoir

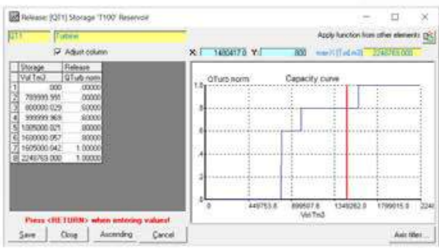
Creating a release function

6. Click on ***Function*** to edit values



7. Edit the function

A function can have up to 200 x-y nodes



Values can be entered by hand or by copy-paste, for example from Excel.

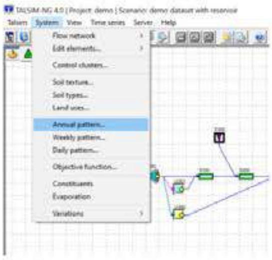
Save, close and reopen the window helps refresh the graph.

! X-values must have an ascending order, y-values do not.

No duplicates for x-values allowed.

Pattern - How to create a pattern?

1. Open the System menu and navigate to *Annual pattern*, *Weekly pattern* or *Daily pattern*

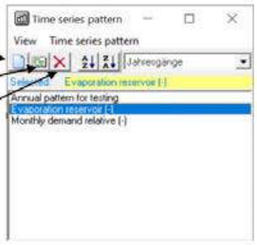


2. The list of patterns appears where you can select an existing one, create a new or delete a pattern.

New

Edit

Delete

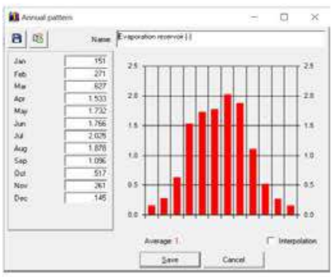


Pattern - How to create a pattern?

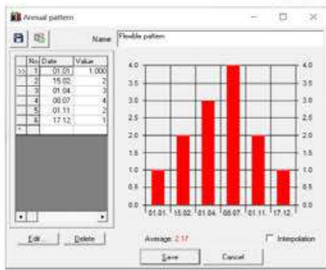
Annual pattern

There are flexible annual patterns or static (monthly) patterns. You will be asked which one you want to create.

Static (monthly) pattern
This is the common approach. One value can be assigned to each month. Values can be interpolated.



Flexible annual pattern
Any date in the year can be used to assign a value to it. Up to 365 values are theoretically possible. Values can be interpolated



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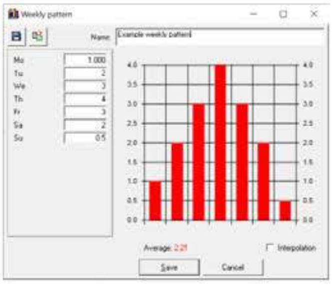
Pattern - How to create a pattern?

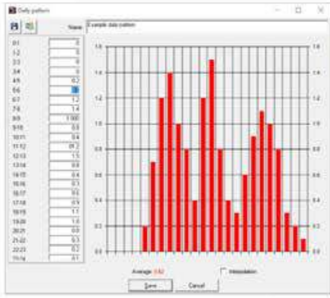
Creating an ***Weekly pattern***

A weekly pattern contains one value for each day of a week. Values can be interpolated.



Creating an ***Daily pattern***

A daily pattern consists of 24 values, one for each hour. Values can be interpolated.



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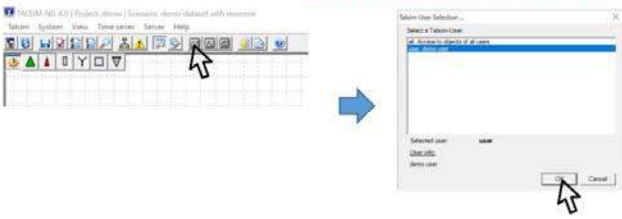
Time series - How to create a time series?

1. Prepare your time series as date/value pairs, best done in Excel
   Date must be: **dd.MM.yyyy** or **dd/MM/yyyy**

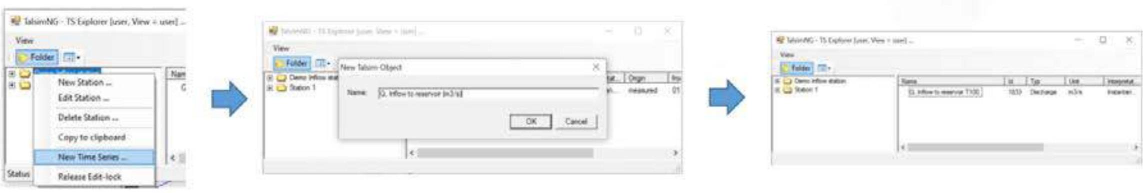
10	Date	Inflow m3/s
11	01.01.1995	119.3
12	02.01.1995	71.3
13	03.01.1995	59.9
14	04.01.1995	46.7
15	05.01.1995	46.9
16	06.01.1995	36.2

2. Open Time Series Manager and make sure you select your user name!



! The time series server requires that the logged-in user and the selected user are identical.

3. Select the relevant station or create a new station. Select the station, right mouse click and select *New Time Series*.
   Provide a name (not more than 50 characters!) and press OK
   The new time series appears in the the time series manager with default properties Type=Discharge, Unit=m3/s



Time series - How to create a time series?

4. Make sure your time series has correct properties!
Right mouse click and select *Edit Time Series* to see the properties.

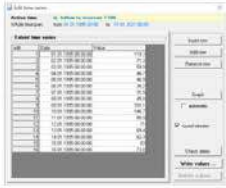
! The time series server requires that the logged-in user and the selected user are identical.

5. Right mouse click on the time series, select *Edit Values* and *add* ...
As long as the time series is still empty, a message pops up saying that no time series could be found. Please confirm.
The *Edit Time Series* window appears where you can paste the date/value pairs.


Mark and copy values

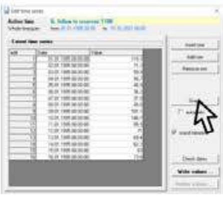
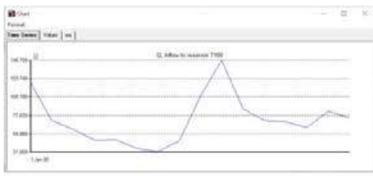
Click once into the first left cell

CTRL+V pastes the values into the spreadsheet



Time series - How to create a time series?

6. Hint: Press Graph and check your time series visually

7. Press *Write Values* ... and your time series will be saved by the time series manager and uploaded to your connected Talsim-NG Server. A success message should pop up. Close the *Edit Time Series* window.

! You can repeat the process several times for the same time series. Always use *Edit Values* and *add* ... !!!
Every time you do that, new values are uploaded and overwrite old values if values for the given time period already exist.

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States – Control Clusters – Operation Rules

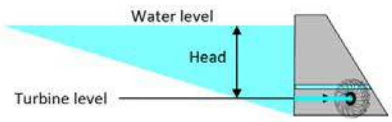
Operation rules are defined by means of *States* and *Control Clusters*.
Each element has a set of states specific for its hydrological context like inflow, outflow, water level, flow velocity, actual evaporation and so on. The states for a sub-basin with precipitation-runoff modelling is of course different to the states of a reservoir. Generally, all states can be used to determine a operation rule. The concept is simple:

1. Create a state you want to use as a driver for an operation rule

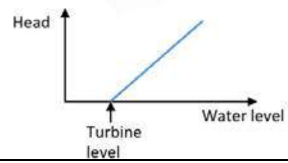
2. Use either *current values* or determine a *transformation function* for the state to be used for the operation rule

Current value: refers to the current value during the simulation for each time step.
Example: When the water level of a reservoir is needed, it will be updated every time step and an operation rule can use the updated water level.

Transformation function: The state uses a functional relationship in order to transform the state into the information required for the operation rule.
Example: The head for a turbine depends on the current water level and the elevation of the turbine. The transformation function uses both to calculate the head.



Transformation function ➡ Head = Water level(t) – Turbine Level



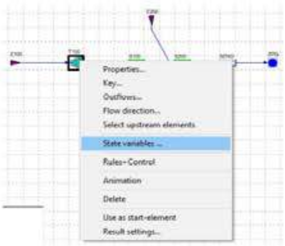
3. Link the output to a release function at a reservoir, which is described here.

SYDRO CONSULT Introduction to Talsim-NG 4 Back to content 27

States

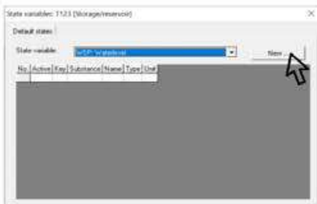
1. In order to *create a state* the element must be selected that holds the state that is required

Example:
Water level of a reservoir

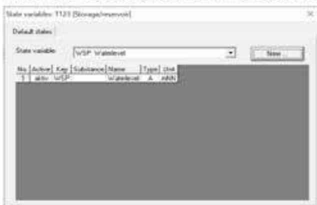


2. Select the state and press *New*

Releases once they are created become visible in the Tab *Releases*

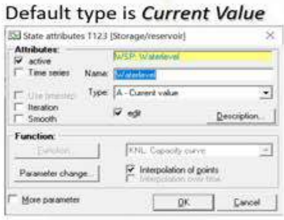


The new state appears in the table



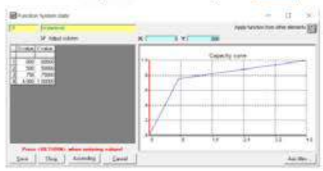
3. Double click on the entry in the table opens the *State Editor*

Default type is *Current Value*



To create a transformation function select *Function* in the *Type* combo box and press the button *Function*.

The *Function Editor* appears where the relationship can be set (see here)



Introduction to Talsim-NG 4

Back to content

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Control- (or State-) Clusters

A *Control Cluster* combines states and creates a logical state that can be used for operation rules. Examples are:

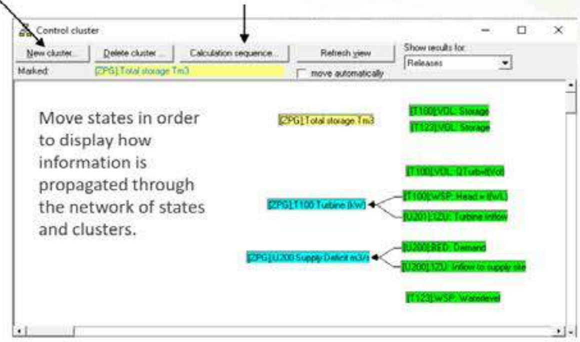
- virtual total storage volume as sum of more than one current storage of reservoirs
- sum of different lateral inflows that might impact on a downstream river reach
- total water demand from various sites that must be fulfilled by a reservoir

States must have been created beforehand in order to combine them. All states and clusters are displayed in the control cluster network.

Open the control cluster network

Create a *New Cluster* here

Determine *Calculation order* of clusters



Link states/clusters by holding CTRL and dragging/dropping them on top of another one

Introduction to Talsim-NG 4

Back to content

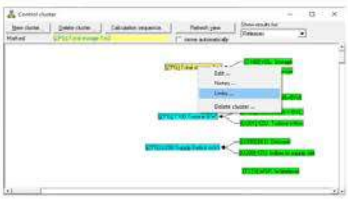
29

Control- (or State-) Clusters

Each cluster has attributes and links to predecessors.

Links to predecessors

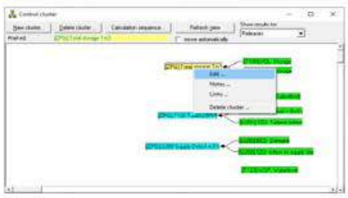
Select a cluster, right mouse click and select *Links*



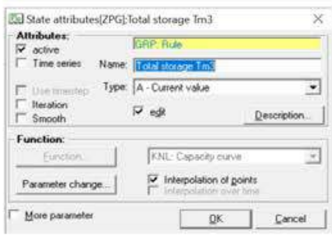
Select how predecessors shall be linked

Edit a cluster

Select a cluster, right mouse click and select *Edit*



The *State Editor* appears, which is described here



SYDRO CONSULT Introduction to Talsim-NG 4

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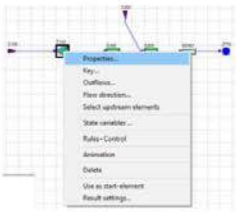
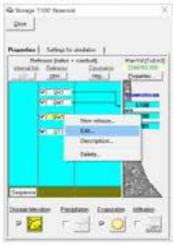
Link States/Clusters to release functions at a reservoir

1. Select the reservoir, which contains the release you want to link.
   - Right mouse click
   - Select *Properties*

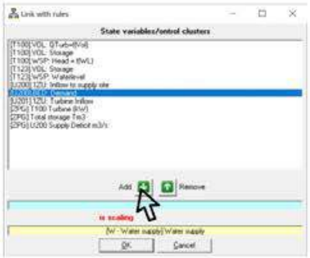


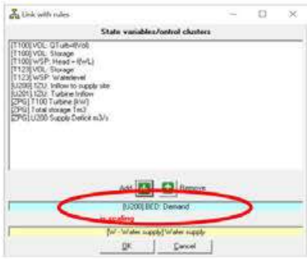
2. Select the *Release*
   - Right mouse click
   - Select *Edit*



3. Click *Rules+Control*

4. Select the State variable or Control Cluster and click **Add,** The selected element appears in the Scaling Box





To remove a connection click ***Remove***

Consulting Engineers
Hydro-Systems • Water Resources Management • Hydro-Informatics

SYDRO CONSULT

Talsim-NG - River Basin and Water Management Model

9c9t specifications

Dr. Hubert Lohr, Felix Froehlich, Nada Abdelwahab, Emanuel Döser, Kai Sonntag

SYDRO CONSULT 2

Downloads of today (23th of November 2022):

GIS, database, dataset:

Without results (28MB): https://twk.pm/28y5ux3n5b
With results plus DEM 30x30m: https://twk.pm/7qun1rlcpz

SYDRO CONSULT 3

Content

- GIS and the 9c9t model
  - Organisation of the GIS project
  - GIS project as basis for the model setup and configuration
  - Generating dataset files based on GIS data
  - Link a shape file with a dataset file
- The 9c9t model database
  - How to connect to a database from within the TalsimNG Client
  - Simulation and simulation of sub-systems

Before we start: Unzip the ZIP file to your computer

Suggestion C:\ Talsim-NG
BlueM.Wave
Client
customers
TalsimNGServer
9c9t Create a folder like this and unzip the file there

SYDRO CONSULT

4

GIS and the 9c9t model

Open the QGIS project file: ..\9c9t\GIS\9c9t.TalsimNG.qgz

- Explanation of the 9c9t GIS project
- ASC files as input to create the dataset files

SYDRO CONSULT

5

GIS and the 9c9t model

Open the QGIS project file: ..\9c9t\GIS\9c9t.TalsimNG.qgz

- Explanation of the 9c9t GIS project
- ASC files as input to create the dataset files

Join the dataset file

..\9c9t\Model\dataSet\9c9t.KeyList.System.forGIS.txt

with the shape file

TalsimNG\Model\9c9t.catchment.Id

from within QGIS

→ **Join establishes a connection to the model keys and enables orientation in QGIS**

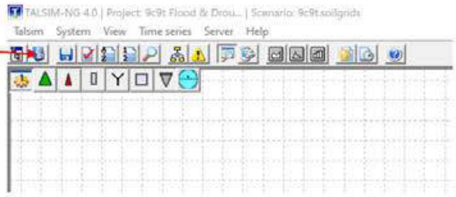
SYDRO CONSULT 6

The 9c9t model database

Open TalsimNG

We connect to the 9c9t database which is located here: ..\9c9t\dataBase\

1 Click here

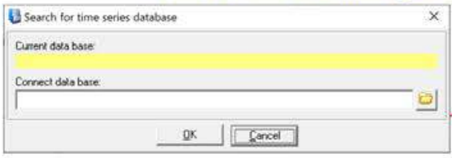


2

Navigate to ..\9c9t\dataBase\

and select: ..\9c9t\dataBase\mrc_data.mdb click Open

3

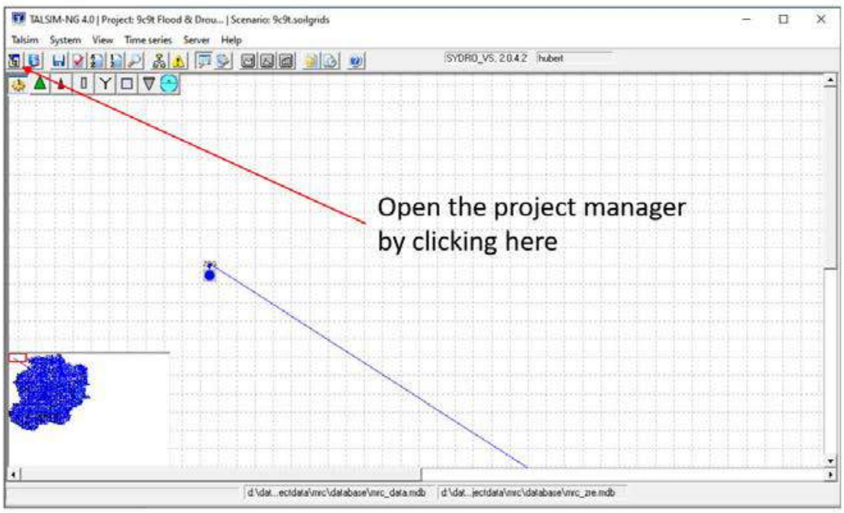


Navigate to ..\9c9t\dataBase\

and select: ..\9c9t\dataBase\mrc_zre.mdb click Open

SYDRO CONSULT 7

The 9c9t model database



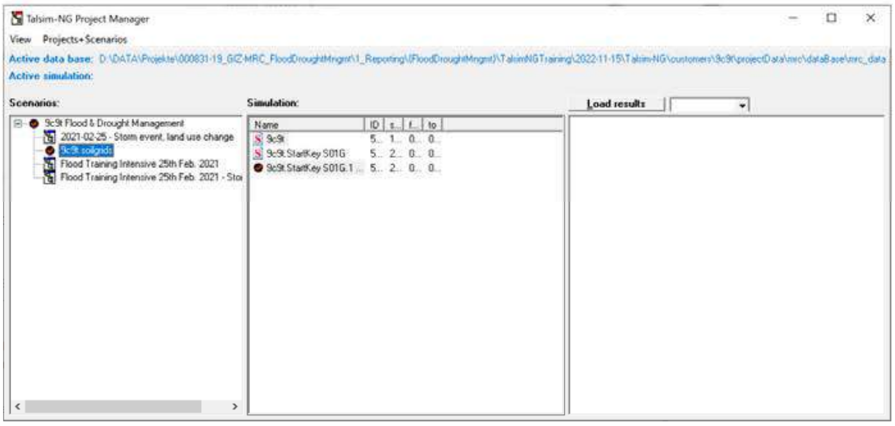
It can take a while until the flow network is built

SYDRO CONSULT

8

The 9c9t model database

- The 9c9t model database
  - We focus on the 9c9t soilgrids scenario



SYDRO CONSULT

9

The 9c9t model database

- The 9c9t model database
  - We focus on the 9c9t soilgrids scenario
  - We will copy a simulation (this one: 9c9t.StartKey S01G.1 year) and will perform a simulation run with a sub system (the full system takes too long).
  - Our downstream element is **S01G**

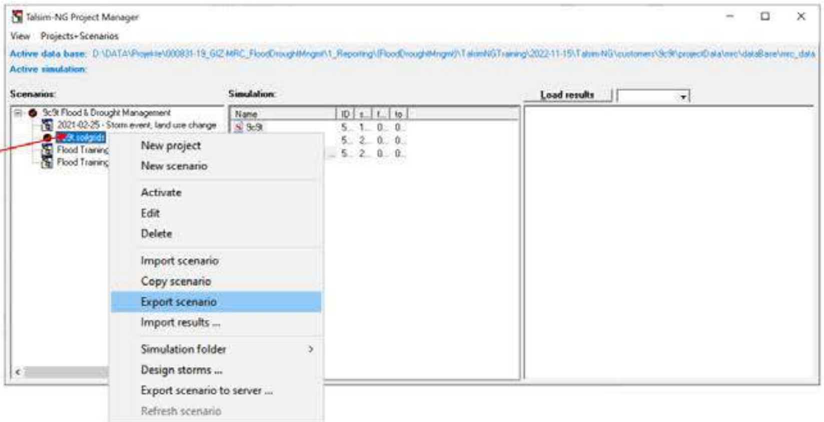
SYDRO CONSULT 10

The 9c9t model database

- Exporting datasets and perform a simulation run
  - Export a scenario to here: ..\9c9t\Model\export\

Activate this scenario if not yet done

Right mouse click and select export scenario

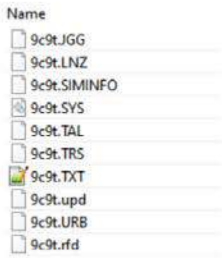


Select this folder ..\9c9t\Model\export\ and click save

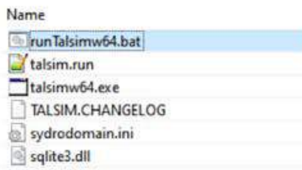
SYDRO CONSULT 11

The 9c9t model database

- Performing the simulation run with the exported dataset
  - Go to the folder : ..\9c9t\Model\export\



  - Go to the folder : ..\9c9t\Model\exe\
  - Open the runTalsimw64.bat with an ASCII Editor




```
talsimw64.exe talsim.run
Pause
```

The engine

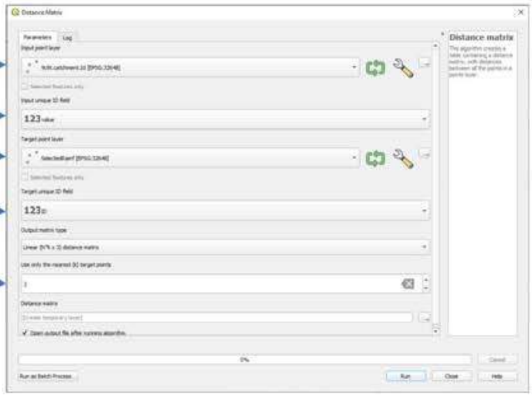
The argument

The Excel-Macro file:
https://twk.pm/6lzhp8fj67

IDW

Use the QGIS tool „Distance Matrix“ from the toolbox

9c9t.catchment.Id →
value →
SelectedRainf →
ID →
3 →

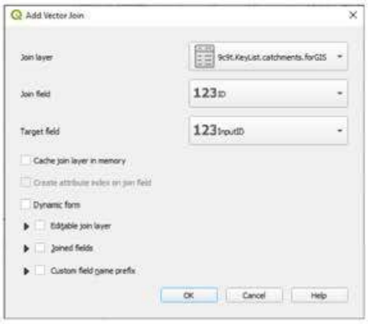


Run the tool and save as shape file

IDW

Use QGIS only:
Import the file 9c9t.KeyList.catchments.forGIS.txt to QGIS as comma separated file

Join the distance matrix shape file with the imported file.



Here goes in the 9c9t.KeyList.catchments.forGIS
Select ID
Select InputID

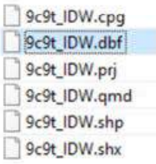
Uncheck „Cache join layer in memory“

Open the attribute table and copy the table content to Excel, keep only the columns „TargetID“, „Distance“ and „9c9t.KeyList.catchments.forGIS_Akey“

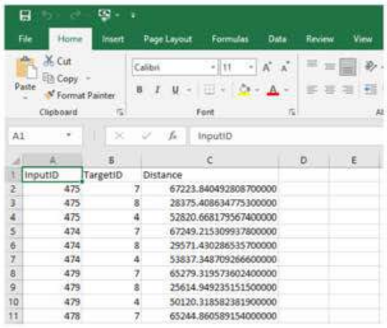
QGIS is incredibly slow with the table, so we opt for an Excel alternative!

IDW

Open the *.dbf file of your distance matrix shape file in Excel.



Drag the file to Excel

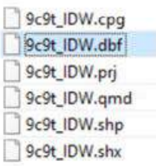


Open Excel file TalsimNG.AddOn.InverseDistanceWeighting.xlsm and allow the Macro

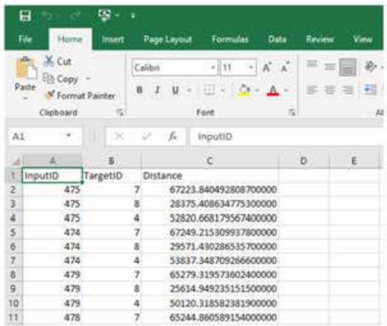
Copy the colums to this file

IDW

Open the *.dbf file of your distance matrix shape file in Excel.



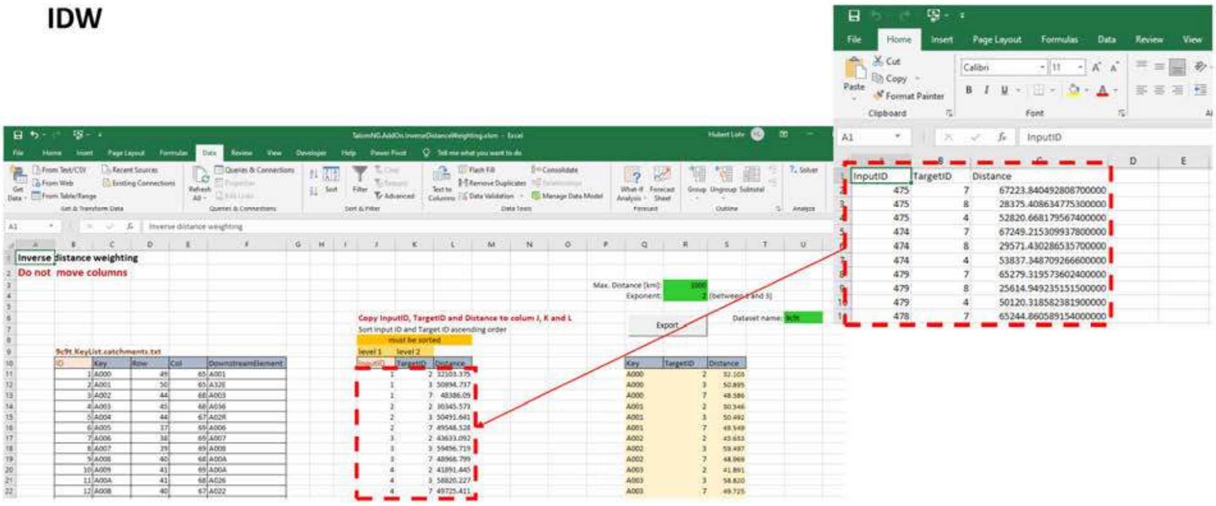
Drag the file to Excel



Open Excel file TalsimNG.AddOn.InverseDistanceWeighting.xlsm and allow the Macro

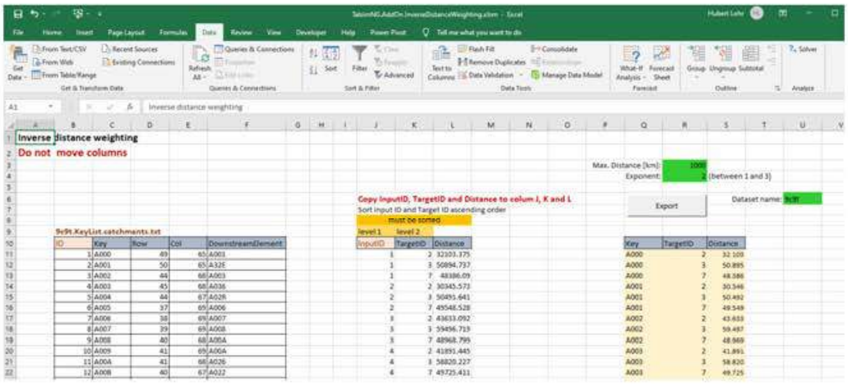
Copy the colums to this file

IDW



IDW

Select the dataset folder
Provide the dataset name (9c9t)
Set maximum Distance and Power
Export the file



IDW

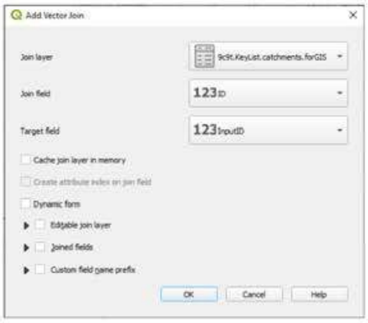
Use the QGIS tool „Distance Matrix“ from the toolbox

Run the tool and save as shape file

IDW

Use QGIS only:
Import the file 9c9t.KeyList.catchments.forGIS.txt to QGIS as comma separated file

Join the distance matrix shape file with the imported file.



Here goes in the 9c9t.KeyList.catchments.forGIS

Select ID

Select InputID

Uncheck „Cache join layer in memory"

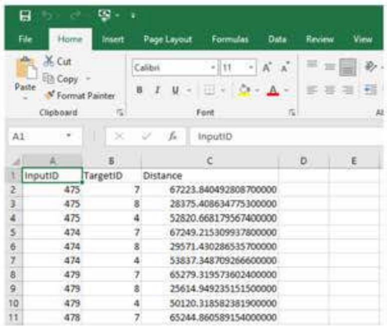
Open the attribute table and copy the table content to Excel, keep only the columns „TargetID", „Distance" and „9c9t.KeyList.catchments.forGIS_Akey"

QGIS is incredibly slow with the table, so we opt for an Excel alternative!

IDW

Use the Excel AddOn:
Open the *.dbf file of your distance matrix shape file in Excel.

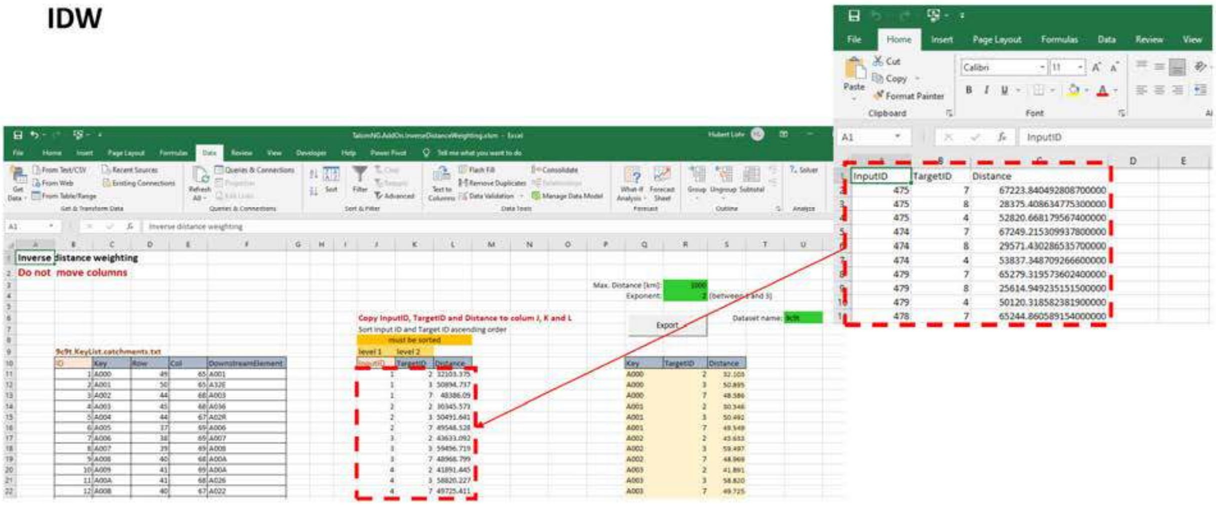
Drag the file to Excel



Open Excel file TalsimNG.AddOn.InverseDistanceWeighting.xlsm and allow the Macro

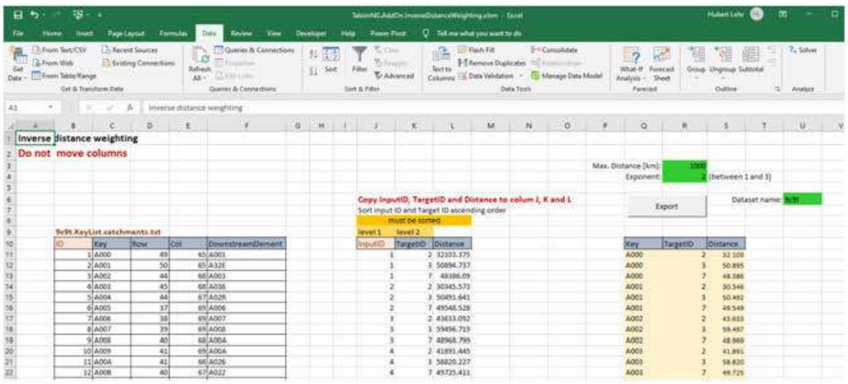
Copy the colums to this file

IDW



IDW

Select the dataset folder
Provide the dataset name (9c9t)
Set maximum Distance (=1000) and Power (=2)
Export the file



IDW

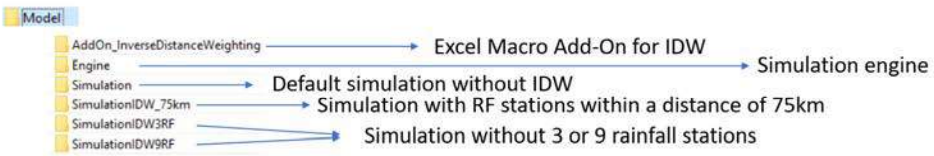
Open the file 9c9t.rfd in the folder you have selected

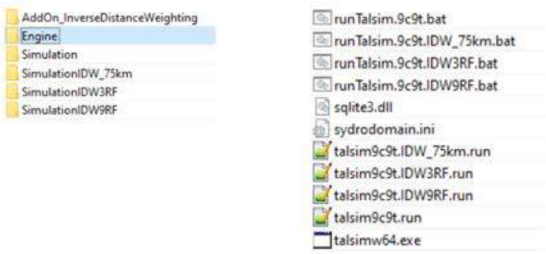
```
*Rainfall distribution (*.RFD)
*==============================
[SETTINGS]
Version = 2
[Parameter]
MaxDistance_km = 1000
Power = 2
[DistanceMatrix]
#EZG Key  Bin TS  Distance [km]
Type=RF
A000    2   32.103374543484
A000    3   50.8947368845229
A000    7   48.3860902199156
A001    2   30.3455732249247
A001    3   50.4916409662219
A001    7   49.548527976522
A002    2   43.6330919242421
A002    3   59.4967194723889
A002    7   48.9687990312979
A003    2   41.8914449807668
A003    3   58.8202271941351
A003    7   49.7254109672158
A004    2   42.7433443528327
A004    3   57.642886889483
```

IDW

Add-On: Simulation with Inverse Distance Weighting

IDW





***.run**: start file for the engine with information on the dataset that will be used

***.bat**: batch file that calls the engine with the argument of the start file

IDW

talsim9c9t.run

```
[TALSIM]
Path=..\Simulation\
System=9c9t
ExecMode=0
VariationId=0
Language=en
```

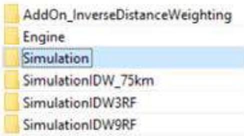
talsim9c9t.bat

```
REM run the simulation engine with the dataset \simulation
talsimw64.exe talsim9c9t.run
Pause
```

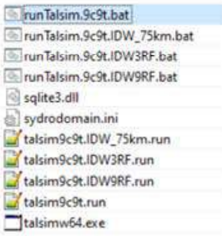
IDW

How to ... : Simulation without IDW

Export the „Import: 9c9t soilgrids“ dataset to (use the GUI to export a dataset)



Double click the



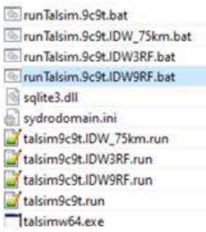
IDW

How to ... : Simulation with IDW

Copy the dataset from folder Simulation to

Copy your 9c9t.rfd file to this folder

Double click the

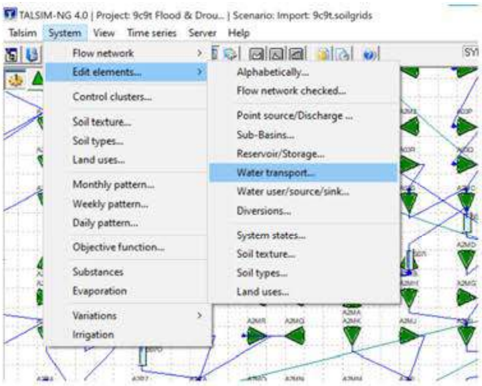


The Excel-Macro file:
https://twk.pm/6lzhp8fj67

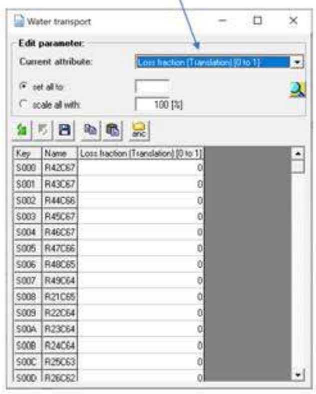
Setting Parameters

Bulk Edit Mode:

No element is selected in the flow network!

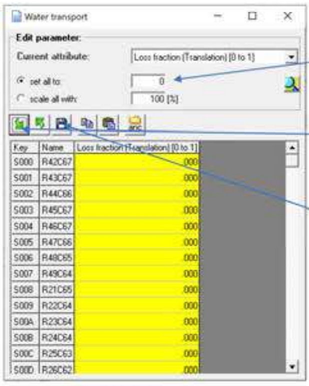


Select: „Loss fraction (Translation) [0 to 1]



Setting Parameters

Bulk Edit Mode:



Set the value to „0"
(we don't want losses)

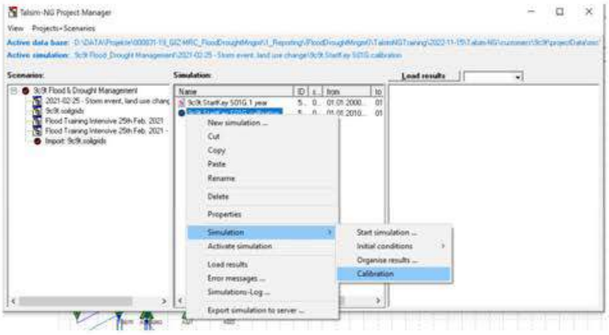
Click this button to set the value for all transport elements

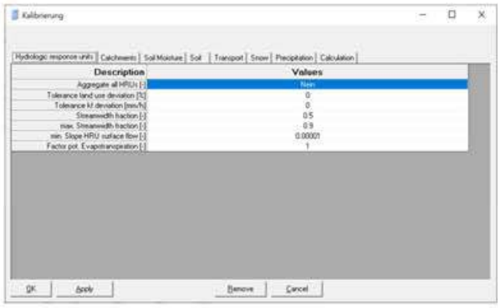
Click the save button to save the new values to the databse

Setting Parameters

Calibration:

Open the Project Manager and select a simulation
Right Mouse click and select „Calibration“





Setting Parameters

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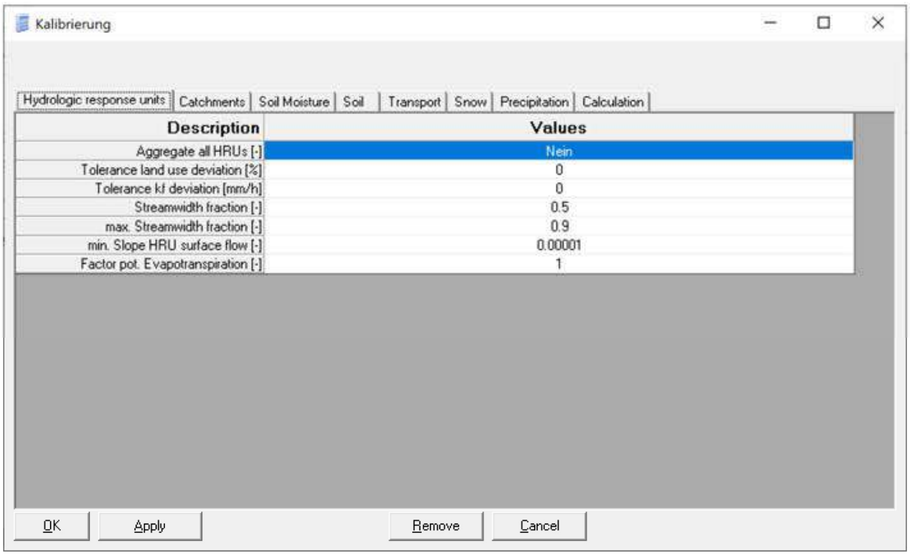


Setting Parameters

Calibration:

Kalibrierung

Hydrologic response units | Catchments | Soil Moisture | Soil | Transport | Snow | Precipitation | Calculation

Description	Values
Factor retention urban areas [-]	5
Factor retention rural areas [-]	5
Factor retention interflow [-]	2
Retention baseflow [-]	0.2
Cascades interflow [n]	3
Cascades interflow (deep) [n]	3
Cascades baseflow [n]	3
Monthly pattern urban loss [mm]	
Monthly pattern natural loss [mm]	
Retention interflow (deep) [-]	0.2
Retention groundwater (deep) [-]	1
Factor deep groundwater [-]	1

OK | Apply | Remove | Cancel

Setting Parameters

Calibration:

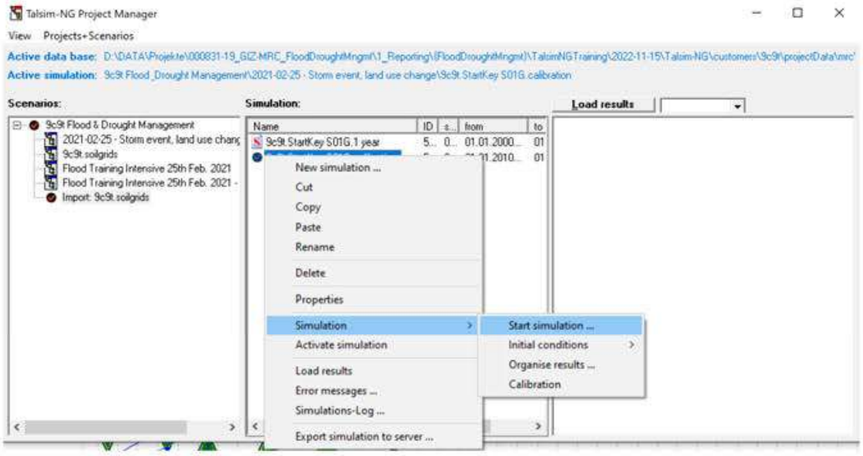
Kalibrierung

Hydrologic response units | Catchments | Soil Moisture | Soil | Transport | Snow | Precipitation | Calculation

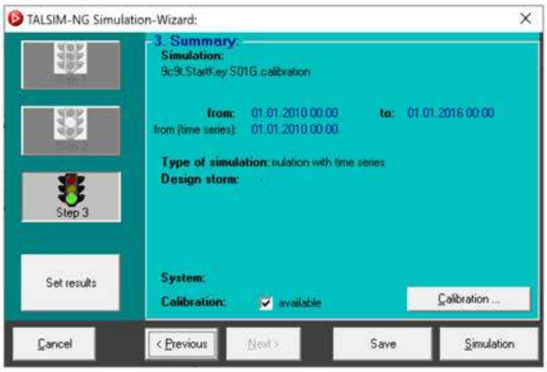
Description	Values
Factor max. Infiltration [-]	25
Scaling kf layer 1 [-]	0.5
Scaling kf layer 2 [-]	0.2
Scaling kf layer 3 [-]	0.1
Scaling interflow [-]	0.1
Scaling deep interflow [-]	0.8
Monthly pattern kf layer 1 [-]	
Monthly pattern kf layer 2 [-]	
Monthly pattern kf layer 3 [-]	
Monthly pattern interflow [-]	
Monthly pattern deep interflow [-]	
Factor initial soil moisture [-]	1
Scaling Wilting Point (WP) [-]	1
Factor utilisable field cap. [-]	1
Factor saturation [-]	1

OK | Apply | Remove | Cancel

Simulation run

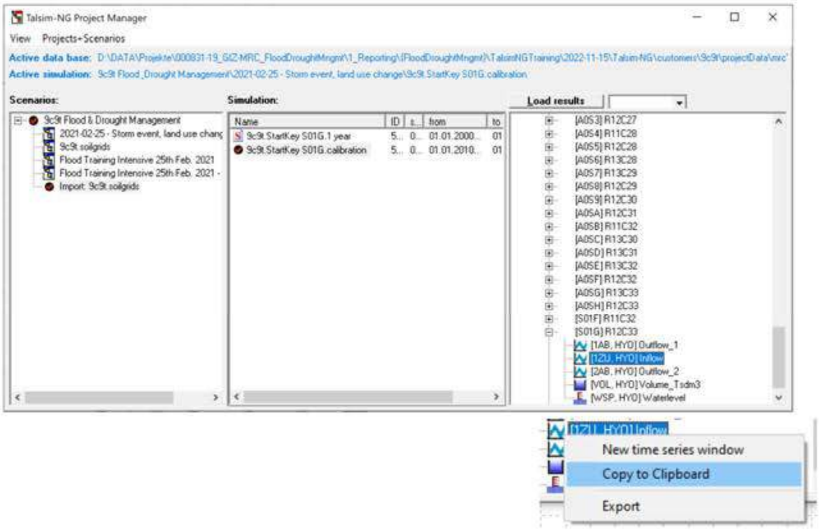


Simulation run



Click Next, Next and Simulation

Change calibration settings and compare results

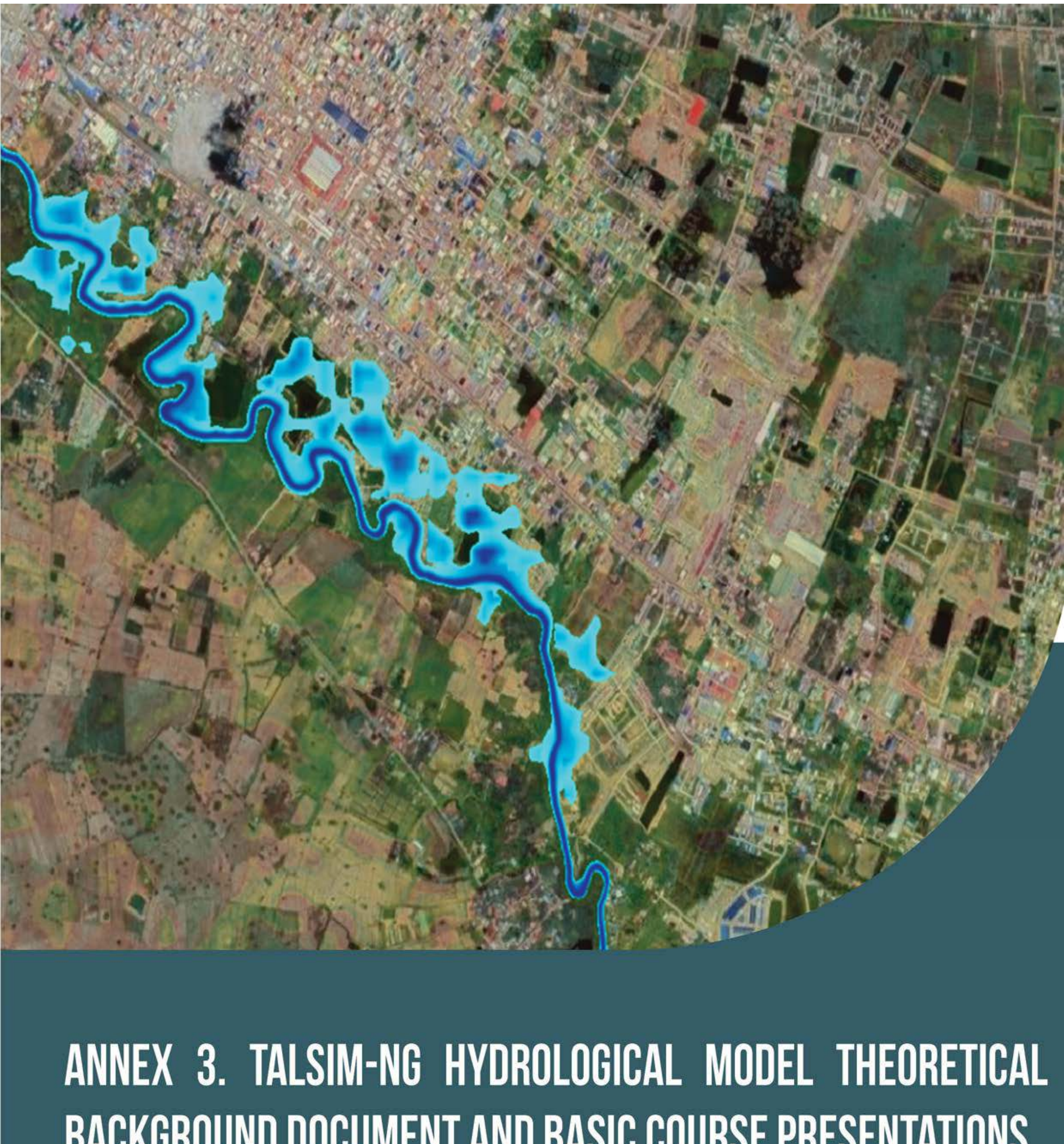


Click „Load Results“

Select your element (here S01G)

Right Mouse click and select „Copy to Clipboard“

Paste in Wave



ANNEX 3. TALSIM-NG HYDROLOGICAL MODEL THEORETICAL BACKGROUND DOCUMENT AND BASIC COURSE PRESENTATIONS

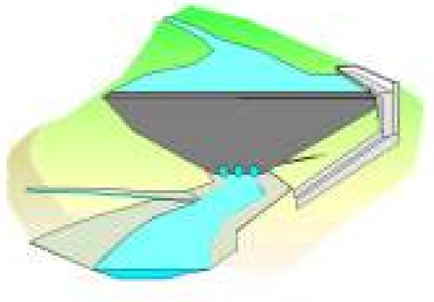
german cooperation
DEUTSCHE ZUSAMMENARBEIT

Implemented by
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

MEKONG RIVER COMMISSION
MRC
FOR SUSTAINABLE DEVELOPMENT

TALSIM-Next Generation

Talsim-NG



Theoretical background

Remarks:

In this document, the theoretical background is confined to water management related topics which were implemented prior to 2010. Features of Talsim-NG which have been implemented after 2010 like:

- Water temperature calculation
- Water quality calculation
- Water quality and stratification calculation of reservoirs
- Advances snow calculation
- Internal calculation evaporation
- Irrigation features
- Modelling simple groundwater storage

are not described.

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1 INTRODUCTION

1.1 Background of TALSIM

In water resources management, the technique of modelling has played an important role for a long time. As both the benefits and possible negative responses of water engineering measures cannot be easily assessed, due to the often complex relationship between causes and effects in water systems, hydrological and hydraulic models are frequently used instead. Such models determine both the short and long-term effects of planned interventions in the water balance. Structural changes and increasingly important operational aspects have to be represented and computed by the model and the results need to be presented in a clear and illustrative way. Of great significance is the consideration of entire river basin per the new European Union Water Framework Directive.

The river basin model TALSIM has been developed to meet the above requirements and thus to support authorities, associations and engineering companies operating in the field of water management in the planning of water engineering measures and their operation efficiently and illustratively.

The combination of a rainfall-runoff model, a management model, computation of watercourses and time series management allows for manifold applications. Together with a monitoring system, an operational use is also possible.

TALSIM is based on an open model architecture, i.e. the user can set up any kind of river basin system and implement it in an almost unlimited variety of management strategies.

In the following chapters, the theoretical background to TALSIM will be explained in-depth.

1.2 Terms and definitions

In the following text, central terms are defined in the same way as they will be used throughout the text.

Water resources management system, System stress, System element

Under the term of *water resources management system*, all water-related transport and storage processes within a constraint area are contained. It is thereby insignificant whether the system actually exists or if it represents a future or imagined planning stage. The water-related processes are divided into single components, or elements, respectively.

A simulation of such a system requires the reproduction of actually occurring hydrological and hydraulic processes (reality) by mathematical equations. In other words, it is about the abstraction and representation of the spatial and temporal distribution of water.

For a full acquisition of the water resources management system, it is necessary to define boundaries. These are on the one hand catchment boundaries of a purely spatial nature and on the other hand, a *system stress* needs to be distinguished from the system itself. System stresses – water yield and water demand – act upon the system from the outside and trigger processes within the system; thus, they do not belong directly to the system itself. The underlying assumption of this distinction is that there is no feedback from the system to the system stress. However, this assumption loses its validity the more the stronger interventions in the water regime by a water management system become.

A system is hence the sum of components or elements, respectively, which represent water-related processes mathematically. The delineation of flow paths between the elements as a flow network is also an integral part of the water resources management system.

Depending of the respective objective, different spatial resolutions result.

Taking all the processes occurring in a water management system into consideration is neither sensible nor possible. The principle to apply is to capture all the relevant processes and to represent them with as much detail as necessary; therefore, the abstraction and summary of different transport and storage processes becomes necessary. From this integration of several processes, a representation of reality consisting of single computational units results. In the following, these units will be called *system elements*. A system element always delivers the same results if the preconditions are the same. The classification of element types will be presented later in this document (s. Chapter 3.5).

Size and structure of a system element are determined by geography, water management processes or both factors together. For example, a dam – reservoir – is bounded by storage space and the structure itself as all the processes happening inside interact. That is why operational facilities like spillways and outlet conduits belong to the system element *dam*; therefore, geography as well as water management processes are responsible for the form of the system element *dam*.

System data, System states, Parameter, Characteristic properties:

The term *system data* summarizes all necessary values to describe the system elements and their flow network (i.e. arrangement of system elements, parameter and characteristic properties). Using the system data, a system stress generates certain *system states* and resultant reactions. System states describe the current conditions within the system and are variable in time. States and reactions are clearly assigned to the single system elements.

The terms parameter and characteristic properties have different meanings. *Characteristic properties* are the attributes of system elements that can be determined unambiguously, e.g. the geometry of a pipe or the dam height. For modelling, they are regarded as constant as long as they are not the subject of a study. *Parameters* are attributes of system elements as well but it is not possible to determine them unambiguously solely by measurements. They can be understood as quantities that can only be measured at a point but need to represent a bigger area (e.g. permeability of soils) or that stand for a sequence of individual natural processes (e.g. a retention constant for the lumped description of the runoff concentration in a catchment). They are subject to calibration and verification. The knowledge of characteristic properties and parameter is necessary to describe the behaviour of system elements and thus of the whole system in a well-defined way.

Controllable system, Usages, Reservoir operation:

If the transport and storage processes of a system are influenced by the operation of control devices as gates, sluices, weirs or valves, it is a *controllable system*. Such interventions in the natural flow behaviour are not conducted to an end in of itself but to meet the demands on water. Inter alia, these demands arise concerning:

- Water supply/ Raw water usage
- Maintenance of minimal flow rates / water levels
- Flood protection
- Low-flow augmentation
- Irrigation
- Energy generation
- Recreational usage

If such demands or usages exist in a water resources management system, there is generally also the possibility to exert direct control on the water balance. In many cases reservoirs are suitable structures to intervene in the water balance due to their balancing effect and their practical control devices. An operation is called *reservoir operation* if a reservoir or its control device directly or indirectly controls or at least influences water usages.

For each usage, an optimal state exists which can be generally expressed in the form of an objective. These objectives may be partly contradicting each other. For example, to secure water supply from a reservoir, it is optimal to retain as much water as possible. On the other hand, flood protection demands an empty reservoir in order to reserve a space in which floodwaters can fill. It is the task of the reservoir operation to find an adequate balance between competing usages.

Simulation model, Reservoir operation model:

The main characteristics of a *simulation model* are the abstraction of reality as well as the computation of the system elements and their mutual dependencies under a given system stress. Thereby, a certain system behaviour is evaluated by computing all relevant hydrological and hydraulic processes. If the system is controllable and the model is able to capture artificial interventions in the runoff processes, the model becomes a *reservoir operation model*. The description of an uncontrolled runoff through man-made structures alone does not make up a reservoir operation model.

Operating plan, Operating rule:

For the operation of water resources management systems, regulations are necessary which define how to control transport and storage processes of water according to certain system states. The sum of these regulations is called *operating plan*. An operating plan generally consists of a number of individual regulations. Such a regulation will be called *operation rule* throughout the text.

Operating plans exist in varying complexity and temporal validity. Rules with a long-term or medium-term validity prevail, i.e. they were defined to satisfy needs in the long run as well as possible, whereby short-term disadvantages of single usages may occur. Such operating plans are normally derived based on long periods that contain as many different system stresses as possible. In contrast, short-term operating plans – so called real time operations – are adjusted to single events. Once this special (and most of the time extreme) event is over, the short-term plan loses its validity.

2 CONCEPT OF OPERATION RULES

For an optimal operation of reservoir systems, instructions are necessary which clearly determine how water is to be stored, released and distributed given different system stresses and states. These instructions are summarised in an operating plan. An operating plan may consist of many individual regulations, e.g. the maintenance of a release as a function of storage. An individual regulation in turn can be called an operation rule.

As the formulation of an operation rule always implicates a corrective intervention in the natural flow behaviour, it requires the possibility to alter a discharge. Only few elements of water resources management are suitable for that. These are typically reservoirs with controllable outlets. Otherwise, other water-retaining or extraction structures like e.g. variable weirs are available.

The purpose of all operation rules is to meet given objectives by modifying system states of a water management system. It does not matter where controllable and targeted system states are located as long as a change in the controllable system states influences the corresponding targeted system states.

2.1 Basic types of operation rules

The operation plan of a dam or a combined system of reservoirs is typically existent in written or graphic form and is often part of the project approval of the entire construction. The complexity of an operation plan can vary a lot. Examples range from a simple specification of flood control storage spaces and an additional plan for emergencies and exceptional situations including the notice of supervisory authorities to complex sets of rules and regulations in the form of functional dependencies that derive the releases of water from different system states.

In the following text, examples are listed which show the diversity of regulations and how to reduce them to the essential dependencies. From this, a concept is derived for how the majority of operation rules can be represented by a few basic algorithms. The given selection is not intended to be exhaustive; however, most of the rules that are applied in practice are covered.

Basic principle: Verification of physical boundaries

When fixing a water release according to an operation rule, it is assumed that the capacity of the outlets is enough to satisfy the releases. Consequently, the requirements of the water resources management need to be considered when dimensioning the outlets. As a general rule, there will be no problems in that respect; however, the physically possible discharge given by the characteristic curve of a fully open outlet always specifies the upper limit.

If the pressure head or the capacity of the outlet when fully opened are enough to release the desired amount, the release can be reduced to the required quantity by closing a gate. If the pressure head does not suffice, only the hydraulically possible release is attainable.

- *Mathematical abstraction:*

  All releases corresponding to an operation rule are functions of the reservoir volume and cannot exceed the maximum capacity of the fully opened outlets. Once the capacity of the fully opened outlets exceeds the required amount to be released, it can be regulated by partially closing the control devices of the outlet.

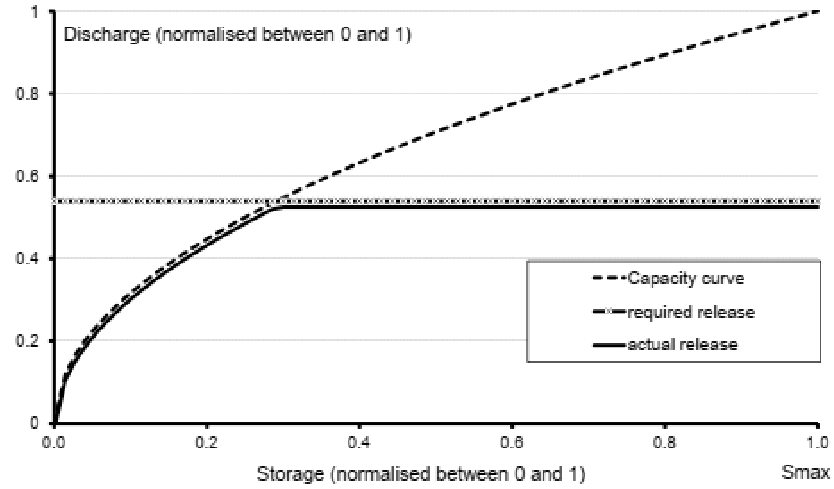


Figure 1: Dependency of a release on storage

All subsequently mentioned forms of releases from reservoirs are subject to this restriction.

<u>Rule Type 1</u>: Fixation of the minimum or maximum release, e.g. the flow that can be released at most without causing damages downstream

- *Dependency:*

  The fixation of the minimum or maximum release results from the requirements downstream of a reservoir. The maximum release is often adapted to the bankfull discharge of a critical downstream stretch of water; thus, a definite hydraulic procedure exists for its determination. In contrast, there is no clear guideline for the minimum flow. Often, certain ratios of average low flows or average flows are applied. Regardless of the determination of the minimum or maximum release, the aforementioned principle of the dependency on the capacity of the outlet applies. The minimum and maximum releases can only be discharged if the given pressure head and the capacity of the outlets suffice. As, in practice, it is not likely that the dimensioning of the outlet organs does not agree with the requested release, the hint about the dependency of storage is more of a theoretical nature but still necessary for the derivation of general principles.

- *Mathematical abstraction:*

The minimum and maximum release are functions of the storage. At a very low storage, they follow the characteristic curve of the fully open outlet. As soon as the capacity of the outlet organs is sufficient for the required release, the release can be kept constant by partially closing the control devices.

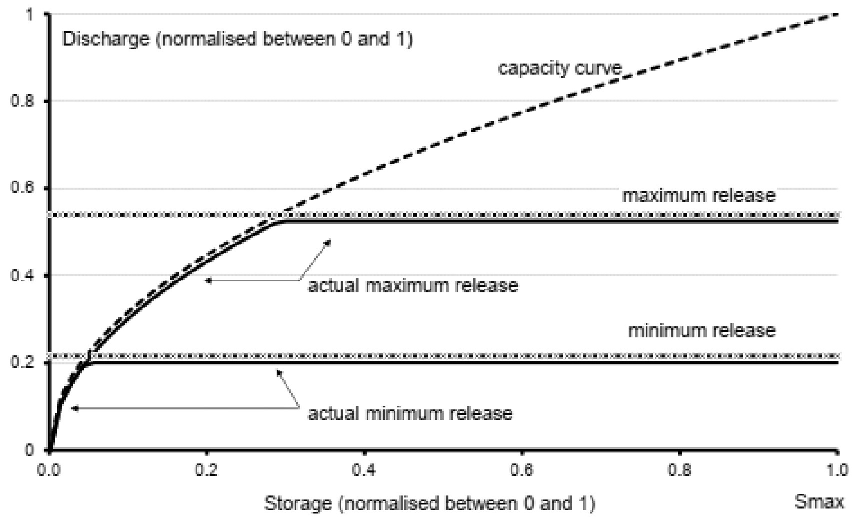


Figure 2: Example of a minimum and maximum release as a function of storage

Rule Type 2: Keeping a flood protection storage space, possibly variability over the year

- *Dependency:*

The minimum requirement for the fixation of the flood protection storage space is to designate a volume, which has to be kept free for the intake of a flood by the reservoir. The dimensioning is done based on the flood volumes of certain recurrence intervals. If the water level exceeds the level of the flood protection storage space, the reservoir is seen to be emptied by increasing the release; thus, this regulation can be reduced to a relationship between release and storage. Thereby the maximum capacity of the outlet or a defined maximum discharge can serve as the upper limit for the increased release. If the flood protection storage space is variable over the year, only the storage content whose exceedance triggers the increased release is changed.

- *Mathematical abstraction:*

Here, a direct relationship between storage and release exists. If the storage exceeds the mark of the flood protection storage space a release occurs, if it is below the mark, the release is set to Zero.

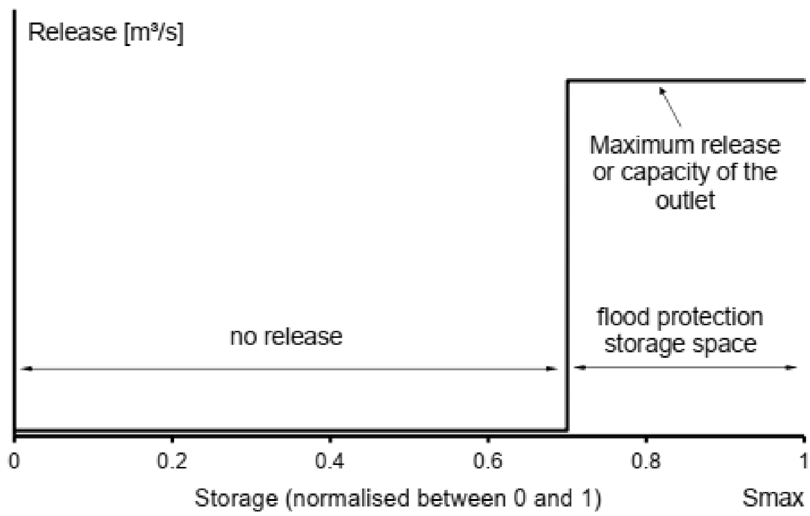


Figure 3 Example of a function implementing a flood protection storage space

Rule Type 3: Direct abstraction of drinking water or raw water from a reservoir

- *Dependency:*

In the first place, the actual demand determines the withdrawal from the reservoir, which is generally subject to fluctuations. The demand is often bounded above by water rights or maximal withdrawals, respectively, referring to specific time horizons as days, months, and quarters of a year, years or others. The actual demand on the reservoir is set by the requirements of a water supplier. There is no relation to storage; however, if the demand can be actually met depends on the actual storage. This relationship is given either by the structure of the facility for the withdrawal or due to a proactive management. E.g. when reaching a particularly low storage, it is sensible to restrain the withdrawals in order to avoid that the reservoir runs dry and the subsequent complete failure during longer low flow periods /Schulz, 1989/. This is the reason why typically a reserve space exists on whose usage special operation plans decide in every dam which mainly serve as drinking water provision.

- *Mathematical abstraction:*

  If the demand is known and constant, a direct relation between withdrawal and storage can be defined; however, typically the demand is subject to variations. That is why it is recommended to normalize the relation withdrawal/ storage, with the actual demand serving as a scaling factor. If the storage falls below a defined threshold value, only a percentage of the actual demand is met. Both the threshold value and the shape of the functions can be variable in time.

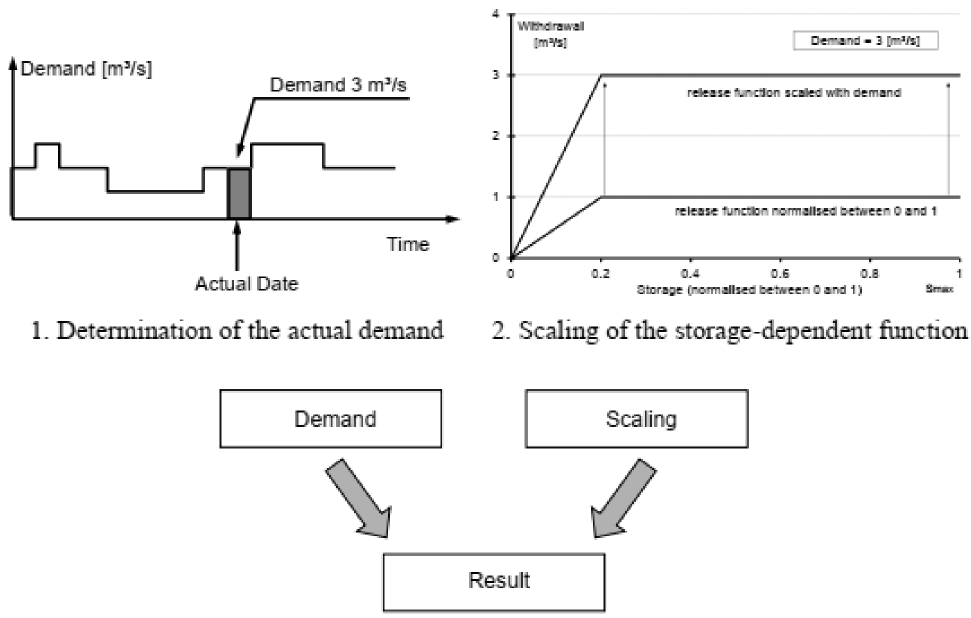


Figure 4: Example of a function for drinking or raw water abstraction

Rule Type 4: Standard release to the downstream reaches

- *Dependency:*

  The standard discharge to the downstream reaches evens out the seasonal differences of the inflow. If a minimum release is defined, it will be included in the standard release. Often, a lamella plan serves for describing the standard release. It divides the storage into different sections (lamellae) and assigns a release to each lamella. When determining the lamella, the long-term runoff regime and the other withdrawals from the reservoir play a crucial role. A reservoir should store water in times of a strong inflow without overflowing in order to contain enough reserves in times of a low inflow. The coupling of the releases to the lamella of the storage is a definite function of the storage. As the purpose is to react to inner-yearly variations of the inflow, a time-variant relation between storage and release is the rule.

- *Mathematical abstraction:*

As in the precedent rules, the release is also dependent on storage. Commonly, a lamella plan is represented by a two dimensional diagram. On the x-axis, the time within a year is plotted, on the y-axis the storage. The lamellae are drawn as lines of equal release into the diagram.

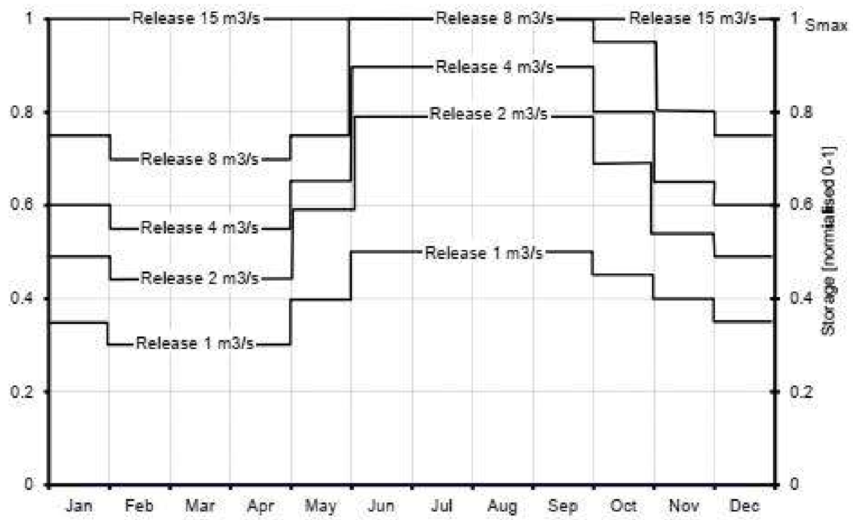


Figure 5: Lamella plan in a 2D view

Such a view, in spite of being practical, is not complete. By a three-dimensional representation of a simple lamella plan, with the release on the z-axis, it becomes clear, that there are different ways of interpreting the 2D lamella plan.

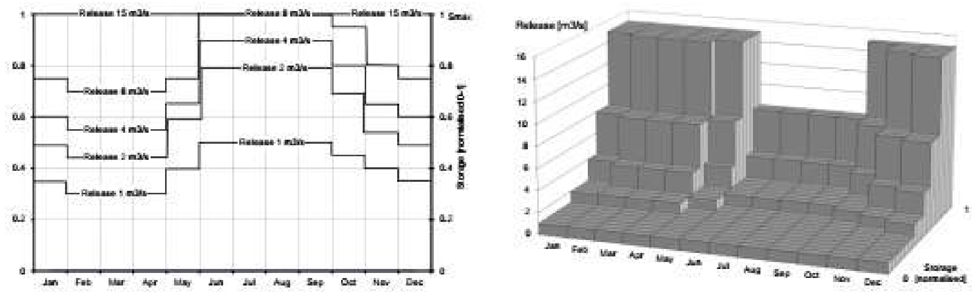


Figure 6: Comparison of a lamella plan in a 2D and 3D view

A top view of the 3D image results in the two-dimensional form. Instead of taking constant blocks for the single time horizons, the nodes are often connected linearly.

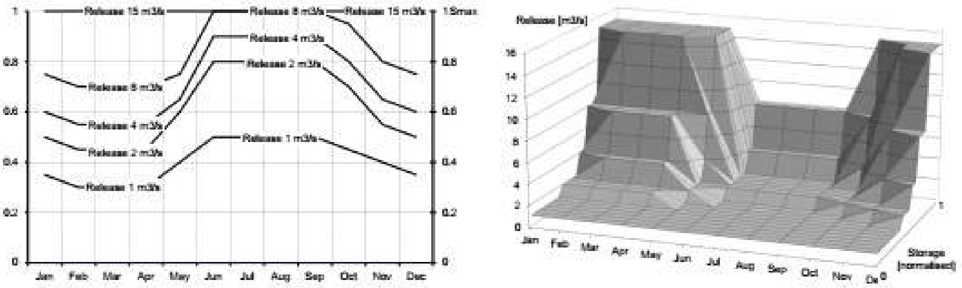


Figure 7: Lamella plan with linear interpolation between succeeding points in time

For the single time periods – here months – different functional relationships between storage and discharge come into effect. If one looks at a chosen point in time at the relation of storage/ releases, there are two possibilities to connect the nodes of the releases. On the one hand, there is the possibility of a linear interpolation; on the other hand, a step-wise connection is possible.

In the two-dimensional space, this information is not visible and has to be additionally inferred. Usually, there is the convention to take the releases between two nodes as constant; thus, interpreting the lamella plan in the form of steps, as shown above.

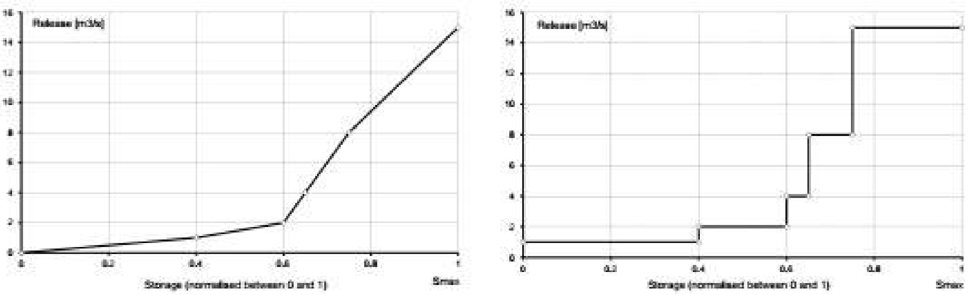


Figure 8: Lamella plan with two types of interpretation (for the selected month May)

Rule type 5: Maintaining defined discharges downstream from the reservoir: Increasing low flows / covering demand

- *Dependency:*

  In this case, the momentary release is determined by the requirements downstream from a reservoir. At a river cross section that will be referred to as control point in the following text, and that is influenced by the releases from a reservoir, the runoff shall not fall below a defined value. The runoff at the control point is composed of the release from the reservoir and the lateral inflows in between the reservoir and the control point. If the actual runoff stays below a target quantity, an extra supply from the upstream reservoir becomes necessary. The amount of the extra supply depends on the difference between the actual and target runoff. Whether or not the required discharge can be fully met by the reservoir depends on the actual storage- the lower the storage, the less favourable it is to release further water. In this respect, the rule to increase low flows/ cover demands behaves just as the drinking/ raw water withdrawal, only the triggering factor changes. As before, the storage-dependent function is scaled by a factor now resulting from the comparison between the target and actual runoff.

- *Mathematical abstraction:*

  The determination of the release for the increase of low flows or the coverage of a demand at control points is comprised of several factors. On the one hand, there is a variable deficit resulting from the runoff falling below a target value. How this deficit should work as a scaling factor on a release from a reservoir can be defined by a functional relationship. Thereby, this deficit works as the independent variable and the scaling factor as the dependent variable.

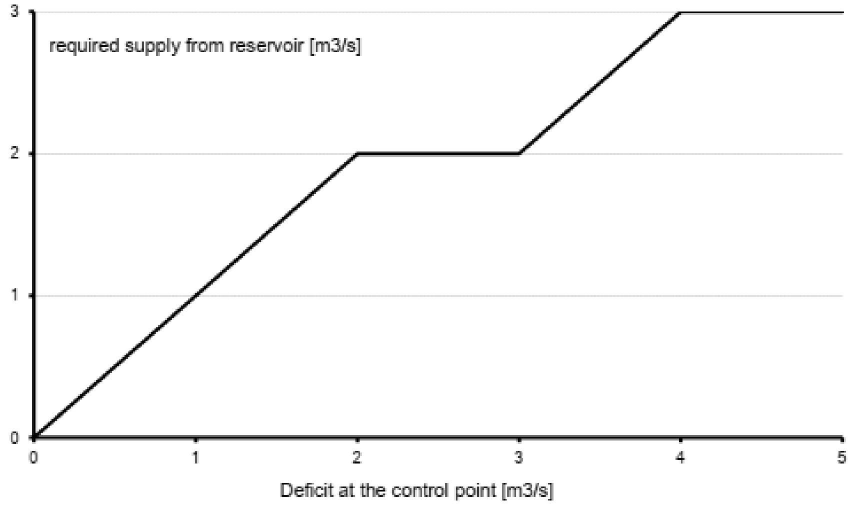


Figure 9: Example of a function between a deficit and a scaling factor for a reservoir

On the other hand, it is a question of the actual storage as to if or how the required extra supply from the reservoir can be met. As before, a normalised storage-dependent function together with the requested demand to a definite determination of the amount of extra supply. In the following graph, a full satisfaction of the target value of the demand is only achievable if the storage lies above a critical threshold of ca. 25%.

If several reservoirs influence the considered control point or if several reservoirs should be used to meet the demand, the required extra supply has to be divided between the reservoirs according to a rule. Thereby it has to be distinguished between a direct and indirect influence of the reservoir on the control point. A direct influence exists if the release from the reservoir can immediately affect the runoff state at the control point, i.e. the natural flow regime cannot be influenced in between the reservoir and the control point by regulating interventions. If this is not the case, an indirect influence is given.

Each reservoir with a direct influence on the control point obtains a deficit/ factor function and a storage-dependent scalable function according to Figure 10. In this way, the dependency of the actually effected release can be determined separately for each reservoir.

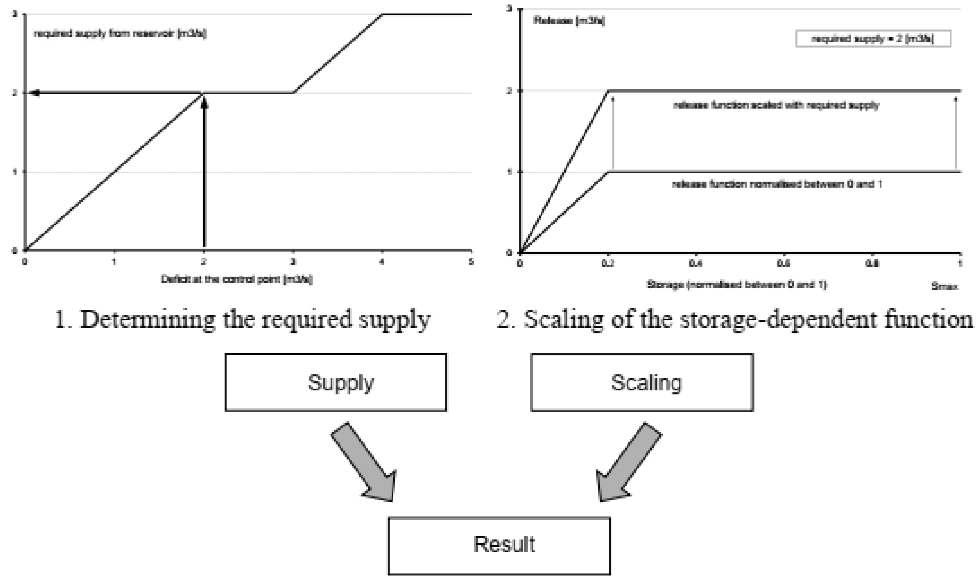


Figure 10: Example of a function for the increase of low flows or the covering of demands

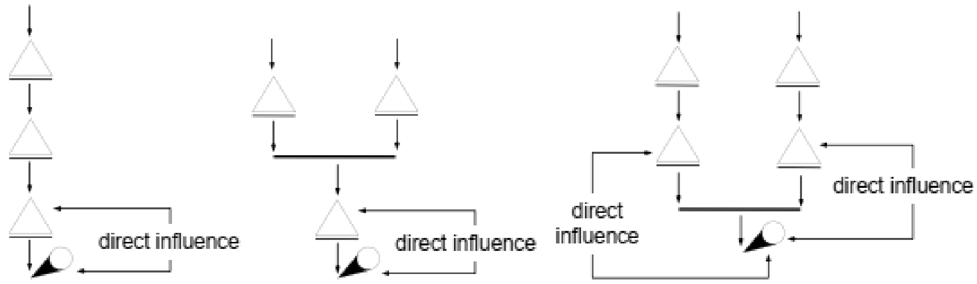


Figure 11: Direct influence between reservoirs and a control point

<u>Rule Type 6</u>: Release dependent on the actual inflow to the reservoir

- *Dependency:*

  Here, the release is directly coupled to the actual inflow to the reservoir. Similar to the lamella plan this also acts as an adaption to different inflow situations. This is done in order to prevent the reservoir from running dry or overflowing or to conserve a variable flow regime downstream. Long-term variations of the inflow cannot be captured easily by this operation rule, as it only performs a momentary view.

  For the final determination of an inflow-dependent release, several components need to be considered. At first, a relation between the actual inflow and the release needs to exist. Apart from the actual inflow, the actual storage also plays an important role, as the relation inflow/release does not have to be valid over the whole storage without restrictions. For instance, it is very likely that the relation will be fully abandoned or at least the reduced when falling below a critical storage level (e.g. holdover storage).

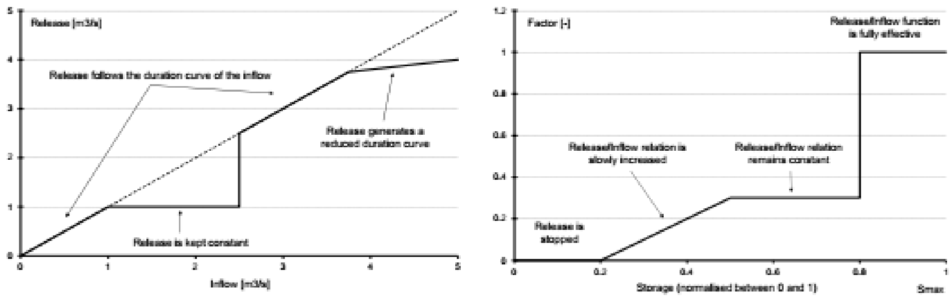
As with this rule, a relatively low storage can meet a relatively high inflow – and, thus, a required high release – special attention needs to be paid to the principle of physical constraints.

- *Mathematical abstraction:*

  In this case, three functional dependencies play a role. On the one hand, a direct function exists between the actual inflow and the release. This function can have any desired shape. It is possible to reproduce only a single range of the inflow corresponding to a partial matching of the release to the duration curve of the inflow.

  On the other hand, the inflow/releases function can be overlain by a relationship between storage and release. For reasons of clarity, it is advisable to work with normalised functions; thus, the possibility exists to influence the result of the inflow/ release function along the whole range of storage levels, which is especially desirable at a low filling of the reservoir.

  Finally, the requested release needs to be checked regarding the capacity of the outlets.



Variable inflow/releases function   Variable and normalised storage/factor function

Figure 12: Example of functions for an inflow-dependent release

In the following text, examples are given on how the interaction between different function affects the releases. The results are presented in the following graphs in the form of inflow and release duration curves

In the case of a linear relationship between inflow / release and a constant factor over the storage, the duration curve of the release corresponds to the inflow in its shape but is reduced by a certain percentage. With a constant factor / storage relationship, the duration curve can be changed systematically. An additional modification of the factor over the storage comes with the advantage of being able to react to certain levels of storage in order to counteract the reservoir to run dry or spill over.

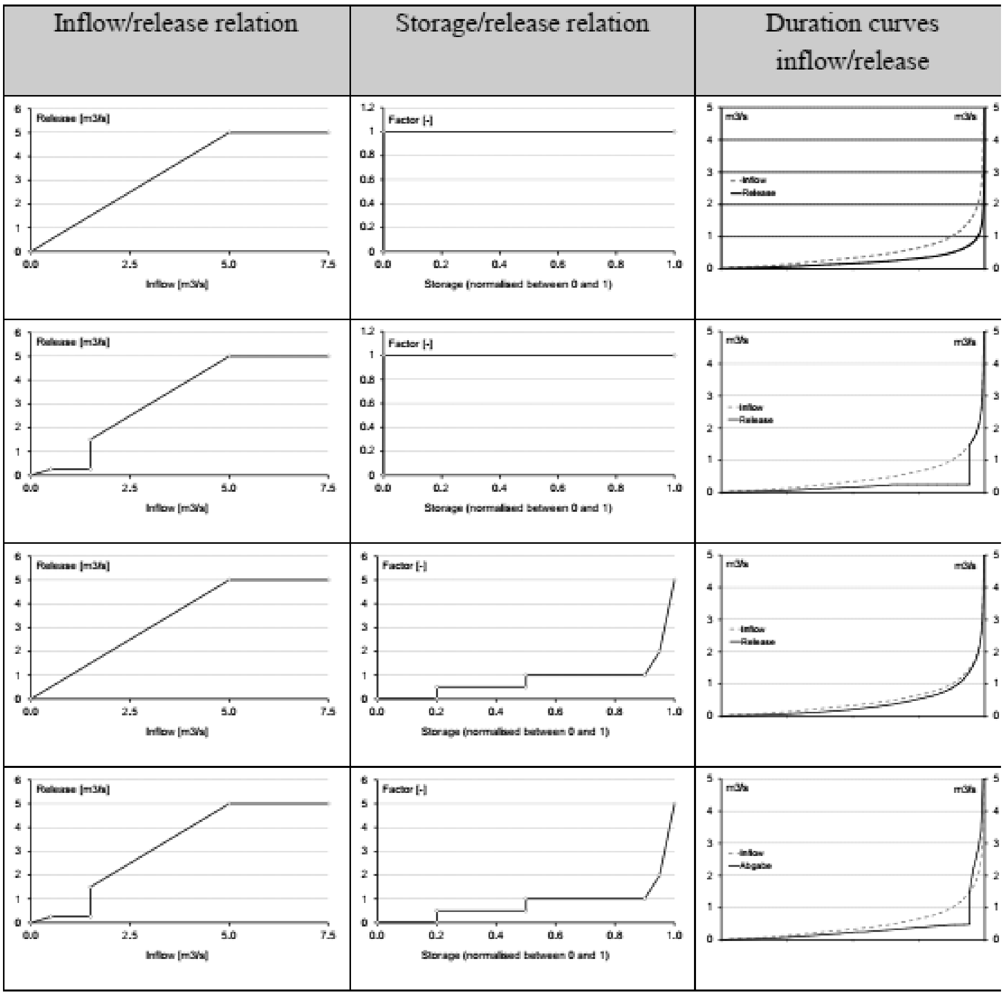


Figure 13: Results of different strategies of inflow-dependent releases

Rule type 7: Controlling a release by system states

- *Dependency:*

Rule 7 is a continuation and generalisation of the low flow increase as described in rule 5. Rule 6 also belongs to this category. In the same way that a runoff deficit at a certain river cross-section or the inflow to a reservoir can influence the release, any other system state can also affect the releases. Phrased in a more general way, this means that the release from a reservoir can be triggered, increased or reduced due to a certain system state. Generally, it is irrelevant at which location the system state occurs. In principle, all measureable quantities that influence the transport and storage of water are qualified as system states as e.g. the storage level of other reservoirs, releases, runoff in a river cross-section, a snow depth in the catchment, actual precipitation, actual soil moisture, etc.

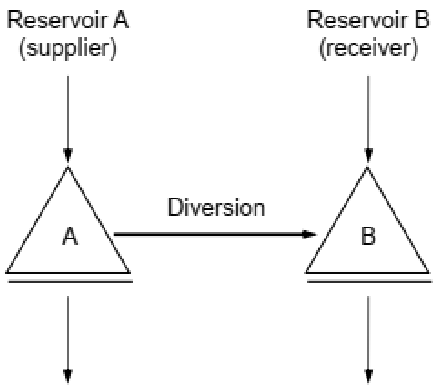
A prerequisite for the application of such dependencies is the assessment of the system state. In practice, that means that there has to be a measuring device for the determination of the quantity or the required value has to be calculated by a mathematical model. Solely momentary quantities are considered.

If several system states shall influence the release, a rule is necessary that defines the interaction between the system states.

- *Mathematical abstraction:*

  Mathematically, the influence of system states on the release can always be resolved by scaling. To this end, two functions are necessary. The first function describes the relationship between storage and release. The second regulates the dependency between a system state and a scaling factor. The combination is done by multiplying the release with the scaling factor.

  A simple example is given by the diversion from reservoir A to reservoir B.



The decisive release is the diversion from A to B. The regarded system state is the storage level of B. It seems evident, that a diversion release from A to B is only sensible if reservoir A has enough reserves and reservoir B enough intake capacity for additional water; thus, the following simple functions result:

1. Determining the scaling factor (reservoir B) | 2. Determining the release (reservoir A)

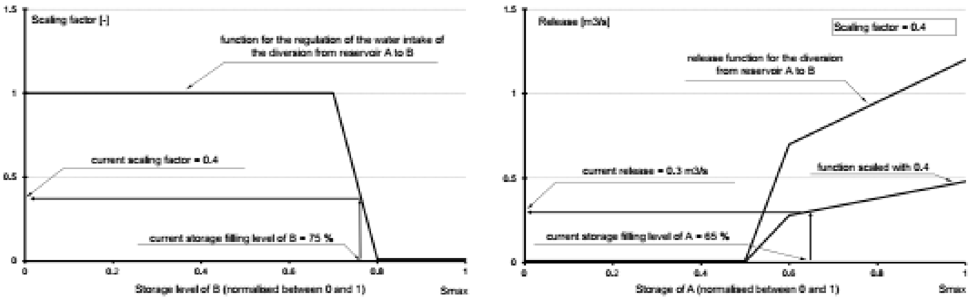


Figure 14: Example function for coupling a system state with a release

Reservoir B takes 100% of the supply from A, as long as its storage level does not exceed 70% of its maximum capacity. Beyond that point, it is undesirable to receive further water due to flood protection. The scaling factor drops from 70% storage down to Zero. Reservoir A can supply B with water from a storage of 50% onward. The actual amount of supply results from the interaction of both functions, thus considering the actual storage of B and the inferred scaling.

For Reservoir A, the definition of the releases is in m³/s, while the function at the Reservoir B contains the dimensionless scaling factor. In principle, it is also possible to switch the meanings of the functions and insert a dimensionless function for reservoir B that scales the required amount of supply at Reservoir B.

Rule Type 8: Influencing a release by balances

- *Dependencies:*

This regulation is an extension of rule 7. Instead of using a current system state, the balance of a system state is linked to a release. It is important that the time period for the balancing is distinct, while it is irrelevant whether the balance is interpreted as a sum or as a mean value. By a function that computes scaling factors in relation to the actual balance, the releases can be influenced.

In practice, this form of dependencies is often found where water rights assign a maximum amount of withdrawal per time period; however, the use of a balance is also interesting in the context of a long-term storage or inflow regime. E.g. for the generation of a reserve, a release can be reduced, if the inflow in the past winter half year was below a defined expected value. An additional application is the comparison between long-term and current moving average of the storage. If the current values deviate from the long-term values by a certain degree, in compensation, the release can be reduced or increased, respectively.

If a coupling between a release and several balances is required, there is the possibility to overlay several balances (see example at the end of this chapter).

- *Mathematical abstraction:*

The influence of the balance on the release is constituted by two functions analogous to rule 7. Additionally, to the in any case necessary storage/release function, a relation exists between the balance and a scaling factor. The scaling factor is derived via the difference between actual balance and expected value.

The method will be demonstrated by a simple example.

For Reservoir A, long-term monthly means of the storage and derived from that moving 30-days averages of the storage as well as a regulation for the release are known.

If e.g. on May 1st the average of the last 30 days of the storage is 5.6 Mio. m³ and, thus, compared to the long-term average of 8 Mio. m³ (Figure 15) there is a deviation of 30%, a scaling factor of 0.5 results (see Figure 16). This value reduces the release by 50% and it is thus only 0.25 m³/s at an actual storage level of 40%.

The relation between the deviation in balance and the scaling factor shows, that only from a difference greater than 20% onwards a change of the release occurs. In case of a negative deviation by more than 20%, the release is reduced in steps. If the actual moving 30-days-average exceeds the long-term values by more than 20% the release is continually increased.

In principle, the possibility exists also here to extend the rule by overlaying and combining several balances.

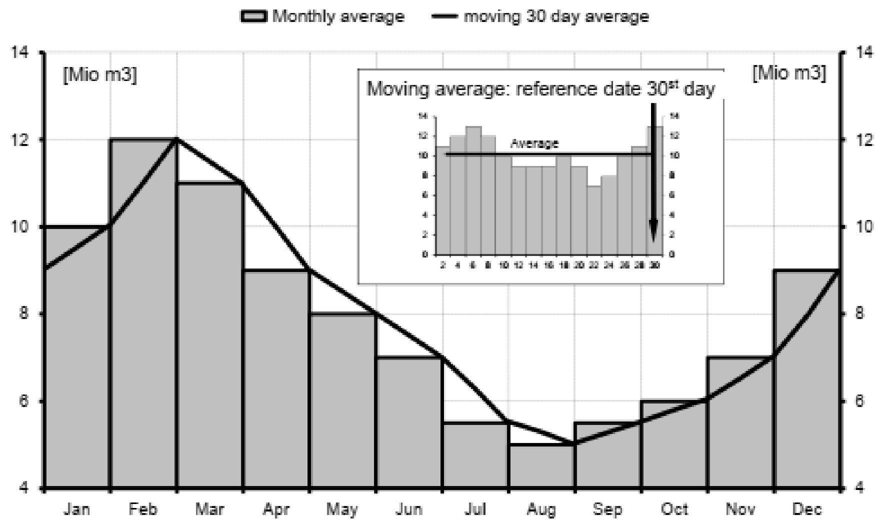


Figure 15: Example of longtime monthly averages and moving 30 day averages of the storage

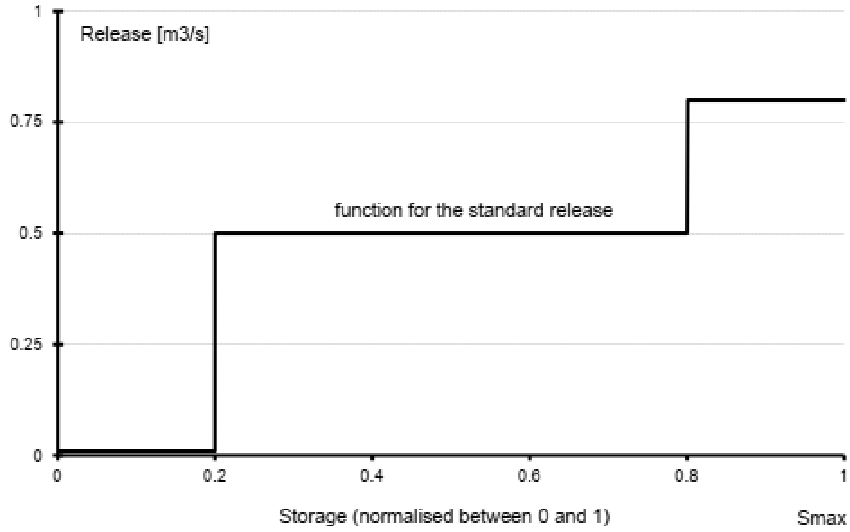


Figure 16: Example for a rule for the standard release

The interaction between balance and release function will be explained in the following text.

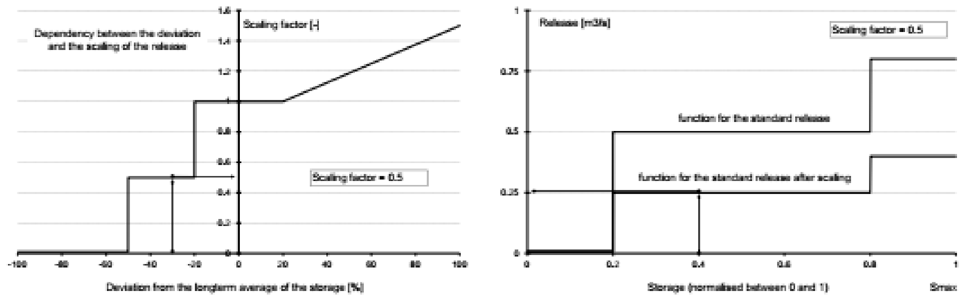


Figure 17: Example function for the coupling of a balance with a release

Rule Type 9: Priorities in the case of several competing releases from a reservoir

- *Dependency:*

If several releases from a reservoir need to be put into effect, the situation can occur that not all the releases (usages) can be fulfilled 100%. In such cases, priorities need to be specified that determine the order in which the releases should be met. The specification of the priorities is often a consequence of political decisions and is no physical condition.

On the other hand, priorities exist that are orientated by physical values. An example in this context is turning off a turbine in cases of water shortage in favour of a secured water supply. Operation rules used in practice often approach the problem by meeting a usage only until a certain storage level but not below.

Another form to describe priorities is given if release A is reduced exactly by the amount that occurs by release B, while the release A can never be negative.

- *Practical example:*

  The operating conditions at the dam „Wiehtalsperre" can serve as an example.

  The primary purpose of the Wiehtalsperre is the drinking water supply and the flood protection, the secondary purpose is power generation. Additionally, downstream from the Wiehtalsperre a minimum flow of 100 l/s should be ensured. In order to guarantee a sufficient water quality in the reservoir, releases used for power generation are stopped if the storage level falls below approx. 70% of the total storage. As both the minimum release as well as the release through the turbine are discharged into the river Wiehl, it would be superfluous to maintain an additional minimum release if water is been released through the turbine at the same time; thus, there is the case of a reduction of release A (minimum release) by the amount of the release B (turbine) as described above /Aggerverband, 1999/.

- *Mathematical abstraction:*

  Assuming that for each usage, a functional dependency exists between storage and release, as described in the aforementioned rules, an order of several usages is already given by the nodes of the functions. The respective storage below which the target value of the release is no longer 100%, or even a reduction to zero, occurs is crucial.

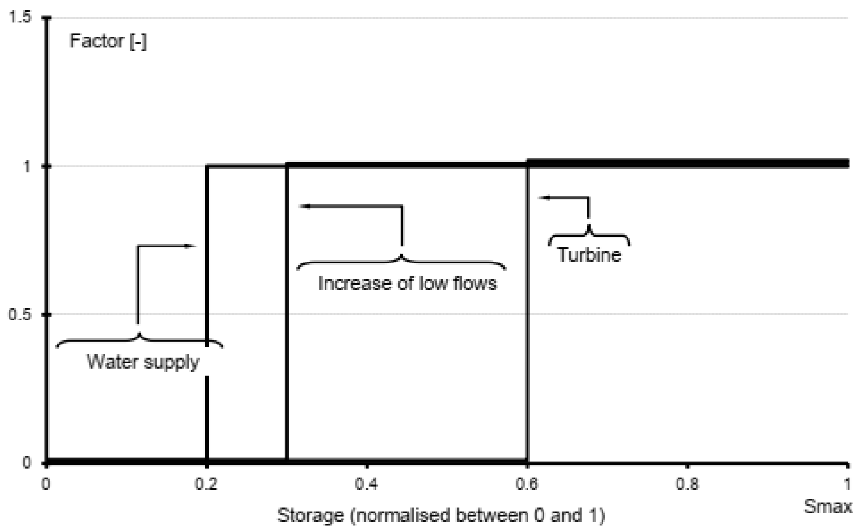


Figure 18: Example of the assignment of priorities through the positioning of the functions

In the example shown, the order of the usages is clearly visible. First the turbine, then the release for the low flow increase are stopped until only the release for the drinking water supply remains.

Furthermore, there is the possibility that two or more releases mutually adjust each other. Such a regulation could read as follows:

If release B > 0 and storage S < X, then reduce release A by the amount of release B, while A cannot be negative.

That means that there is a linear dependency between A and B as long as B has the same value as A. If B increases further, A remains constant and zero.

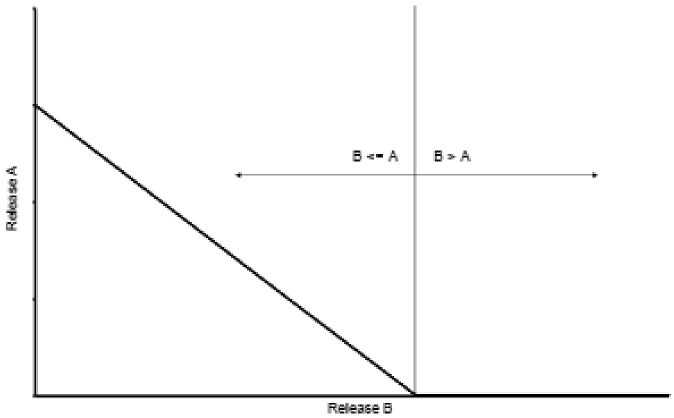
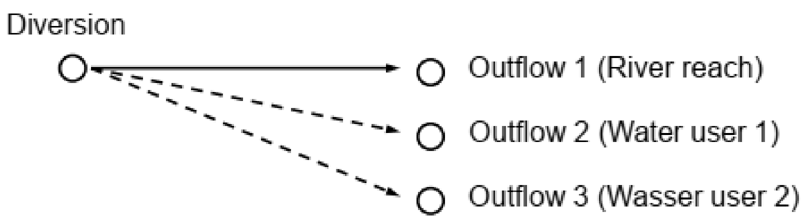


Figure 19: Example of a functional relation between two releases

Rule Type 11: Diversion of Water

- *Dependency:*

If the necessity exists in a water management system to divert water, a corresponding rule has to be defined.



Two types of diversion can exist:

1. Diversions that are only subject to hydraulic laws.
2. Controllable diversions

In both cases, relationships can be always defined as a function of the inflow. In the second case, this diversion rule is an operation rule, as it directly influences the transport and storage regime of the water. In contrast to diversions at a reservoir, in this case no storage level can be used as a reference.

- *Practical example:*

  Three dams are available for the drinking water supply of Windhoek, the capital of Namibia; however, the withdrawal for drinking water supply is only possible from one dam – Von Bach Dam. The other two reservoirs are connected to the main dam via diversions. The amount of water diverted from the Swakopport Dam to the Von Bach Dam is not only available to replenish the Von Back Dam, but also supplies the city Karibib with drinking water.

- *Mathematical abstraction:*

  The appropriate representation for a definition of a diversion rule is by functions depending on the actual inflow. In this way, both a hydraulic and a reservoir management is possible. For each outlet from the diversion structure, an allocation function has to be set. Again, if the function should be variable, scaling functions can be used.

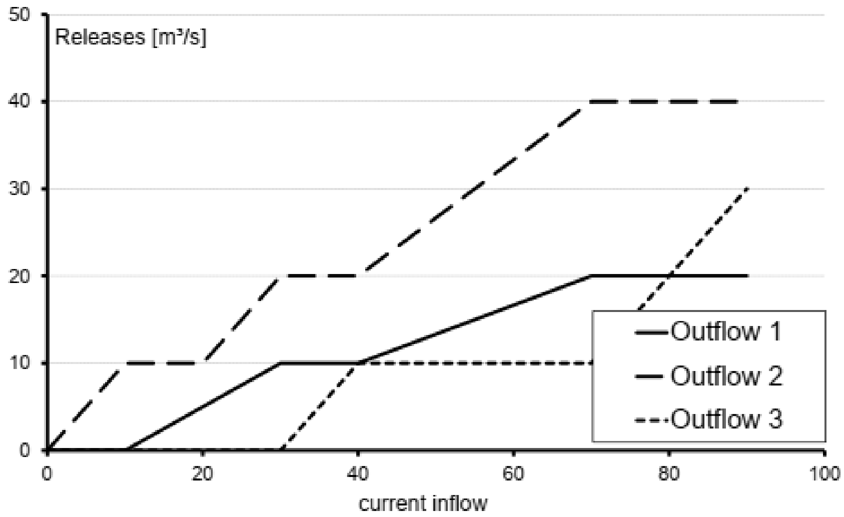


Figure 20: Example of an allocation function for several outflows

If the allocation functions cannot be defined a priori, but the amount to be diverted results later from a computation of demands, the concept of a defined threshold seems appropriate, which in turn can work with scaling factors. The threshold value is scaled by a factor and thus variable. As long as the inflow is lower than the threshold value, the total inflow is used for meeting the demand. Only if the actual inflow exceeds the threshold, the remaining amount is diverted.

If a diversion to more than two outflows is necessary, the threshold concept can be applied several times in succession. The order determines the priorities of the water allocation.

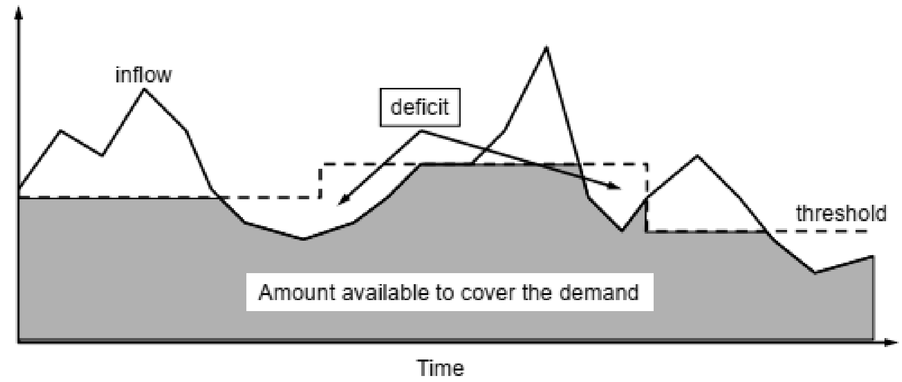


Figure 21: Example of a diversion into two outflows using the concept of a fixed threshold value

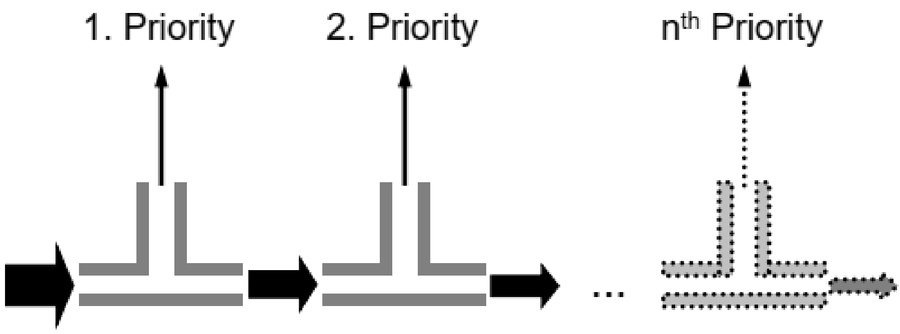


Figure 22: Example of a sequential application of the threshold concept for the diversion of water to supply several users

2.2 Basic principles for describing operation rules

Most practically-used operation rules and several new options for rules can be found in the aforementioned eleven types of rules. If they are analysed for common features and abstracted, a mathematical formalism for the general description of operation rules can be derived that essentially consists in the following six principles:

1. **Releases can be described in the form of mathematical functions**

   $Q = f(...)$

2. **A release is defined dependent on the storage**

$Q_{Release}$ = f(actual storage)

These functional relationships will be called *release functions* in the following.

3. A release can be influenced by system states via scaling.

$Q_{Release}$ = f(system state)

Beyond the mere dependency on the storage, the release can also be influenced by any system state. These influences will be called *system state functions* in the following text. The system states do not necessarily have to occur at the reservoir itself. The mathematical description of the influence results from a scaling of the *release function* by a scaling factor. This is given by the relation system state/ scaling factor.

The system states can have three different manifestations:

3a State variable as actual value

scaling factor = f(actual system state)

3b State variable as balance

scaling factor = f(balance of a system state)

3c State variable as a prediction

scaling factor = f(balance of a prediction of a system state)

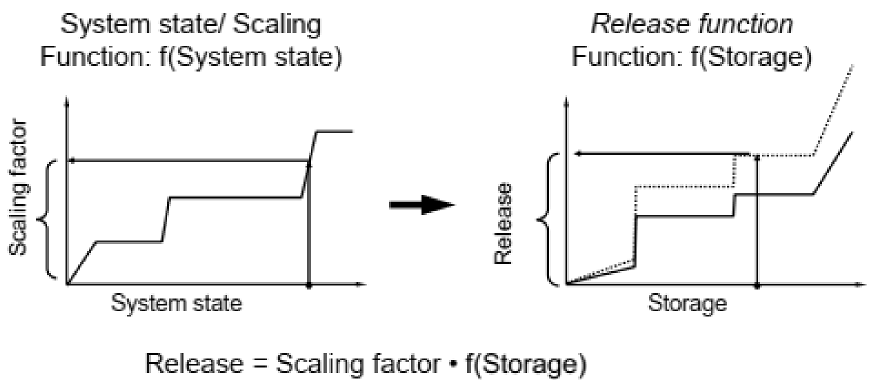


Figure 23: Specification of the dependency between a release and a system state

4. System states can be combined to state clusters

scaling factor = f(state cluster)

Nested dependencies between a release and several system states can be described by overlaying the state variables. To this end, the different system states have to be grouped to a state cluster according to a certain rule. For a regulation, summation, multiplication, division, <; <=; >, >=, or if-then-conditions are suitable.

If all the system states included in a state cluster are captured and evaluated according to the rule, a scaling factor results that is used to influence the release functions (as in Figure 23).

5. **Several releases from a reservoir can be interdependent**

$Q_{Release} = f(Q_i)$ with i = 1...n (n = number of releases from a reservoir)

If there are several releases from a reservoir, it is often the case that they are interdependent. On the one hand, this can be implicitly given by the positions of the nodes of the release function, e.g. release A is reduced at a higher storage level than release B; however, a dependency could also occur via a reduction of release A in favour of release B. Explicitly defined interdependencies as in rule 10 fall into this category. The definition of such dependencies corresponds to the specification of priorities. These forms of dependencies will be called *internal dependencies* in the following.

6. **All aforementioned dependencies (rules) can vary in time.**

$Q_{Release} = f(time)$

All aforementioned rules are possibly only valid for a certain time period. After leaving this period, they are replaced by new functional relationships. If this is the case, it needs to be clear if and how to interpolate between the relationships. An example is given by every lamella plan.

2.3 Implementation of the rules for a simulation

To implement the basic concepts for a simulation, an appropriate mathematical formulation is necessary.

The sequence of the rules given before already prescribes a structure that can be used for the mathematical description. The central dependency is given by the storage. In system hydrology, such a form of a dependency is known by the linear reservoir and a closed-form solution exists. Its principle is based on the assumption that the discharge is always proportional to the amount of water in the reservoir (storage). The proportionality factor, k, is named storage constant. Together with the equation of continuity, a differential equation of the linear reservoir results. This form of the reservoir equation is not suitable for the concrete application on an operated reservoir system. On the one hand, releases are normally not proportional to storage, on the other hand, the equation needs to be extended to any number of releases.

As the examples in this chapter show, the functional relationships between storage and release normally are given only in the form of a number of supporting points. The connection between these nodes provides the curve shape. A release function that is given by several nodes, e.g. the characteristic curve of a spillway, can be connected linearly between its nodes (or supporting points). A general representation of functions with a sectionwise linearization is given by the following figure:

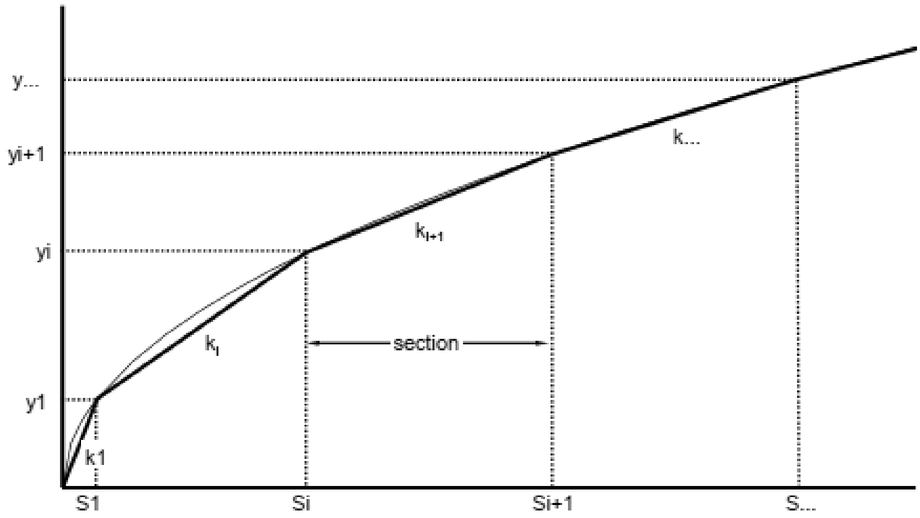


Figure 24: Sectionwise linearization of a function

For one section of the function, the following equations apply:

(2-1) $$y_{(t)} = y_{i-1} + k_i \cdot \left(S_{(t)} - S_{i-1}\right)$$

$$\text{mit} \quad S_i < S_{(t)} \leq S_{i+1}$$

For any number of release functions, the equation of the linear storage within a section becomes:

(2-2) $$\frac{dS}{dt} = \sum_{z=1}^{n} Q_{in} - \sum_{p=1}^{m} \left(y_{p,i-1} + k_{p,i} \cdot \left(S_{(t)} - S_{p,i-1}\right)\right)$$

with

S : storage
Q_{in} : inflow (independent of storage)
y : release value (at node i-1)
k : slope between nodes i-1 and i
n : number of inflows
m : number of storage dependent releases
t : time

After separating the equation into a constant part, and a part depending on the storage, S, the known and closed-form solvable equation of the linear reservoir results.

(2-3) $$\frac{dS}{dt} = \underbrace{\sum_{z=1}^{n} Q_z - \sum_{p=1}^{m} \left(y_{p,i-1} - k_{p,i} \cdot S_{p,i-1}\right)}_{C1 = \text{constant part}} - \underbrace{\sum_{p=1}^{m} \left(k_{p,i}\right)}_{C2 = \text{depending on S}} \cdot S_{(t)}$$

$$\frac{dS}{dt} = C1 - C2 \cdot S_{(t)}$$

As long as the storage lies within a section S_{i-1} to S_i, the solution to the differential equation reads as follows:

$$(2\text{-}4)\qquad S_{(t)} = \frac{C1}{C2}\cdot\left[1 - e^{-C2(t-t_0)}\right] + S_0\cdot e^{-C2(t-t_0)}$$

If the section is exceeded with at least one release function, all the changes that occurred up to that point, both in storage and in releases, need to be registered and C1 and C2 recalculated. With this method, the used time interval – the outer time step – is being processed by a number of inner time steps depending on the density of the nodes. The time until a change of section occurs, can be calculated after rearranging equation (2-4) by t:

$$(2\text{-}5)\qquad t_1 = -\frac{1}{C2}\cdot\ln\left(\frac{S_{(t)} - \frac{C1}{C2}}{S_0 - \frac{C1}{C2}}\right) + t_0$$

If there is a storage section increase or decrease in the considered interval, it can be assessed by inserting the value of the upper section limit for S(t). Thereby, it is the closest node of all functions that is decisive for the determination of the section limit. The resulting value t_1 determines the following three cases:

1. $t_1 > \Delta t$ (outer time step)

   There is no change of section in the considered time interval.

2. $0 < t_1 < \Delta t$

   There is a change of section after time t_1. The time span between t_0 und t_1 is the inner time step length.

3. $t_1 < 0$

   There is no increase in storage but a –decrease. Instead of using the upper section limit, the lower limit needs to be inserted and the calculation repeated.

Considering the section changes, the storage is known at any point in time t. Thus, also the storage dependent processes are known in their course over time. However, a time course is generally not demanded, but rather a mean value within a time interval. If equation 2-4 is inserted into equation 2-1 and integrated over the inner time length, the average process rate in the respective time interval results.

$$(2\text{-}6)\qquad \bar{y} = y_{p,i-1} - k_{p,i}\cdot S_{p,i-1} + k_{p,i}\cdot\left[\frac{C1}{C2} + \left(1 - e^{-C2(t_1-t_0)}\right)\cdot\left(\frac{S_0}{(t_1-t_0)\cdot C2} - \frac{C1}{(t_1-t_0)\cdot C2^2}\right)\right]$$

After summing up the values of all inner time steps, the average process rate over the total outer time interval results.

From the principles for describing operation rules, it is apparent that a release can depend both on storage and on other system states. Consequently, a one-dimensional dependency – only on storage – is not given anymore. In such a case, a two- or multi-dimensional relationship for the distinct determination of a release exists. If there is an additional time-dependency, the problem is extended by another dimension. A simple graphical representation is no longer feasible. Likewise, the solution described above is not enough, as more dependencies have to be added to the storage-dependency. For reasons of clarity and to have a suitable mathematical formulation, it is worthwhile to translate all the dependencies into one-dimensional relationships without information loss. This works by scaling the *release functions*. A scaling is possible both for the release (y-axis) and for the storage (x-axis).

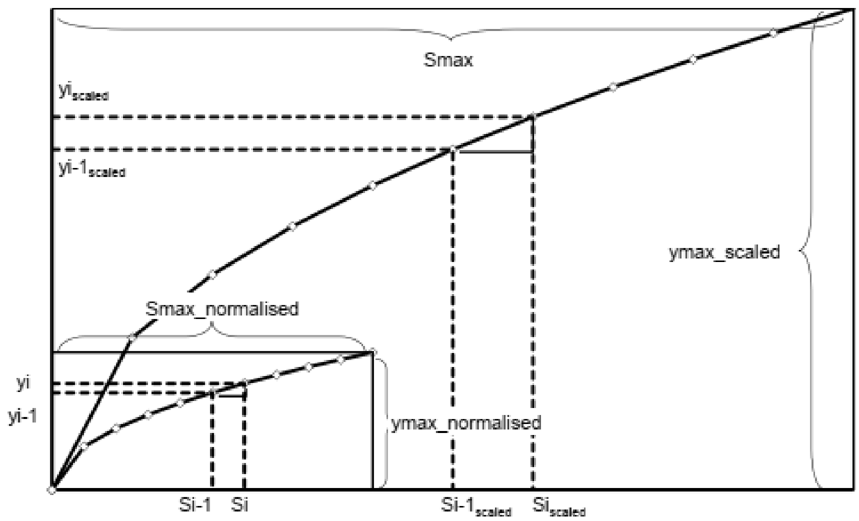


Figure 25: Sectionwise linearization of a scaled release function

After introducing the scaling factors for a scaled section of a function, the following equation results:

(2-7)

$$y^s(t) = y_{i-1} \cdot y_{faktor} + k_i \cdot \frac{y_{factor}}{x_{factor}} \cdot \left(S_{(t)} \cdot x_{factor} - S_{i-1} \cdot x_{factor}\right)$$

$$y^s_{(t)} = y^s_{i-1} + k^s_i \cdot \left(S^s_{(t)} - S^s_{i-1}\right)$$

For the calculation of the *release function* scaled with external system states, the procedure is analogous to the above method. Thereby x_{factor} corresponds to the maximal storage and y_{factor} corresponds to the scaling factor of the external system state or state cluster. It is assumed that the factors remain constant during the outer time interval. The sum of the integration over the internal time loop divided by the outer time step results in the final release value.

(2-8)

$$\bar{y} = y_{factor} \cdot \left[y_{p,i-1} - k_{p,i} \cdot S_{p,i-1} + \frac{1}{x_{factor}} k_{p,i} \cdot \left[\frac{C1^s}{C2^s} + \left(1 - e^{-C2^s \cdot (t_1 - t_0)}\right) \cdot \left(\frac{S_0 \cdot x_{factor}}{(t_1 - t_0) \cdot C2^s} - \frac{C1^s}{(t_1 - t_0) \cdot C2^{s^2}} \right) \right] \right]$$

The computation of a sectionwise linear storage with any number of in- and outlets was described by /Ostrowski, 1992/. This solution was extended by the scaling of both x- and y-axis /Ostrowski, 1999/.

In summary, a reservoir can have any number of usages. For each usage, a storage-dependent function exists that has to remain constant within an outer time step but can vary from time step to time step (time-dependency). Additionally, these functions can be scaled by external dependency via factors per time step, provided that the factors are constant over a time step. The result of the computation is independent of the time step, as it is separated into many inner time steps corresponding to the exceedance of the section limits. This means that the method is suitable for very different time intervals and that it produces results that conserve volume. Thus, both a flood event with a time step of several minutes and a long-term simulation with daily values or even bigger time intervals can be simulated. It is crucial that the release functions are defined by a sufficient number of nodes.

2.4 Example of an application

The example of the Wehebachtal dam should apply its operation plan in clear accordance with the described laws.

The Wehebachtal dam is a multi-purpose entity with applications for water supply and flood protection. Additionally, a control output of 100 l/s is implemented to maintain the lower reaches of the system. Operation of the dam is undertaken by the water association of the Eifel-Ruhr region, and is responsible for the drinking water supply of the metropolitan region of Aachen, the northern Eifel region and the preparation of tap water for a variety of industries. The dam catchment area is 43.61 km^2, the mean inflow is 21 Mio.m^3, and the degree of storage expansion amounts to 119.3%. The construction of the reservoir was completed in 1983.

The following operation plan was formulated for the Wehebachtal dam:

- *Characteristics of the dam:*

Max. volume to top rim:	27.1	Mio. m^3
Volume to spillway:	25.06	Mio. m^3
Storage target (normal storage level):	see flood protection zones	

- *Discharge amount for water supply:*

  The preparation of water from the dam is carried out by two water supply companies. The companies meet the daily water requirements. Up to 11 million m^3 of water is provided yearly for drinking water purposes; however, no more than 2.5 million m^3 of that water can be used on a monthly basis.

- *Control outflow:*

  The control outflow should ensure a minimum flow of water below the dam and is a function of the inflow:

	Inflow	≥200 l/s	→	Control outflow	=	200 l/s
100 l/s ≤	Inflow	<200 l/s	→	Control outflow	=	Inflow
	Inflow	< 100 l/s	→	Control outflow	=	100 l/s

A 6 hour flushing wave of the downstream opening should be conducted every management year by no later than the end of March. The volume of water should amount to a value of 4 m^3/s for the entire duration of the flush.

- *Flood protection zones:*

In order to ensure adequate flood protection, a temporarily variable flood lamelle plan is designated. The lower limit of the protection zone is defined as storage target.

1.10. - 31.10.	Flood prot. zone	=1.0 Mil. m^3	Storage target:	=24.06 Mil. m^3
1.11. - 30.11.	Flood prot. zone	=2.75 Mil. m^3	Storage target:	=22.31 Mil. m^3
1.12. - 15.1.	Flood prot. zone	=4.5 Mil. m^3	Storage target:	=20.56 Mil. m^3
16.1. - 31.3.	Flood prot. zone	=2.5 Mil. m^3	Storage target:	=22.56 Mil. m^3
1.4. - 30.4.	Flood prot. zone	=1.75 Mil. m^3	Storage target:	=23.31 Mil. m^3
1.5. - 30.9.	Flood prot. zone	=1.0 Mil. m^3	Storage target:	=24.06 Mil. m^3

The clearing of the flood protection zones is carried out following the highest permissable outflow volume.

- *Highest permissible outflow:*

As long as the normal storage level is not yet reached, a downstream release of no more than 5 m^3/s is permitted.

If the normal storage level is exceeded, and the inflow exceedes the maximum permissable outflow of 5 m^3/s, no more than 5 m^3/s will be delivered from the bottom outlet. The leftover inflow is released via the spillways

- *Characteristic curve of flood discharge:*

The characteristic curve is given in the form of an X-Y curve and includes nodes. The implementation of the operational plan in the terminology described above first requires the identification of all requirements and uses of the dam and the definition of the *release functions*. The following information serves only to illustrate the operating concepts and rules and does not claim to be a complete or accurate representation of the real conditions.

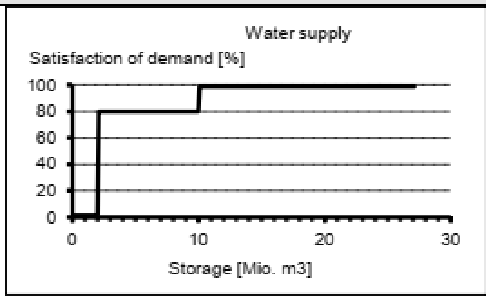
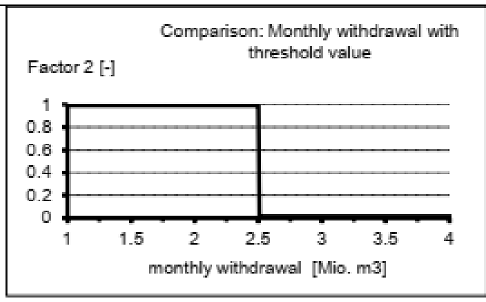
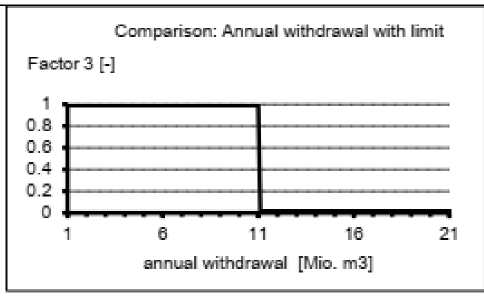
- **Function:** *Water supply*

<u>Time dependence</u>: constant release function throughout the year, may be variable

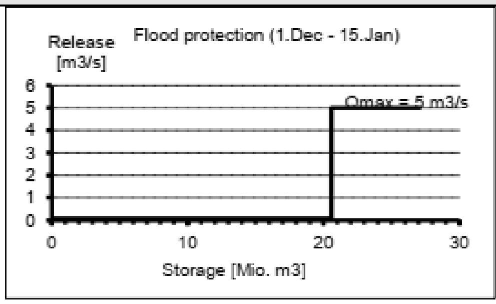
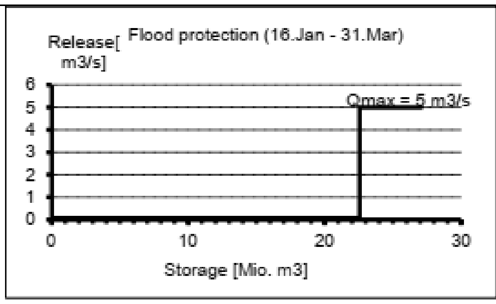
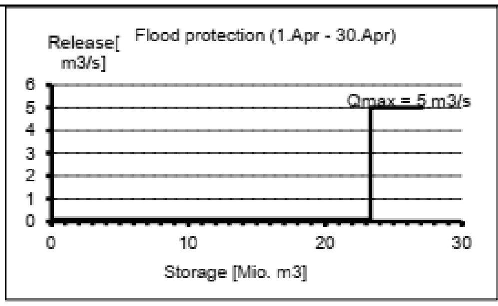
<u>External dependencies</u> yes

1. Current water demand [m^3/s]: Factor 1 (Calculation rule: Multiplication)
2. Monthly withdrawal balance: Factor 2 (Calculation rule: Multiplication)
3. Annual withdrawal balance: Factor 3 (Calculation rule: Multiplication)

Release per time step:	Calculation of 'Water supply' through: $Release = Factor1 \times Factor2 \times Factor3 \times f(Storagevolume)$

Conditions	Release function
Coverage of demand [%]: Period of validity: 1.Jan. - 31.Dec. Explanation: Reduction of the coverage of demand to 80% if storage volume < 10 Mio. m³. If the storage volume falls below 2 Mio. m³, no further water will be released.	
Conditions	**System condition function**
Current water demand [m³/s]: (Factor 1) Time period: Current value Calculation rule: Multiplication	No function necessary
Monthly balance of withdrawals [-]: (Factor 2) Time period: Monthly balance Period of validity: 1.Jan. - 31.Dec. Threshold value: 2.5 Mio. m³ Calculation rule: Multiplication	
Annual balance of withdrawals [-]: (Factor 3) Time period: Annual balance Period of validity: 1.Jan. - 31.Dec. Threshold value: 11.0 Mio. m³ Calculation rule: Multiplication	

- **Function:** *Flood protection*
  Time dependency: yes
  External dependencies: no
  Release per time step: The release 'Flood protection' is a function of the given date
  Release = f(Storage volume)

<table>
<tr><th>Conditions</th><th>Release function</th></tr>
<tr><td>Period of validity: 1.Dec. – 15.Jan.
Max. permitted release: 5 m3/s
Storage target: 20.56 Mio. m^3</td><td>
</td></tr>
<tr><td>Period of validity: 16.Jan. – 31.Mar.
Max. permitted release: 5 m³/s
Storage target: 22.56 Mio. m^3</td><td>
</td></tr>
<tr><td>Period of validity: 1.Apr. – 30.Apr.
Max. permitted release: 5 m³/s
Storage target: 23.31 Mio. m^3</td><td>
</td></tr>
<tr><td colspan="2">For the remaining time periods, produce analogous Release functions.</td></tr>
</table>

- **Function:** *Control output*

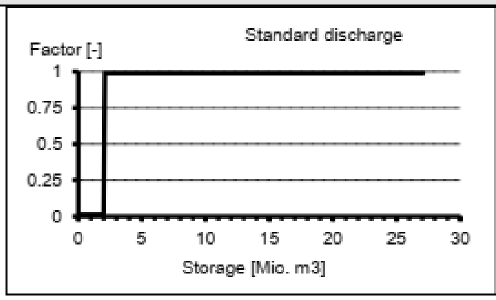
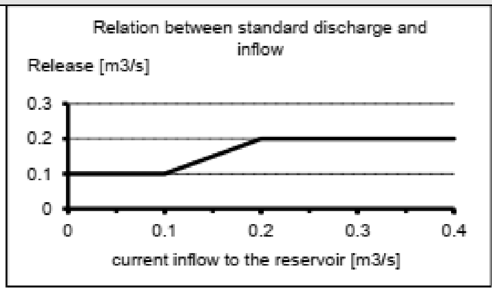
<u>Time dependency</u>: yes

<u>External dependencies</u>: yes

1. Current inflow [m^3/s]: Factor 1 (Calculation rule: Multiplication)

<u>Release per time step</u>: Calculation of the function 'control output' through:

Release = Factor * f(Storage volume)

Conditions	Release functions
Control output factor [-]: Period of validity: 1.Jan. – 31.Dec. Explanation: If the storage volume falls below 2 Mio.m^3 control output will cease.	
Conditions	**System condition function**
Current inflow [m³/s]: (Factor 1) Period of validity: 1.Jan. - 31.Dec. Max. permitted release: 5 m³/s Explanation: Inflow exceeding 0.2 m^3/s will result in a release of 0.2 m^3/s	

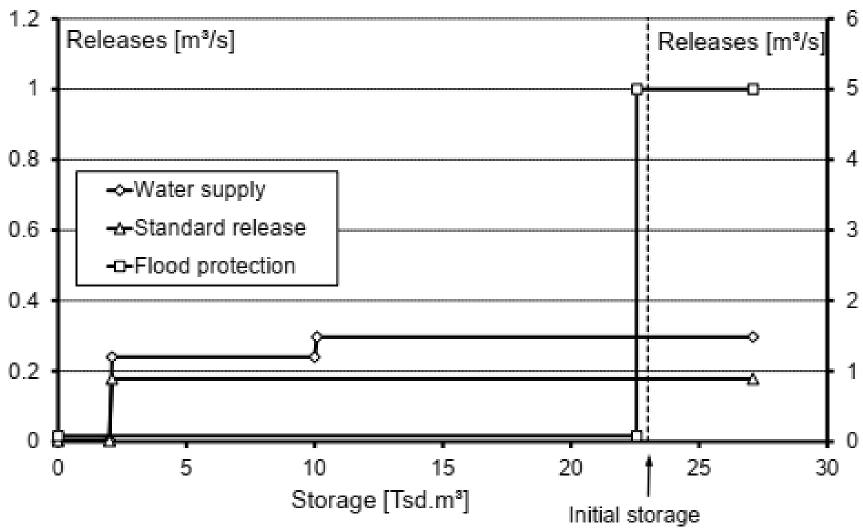


Figure 26: Scaled release functions

All relationships are plotted for a selected point in time and an assumed initial storage volume of S_0 = 23000 Tsd. m³

For illustration purposes, the function for flood protection was recorded with another Y axis.

Parameter	Required Value	Applies to
Time	30.January	Flood protection, Water supply (Factor1, Factor2)
Initial storage volume	23.000 Mio. m^3	All release functions
Average daily inflow	0.180 m^3/s	Control output
Average water demand	0.300 m^3/s	Withdrawal for water supply
Withdrawal for water supply since 1.Jan	0.750 Mio. m^3	Withdrawal for water supply

3 DESCRIPTION OF THE MODEL

In the following text, the program structure of TALSIM and the implemented system elements and concepts are documented.

3.1 Modelling of water management systems

The simulation of the operation of a reservoir requires the mathematical representation of a water management system. Thereby, the reality needs to be abstracted to be de divided into hydrological or hydraulic process and expressed by algorithms. The result of the abstraction is a number of different system elements. The main characteristics of a system element are listed below:

1. A system element integrates transport and storage processes that belong together as a computational unit.
2. A system element has attributes in the form of characteristic properties and parameters. Characteristic properties are attributes that can be clearly and unambiguously determined. Parameters are also attributes of system elements; however, they are subject to calibration and validation.
3. System elements have methods corresponding to their type that describe the behaviour of an element. A stress on the element triggers certain system reactions and states by applying the methods.
4. Under the same stress as well as equal characteristic properties, parameters and initial conditions, the methods always result in the same system reaction and states.

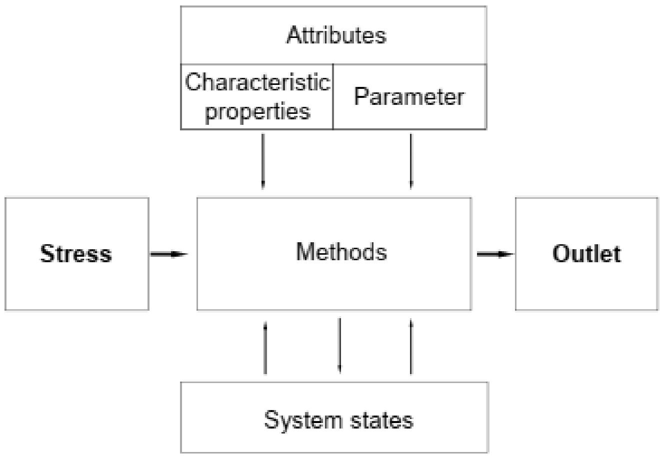


Figure 27: General representation of a system element

The system elements are then arranged in the way that reproduces the actual flow network; thus, processing the water management structure for a mathematical simulation. This procedure, also called *structural analysis*, specifies the geographic conditions and interactions. The result of a structural analysis is the *system logic*. The interactions between several elements occur through the stress and the outlet of the element while the stress corresponds in most cases to an inflow and the outlet to an outflow. The outlet of an element is equivalent to the stress on the next downstream element. The system structures of almost any water management systems can be reproduced by different arrangements of the elements.

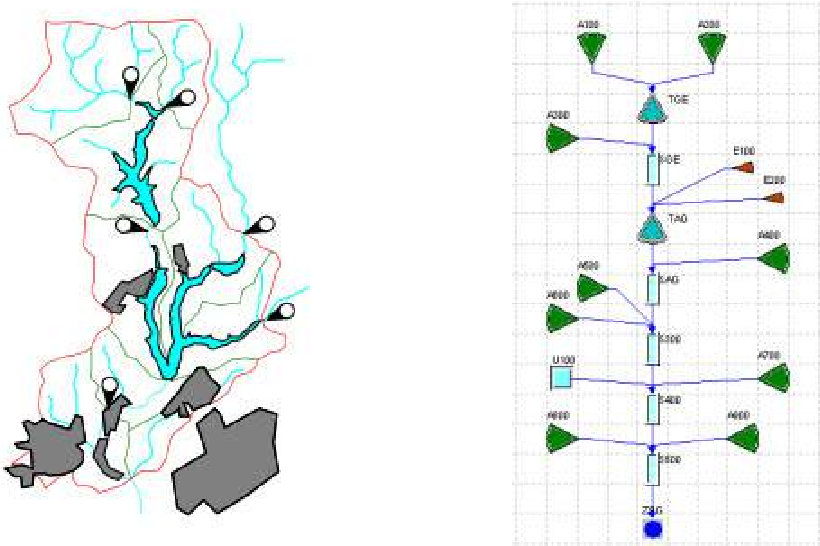


Figure 28: Comparison of a real water management structure with a system logic

The more detailed the spatial and temporal discretisation is carried out, the more information can be gained on the system itself. However, a higher resolution of the system is not always an advantage, as a closer view requires more characteristic properties and parameters that might not be available in sufficient quality and are difficult to estimate. Thus, there is a corresponding degree of abstraction to each task, which underlies a change by increasing requirements or a better availability of input data.

The collection of characteristic properties and parameters can be summarized under the term *system data analysis*. The determination of the operating and control relations and their implementation for the simulation is included in the *operation analysis*. From this, a second type of system logic evolves that does not contain the flow network, but the logical connections of the system states to derive decisions on the releases. This can be called *operation logic*.

3.2 Program structure and Data management

The program structure describes the software concept of a simulation model and the management of system data. It notably affects the applicability of a model. In order to meet the demand to represent systems with different structures, certain requirements on the model structure are necessary and certain approaches are not suitable.

- *Complete separation of system data and source code*

A consequent separation between system data and the simulation program comes with many advantages while posing a greater challenge to the formulation of the algorithms. As the most valuable advantage the free configurability shall be mentioned, which makes it possible to represent different water management systems with one simulation program without reprogramming. In addition, by a variation of the operation logic, different operation strategies can be investigated. This flexibility requires modular, object-oriented programming. By such a program set-up, it is ensured that the program development and maintenance is manageable. Such programs need an extensive graphical user interface (GUI). Via the GUI, the user configures its system and enters the required system data.

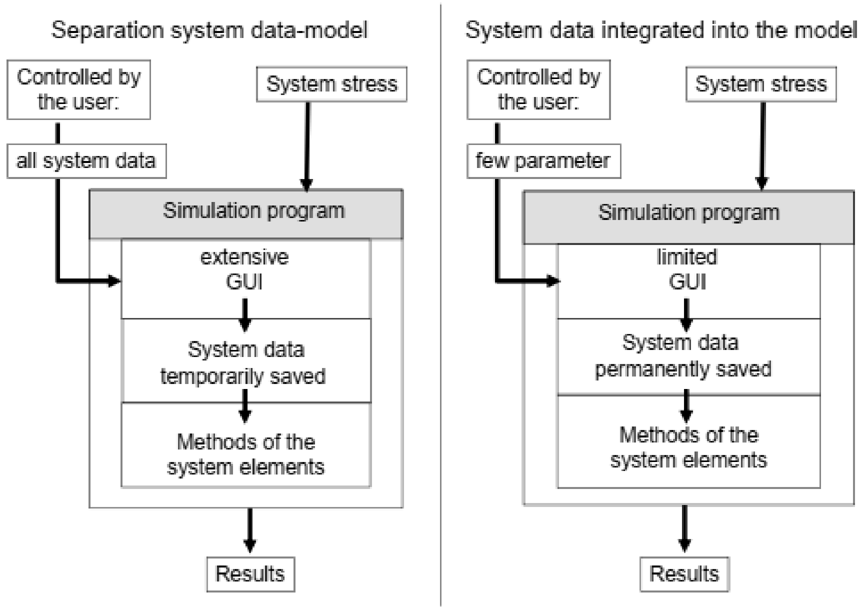


Figure 29: Comparison of different program structures

The program TALSIM works after the principle of a strict separation between system data and simulation program.

3.3 Generation of the system stress

The generation of a stress on the system can occur within the program or externally.

- *Separation between the generation of the inflow stress and of the simulation program*

The system stress and the program are kept strictly separated in TALSIM. The prerequisite is that the system stresses are digitally available on the data storage device and are read in during a simulation. It is irrelevant whether the stresses are historic or synthetic discharges. A consideration of the stochastic character of the inflow is given when using sufficiently long time-series. The external processing of the system stresses requires an elaborate time series management due to the extensive data.

Regarding a forecast or prediction of system stresses, there is also the possibility to integrate a prediction model into the reservoir operation model or to keep them separate.

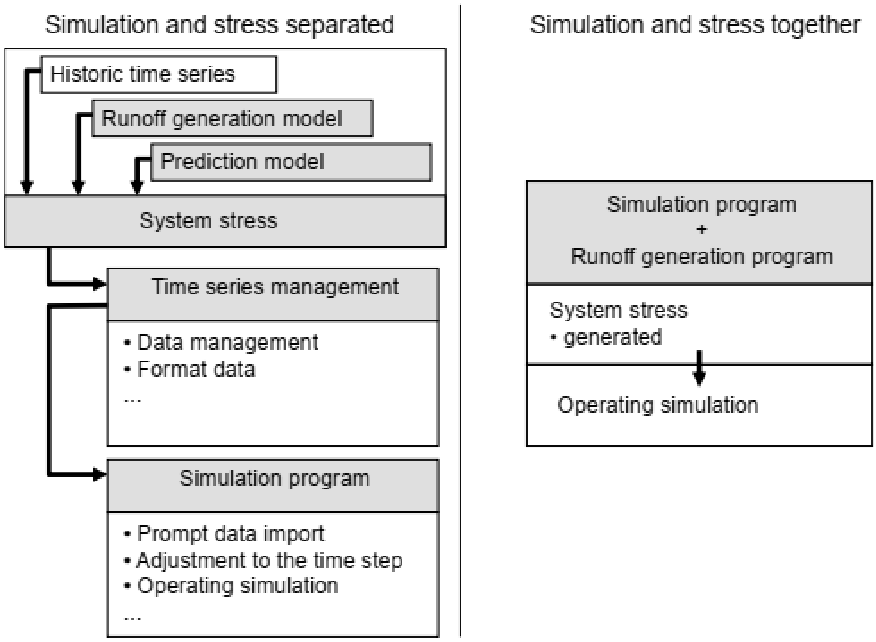


Figure 30: Generation of the system stress

As the separation of the simulation program and the system stress offers extensive applications, the model TALSIM was consequently designed to maximize the extent of its applicability. This is the reason why the programming of a time series management became necessary for TALSIM, which stores the time series attributes (as metadata) in a relational database and the actual time series values in binary files.

3.4 Sequence of computation

TALSIM uses the sequence of computation over time. Thus, all system states of all system elements are computed within a time step before passing on to the next time interval. Only with this concept, the simulation of control systems with complex dependencies between different system states is possible. Additionally, there is the option of variable time steps as well as the option to iterate several times on a time step.

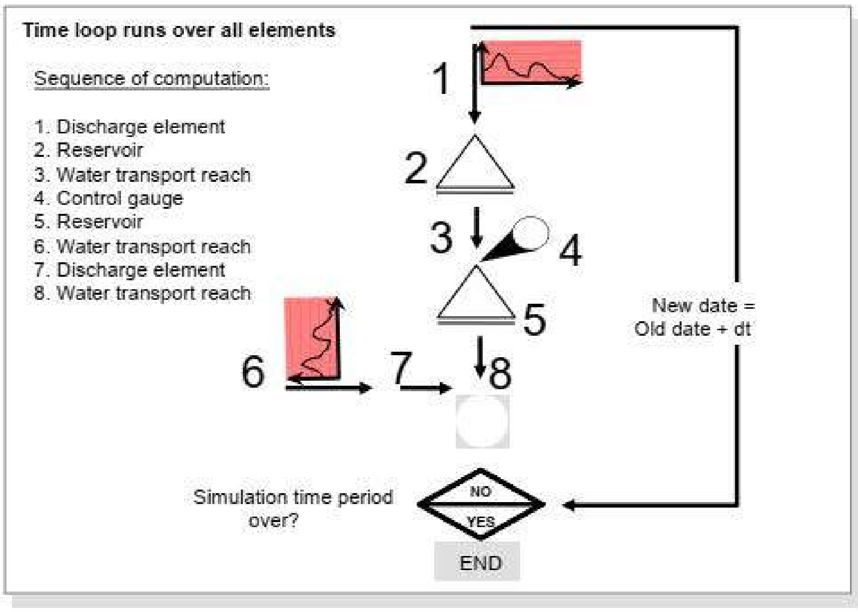


Figure 31: Sequence of computation over time

The flow chart of the program TALSIM is represented in the following Figure.

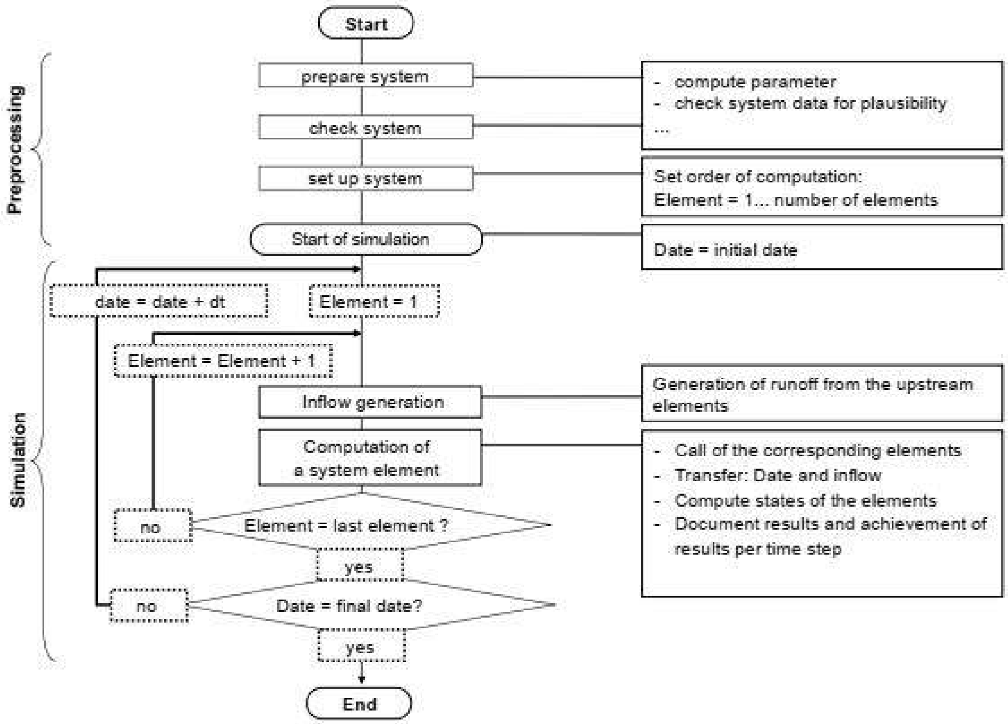


Figure 32: Flow chart of the program TALSIM

3.5 Description of the system elements

A simulation model for the operation of reservoirs requires the representation of all relevant objects and processes of a water management system if said relations and interactions between other hydrologically effective elements as e.g. catchments and river reaches should be considered. As already described, this leads to the generation of system elements. To represent a great variety of systems, the following elements are needed:

- Natural and urban sub-catchments
- Discharge elements
- Water transport elements
- Consumer
- Diversion
- Reservoir (possibly with a hydroelectric power station)

Hydroelectric power stations are no system elements on their own, i.e. they can only occur in the connection of other elements. In order to come into effect, a hydroelectric power station needs a reservoir. If the hydro power station is a run-of-river power station at the cross section of a river reach, the river reach has to be defined as a reservoir.

The following table provides an overview of the most important input and output quantities as well as the attributes of the elements.

Element	Important stresses	Attributes	Element outlet
Natural sub-catchment	- Precipitation - Temperature - Evaporation	- Soil characteristics - Runoff generation - Runoff separation - Runoff concentration - ...	- Surface runoff - Base flow - Total runoff - ...
Urban sub-catchment	- Precipitation - Temperature - Evaporation	- Proportion of impermeable areas - Runoff generation - Runoff separation - Runoff concentration - ...	- Surface runoff - Base flow - Total runoff - ...
Discharge element		- Entry of water into the system	- Runoff
Water transport element	- Inflow	- Translation - Retention	- Runoff
Consumer	- Inflow	- Consumption behaviour - Supply from other areas - Re-entry into the system	- Re-entry - Supply - Total runoff

Diversion	- Inflow	- Specification of the division	- Two outflows
Reservoir - Dam - Flood retention basin - Rain Retention Basin	- Inflow optional: - Precipitation - Evaporation	- Storage – elevation curve - Storage – surface curve - Efficiency of the operation facilities - Operation rules (- Seepage behaviour) - ...	- Releases - Storage - Water level

Table 1: List of the system elements with their most important attributes/methods

3.5.1 Natural and urban sub-catchments

The simulation of natural sub-catchments requires the determination of the stress generation, runoff separation and runoff concentration. In the following text, the underlying approaches for the computation are listed.

- ***Stress generation:***

  The stress generation describes the determination of the areal precipitation on the sub-catchment being considered. Per sub-catchment, only one precipitation is used. If there are several rain gauges in the sub-catchment, it is advisable to further divide the catchment into several system elements „sub-catchments", until there is only one precipitation that can be assigned to an element.

- ***Runoff generation on permeable / impermeable areas:***

  The runoff generation is created from the precipitation which reaches the earth's surface- the effective precipitation, and thereby is derived from the components surface runoff, infiltration, evapotranspiration and interflow. A snow computation is run when the temperatures fall below 0°C and is done based on the snow compaction method. Regarding the algorithms of the method, the reader may refer to the respective literature.

  The natural occurring process from precipitation to runoff is divided into separate phases for the mathematical simulation. In the phase of the runoff generation the division of the precipitation (system stress) into the proportion of the „effective precipitation" that directly becomes runoff and the ineffective losses (Wetting, depression storage, evaporation and infiltration losses). Accordingly, this phase is also referred to as stress separation. The resulting mathematical equation for the actual stress separation can be written as follows:

$$P_{eff}(t) = P(t) - E_{pot}(t) - I(t) - \frac{dO}{dt} - \left(\frac{dS}{dt}\right)$$

with: P_{eff} = effective Precipitation
P = Precipitation
E_{pot} = Potential evaporation
I = Infiltration into the soil
O = Surface water storage
S = Snow storage

In the following text, the terms used in the equation and their computation are explained in detail:

<u>Precipitation P(t)</u>:

The model needs to access the precipitation data in the form of a time series. In principle, it is of no significance whether this time series is a block rainfall, a synthetic rainfall, a measured natural rainfall event, a rain spectrum or a long-term time series. Depending on the purpose of the simulation, the suitable stress has to be selected. The precipitation time series comes either from the time series manager in TALSIM, or when conducting a design storm analysis, it is generated directly before a simulation by inserting a rain duration value, a rain depth and the choice of a model rain.

Evaporation E(t):

The evaporation affects the runoff generation in two ways. On the one hand, the initial conditions in the catchment (wetting and depression storage on the surface as well as the soil moisture of permeable areas) a result of the evaporation before the rainfall event. On the other hand, it is the effective rainfall reduced by the actual evaporation rate.

The potential evaporation, $E_{pot.}$(energetically possible) varies substantially in time and space and therefore an exact assessment is difficult. From analysed measurements of 20 stations, whose means are depicted as a histogram, the following best-fit curve was found (dotted line in Figure 33) /BRANDT, 1979/.

$$VP[mm] = (0.96 + 0.0033 \cdot i) \cdot \sin \frac{2\pi}{365}(i - 148) + 1.58$$

with i = day of water year

i = 1 → November 1st

The annual potential total evaporation is 642 mm. If there is measured evaporation data, this normalised annual pattern of the potential evaporation can be used for the calculation of the actual evaporation. If the calculation time step is smaller than a day, a daily pattern is used to assess the final potential evaporation in each time step. If the computation interval is greater than a day, no daily pattern is considered.

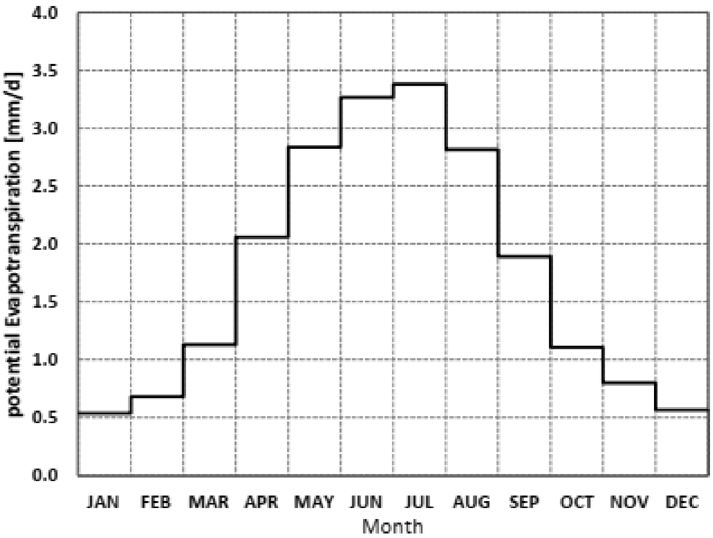


Figure 33: Annual pattern of the potential evapotranspiration by /BRANDT, 1979/

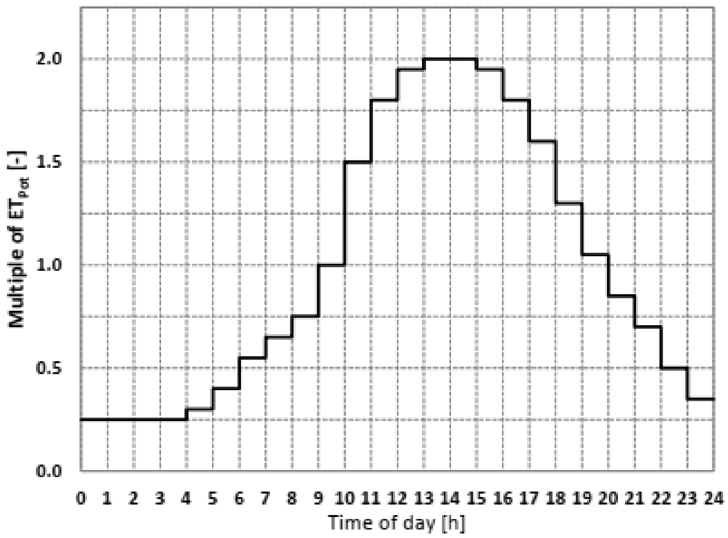


Figure 34: Diurnal variation of the potential evapotranspiration as a multiple of the average daily evapotranspiration

Surface water storage (impermeable area) O:

For the impermeable areas, both the snow storage and the infiltration can be neglected, so that the balance equation is simplified as follows:

$$Pe_{ff}(t) = P(t) - E_{pot}(t) - \frac{dO}{dt}$$

where the change in surface water storage dO/dt represents the wetting of the surface as well as the filling and emptying (by evaporation) of depressions.

As the wetting loss WL for impermeable areas, the following standard value is set.

WL = 0.5 mm

The depression loss DL is inserted by the user. The standard, and at the same time maximum value, in the model is 1 mm.

The depression loss represents a mean value for an inclined surface; however, as the depressions are not spread evenly and experience has shown that runoff already occurs before a complete filling of the depressions, it is assumed that

- 1/3 of the impermeable area has a reduced depression loss of 1/3·MV
- 1/3 of the impermeable area has the average depression loss of 3/3·MV
- 1/3 of the impermeable area has an increased depression loss of 5/3·MV

Thus runoff already occurs if the precipitation (reduced by the evaporation rate) exceeds the wetting loss and 1/3 of the depression loss (with a dry pre-event history). In Figure 35 the above assumptions are depicted schematically.

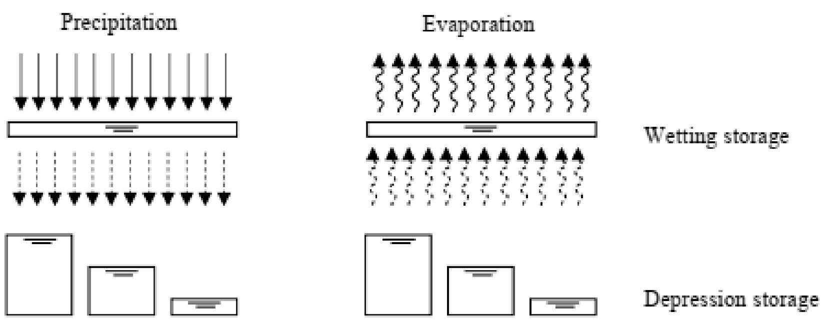


Figure 35: Scheme of the modelling approaches for wetting and depression losses

The runoff coefficient of the impermeable areas (after initial abstraction) is set to Ψ = 1. When assessing the proportion of the impermeable area in a sub-catchment, it is important to consider that not all the paved or impermeable areas are connected to a drainage system.

The continuous allocation of wetting and depression losses is done by constantly balancing these storage components and the evaporation.

Surface water storage (permeable area) O:

The surface water storage is calculated by balancing a loss of storage which is dependent on the chosen method for runoff generation. Details can be found in the following sections on the calculation of infiltration or effective precipitation.

Infiltration/ effective precipitation I(t), $P_{eff}(t)$:

On permeable areas, the infiltration into the soil cannot be neglected as it decisively influences the runoff regime. For its computation, three approaches have been implemented in the model:

1. Constant runoff coefficient, Ψ
2. Event specific runoff coefficient corresponding to the method of the Soil-Conservation-Service (SCS)
3. Soil moisture model

Constant runoff coefficient, Ψ:

When specifying a Ψ-value, after covering the initial losses (wetting and depression storage losses) a proportion of the residual precipitation equal to the runoff coefficient becomes runoff independent of the pre-event history and of the properties of the precipitation (depth, intensity, duration). Whenever possible, this method should not be used, as the process of the runoff generation is only described in very simplified terms.

Event-specific runoff-coefficient following the method by the Soil-Conservation-Service (SCS):

When specifying a soil type and land use dependent CN-value (s. /DVWK, 1991/), an initial loss depending on the pre-event history and a runoff coefficient depending on the precipitation sum cumulated to the regarded time step can be formulated /Zaiss, 1987/; i.e. the runoff coefficient increases with increasing precipitation in the course of the event.

The quantification of the pre-event history is done by the 21-day antecedent rain index I_P.

$$I_P = \sum_{j=1}^{21} C(j)^j \cdot h_{P,j}$$

where: $h_{P,j}$ = Precipitation amount of the j[th] preceding day

C(j) = factor to describe the influence of the j[th] preceding day

The seasonal influence is described by the annual pattern of the factor C.

$$C = 0.05 \cdot \sin\frac{2\pi}{365}(i + 0.75) + 0.85$$

where i = day of the water year

The value, C, varies between $0.8 < C < 0.9$. By this, the same antecedent rain results in different antecedent rain indices depending on the season; thus, considering a varying readiness to generate runoff.

Depending on the quantified pre-event history, an actual runoff coefficient can be computed using the area-specific CN-values valid for the average antecedent soil moisture conditions. Figure 37 shows different CN-values for how the actual runoff coefficient changes depending on the pre-event history.

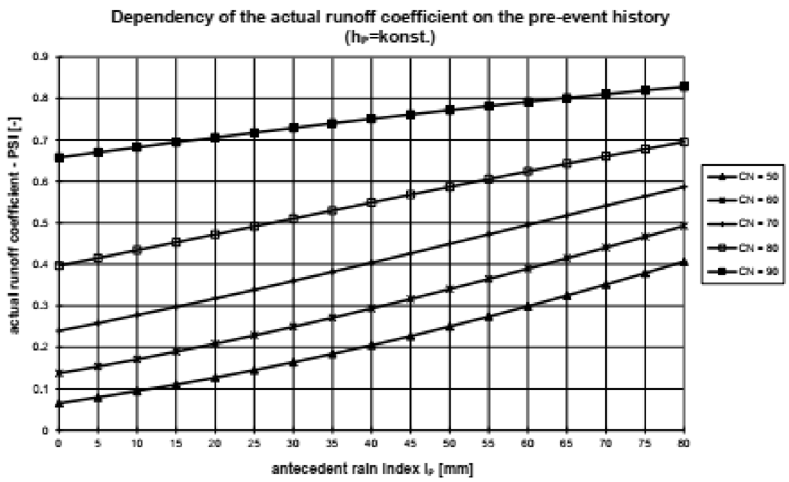


Figure 36: Dependency of the runoff coefficient on the pre-event history

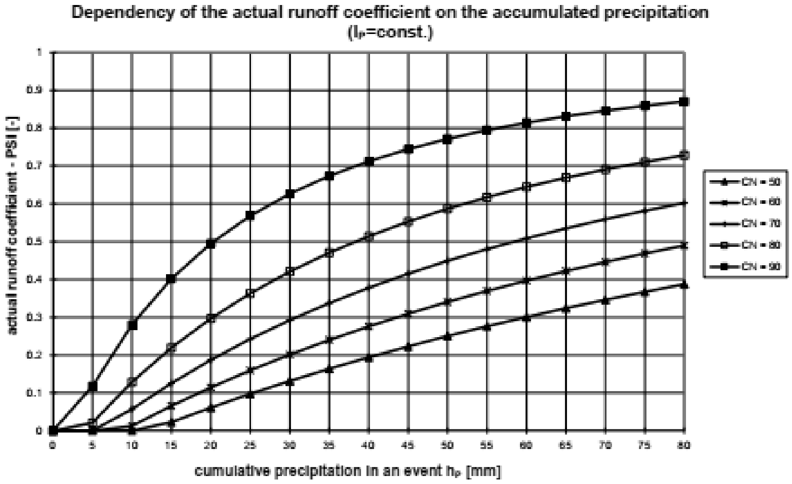


Figure 37: Dependency of the runoff coefficient on the cumulative precipitation

As in the course of a rainfall event, the readiness to generate runoff of a catchment changes by the increasing soil moisture. The runoff coefficient is also adjusted during the event as a function of the cumulated precipitation depth. Figure 37 shows this relation for different CN-values.

TALSIM offers two possibilities for the dependency of the readiness to generate runoff on the accumulated precipitation:

1) Approach of variable loss (default):
   The adjustment of a loss value for the function of the runoff coefficient is recomputed at every time step.
   (results in higher runoff coefficients, so it is not necessary to consider an antecedent rainfall)

2) Approach of constant loss:
   The adjustment of the loss value is only done once at the beginning of the event
   (the approach of an antecedent rainfall is appropriate in this case)

Which approach yields the better results can be only determined by a comparison with measured hydrographs. In general, under the same conditions higher peak flows and runoff volumes arise with the approach of variable loss.

Another option to influence the runoff generation is given by the option to assign a final runoff coefficient. In doing so, the maximum runoff coefficient is restricted independently of the selected approach for the loss. The default value for the final runoff coefficient in TALSIM is 1.

Soil moisture model:

Land use:

When using a soil moisture model, the specification of the land use is necessary. Out of the specifications of the land use, the root depth is required to assess the size of the rooting layer. Other land use parameters that serve for the computation of the interception and the transpiration are:

- Root depth
- Plant coverage
- Annual pattern of the plant coverage
- Leaf area index (LAI)
- Annual pattern of the LAI

The specification of Haude-factors of a better consideration of the evaporation depending on the land use is possible by inserting annual patterns and can be assigned to the requested land uses.

Soil horizons / soil types:

The soil moisture model is based on a non-linear computation of the single soil horizons. To this end, the soil is divided into several horizons (layers). Each layer is calculated and adjusted to the layers above or below (if they exist). As parameter for the soil moisture model, the following soil physical quantities serve:

- Wilting point (WP)
- Field capacity (FC)
- Saturation (SAT)
- Permeability at saturation (k_f-Value)
- Maximum infiltration (Max.Inf.)
- Maximum capillary rise (Max.Cap.)
- Attribution of a soil type: sand, silt, clay

The possible number of soil layers ranges from a minimum of one to a maximum of six. Experience shows that best results are achieved by a division into three layers. This is the reason why the inserted layers are always divides into three horizons by the program.

- Infiltration layer (standard depth [cm] = 20)
- Root layer (minimum thickness [cm] = 5)
- Transport layer (minimum thickness [cm] = 5)

The computation of the new soil characteristics for the layers used by the program is done by weighting according to the given original thicknesses of the layers. In the case of the saturated permeability, the computation is done by the principle of the conservation of the continuity of the flow. In a vertical flow, the velocity, v, should have the same value within a program layer due to the conservation of the continuity of the flow. Thus, the hydraulic gradient is no longer constant.

$$kf_v = \frac{\sum d}{\left(\frac{d_1}{k_1} + \frac{d_i}{k_i} + \ldots \frac{d_n}{k_n}\right)}$$

where: d_i = thickness of the part of the respective original layer forming the layer used by the program [mm]

k_i = saturated permeability of the respective original layer [mm/h]

kf_v = saturated permeability of the layer used by the program [mm/h]

The aggregation of the layers is documented in the following figure:

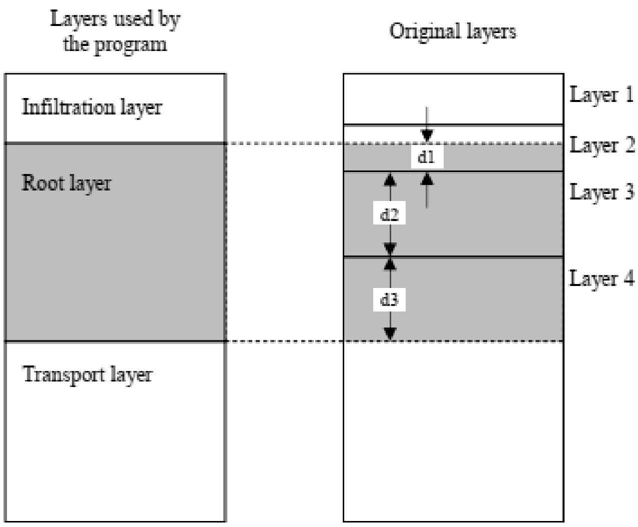


Figure 38: Example of lumping together several soil horizons into one computational layer (root layer in this example)

Al the quantities calculated by the soil moisture model are given in the following figure:

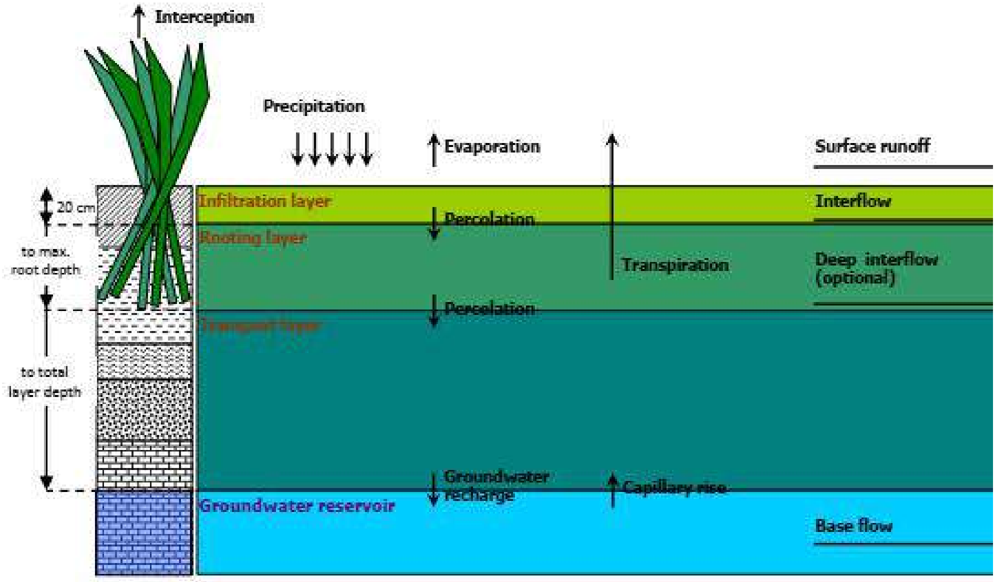


Figure 39: Quantities calculated by the soil moisture model

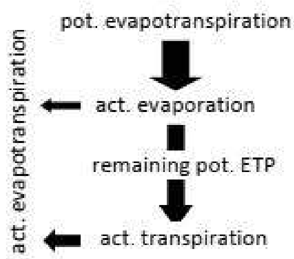
On the basis of the section-wise linear representation of the process functions influencing soil moisture- infiltration, actual evapotranspiration (evaporation + transpiration), percolation, interflow and capillary rise, the water balance equation is solved for a soil layer. The input values for the evaporation and transpiration are determined by the potential evaporation.

The equation to be solved is:

$$\frac{dSM(t)}{dt} = Inf(t) - Perc(t) - Eva_{act}(t) - Trans_{act}(t) - Int(t) + Cap(t)$$

with:

- SM(t) : actual soil moisture
- Inf(t) : infiltration into the soil
- Perc(t) : percolation (seepage)
- $Eva_{act}(t)$: actual evaporation
- $Trans_{act}(t)$: actual transpiration
- Int(t) : interflow
- Cap(t) : capillary rise



Infiltration, percolation, evaporation, transpiration, interflow and capillary rise depend on the actual soil moisture. In the simulation, this dependency is described by the following functions.

$$Inf(SM(t)) = a_v \cdot (SAT - SM(t))^{1.4} + k_f$$ (Approach by HOLTAN)

The formerly used approach:

$$Perc(SM(t)) = \begin{cases} 0 & ,SM(t) \le f_{PK} \cdot uFC + WP \\ k_f \cdot \left(\dfrac{SM(t) - (f_{PK} \cdot uFC + WP)}{SAT - (f_{PK} \cdot uFC + WP)} \right)^{exp.PK} & ,SM(t) > f_{PK} \cdot uFC + WP \end{cases}$$

(mod. approach by /OSTROWSKI, 1992/)

was changed in favour of the approach by VAN GENUCHTEN.

$$Perc(SM(t)) = k_f \cdot SMr^{0.5} \cdot \left[1 - \left(1 - BFr^{\frac{exp.PK}{exp.PK-1}} \right)^{\frac{exp.PK-1}{exp.PK}} \right]^2$$

$$SMr = \frac{SM(t) - WP}{SAT - WP}$$

(Approach by Wösten and van Genuchten /BENECKE, 1992/.

$$Eva(SM(t)) = \begin{cases} 0 & ,SM(t) \le WP \\ f_{Eva} \cdot \left(\dfrac{SM(t) - WP}{SAT - WP} \right) & ,SM(t) > WP \end{cases}$$

$$Trans(SM(t)) = \begin{cases} 0 & ,SM(t) \le f_{Trans} \cdot nFC + WP \\ f_{Trans} \cdot \left(\dfrac{SM(t) - (f_{Trans} \cdot uFC + WP)}{SAT - (f_{Trans} \cdot uFC + WP)} \right)^{exp.Trans} & ,SM(t) > f_{Trans} \cdot uFC + WP \end{cases}$$

where:
- av : Infiltration factor by Holtan (in TALSIM av = 1)
- k_f : Permeability of the saturated soil
- uFC : Usable field capacity (uFC = FC - WP)
- WP : Wilting point
- FK : Field capacity
- SAT : Saturation
- f_{PK} : Soil dependent scaling factor of the percolation function
- exp,PK : Soil dependent shape parameter of the percolation function
- f_{Eva} : Soil dependent scaling factor of the evaporation function
- f_{Trans} : Soil dependent scaling factor of the transpiration function
- exp,Trans : Shape parameter of the transpiration function

The program parameters are computed internally. The user only needs to specify the soil characteristics k_f, WP, FC and SAT.

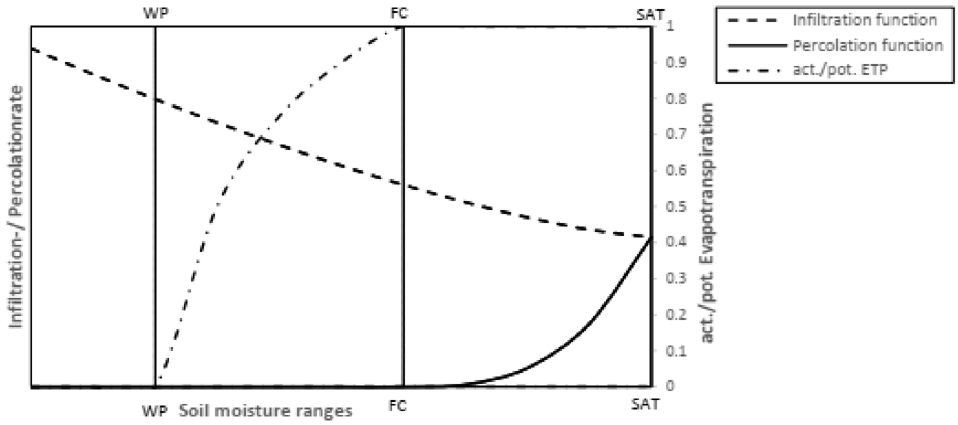


Figure 40: Illustration of selected soil process functions

The simulation is done with a newly developed module for the simulation of reservoirs whose process functions are represented by section-wise linear functions. The module extends the approach by /OSTROWSKI, 1991/ and is described in detail in /MEHLER, 1995/. It allows for a simultaneous solving of the continuity equation for several processes without elaborate iterations. It is briefly described in the following text.

For a reservoir whose storage depends on several inflow and outflow processes, the continuity equation can be written as follows:

$$\frac{dS(t)}{dt} = \sum_{j=1}^{m} Q_{in,j}(t) - \sum_{i=1}^{n} Q_{out,i}(t)$$

where: S(t) : Storage

$Q_{zu,j}(t)$: Inflow

$Q_{ab,i}(t)$: Outflow

m : Number of inflows

n : Number of outflows

The terms of withdrawal are generally non-linear functions of storage (e.g. the withdrawal from the soil storage withe the process functions)

These functions are linearized section by section.

$$y(t) = A \cdot \left(\frac{y_{i+1} - y_i}{S_{i+1} - S_i} \cdot \left(S(t) - S_i \right) + y_i \right) \qquad \text{mit} : A = A_1 \cdot A_l \cdot A_{l+1} \cdot \ldots \cdot A_{p-1} \cdot A_p$$

where: y(t) : Withdrawal from the storage

S(t) : Storage

y_i : Withdrawal at the node i

S_i : Storage at the node i

A : Multiplicator of the process quantity as a product of all further dependencies

p : number of further dependencies

For each withdrawal function, a linear equation can be formulated after linearization that only depends on storage. The slope "m" of the straight line changes from node to node.

Thus, there is a section-wise linear course along the storage for each storage dependent function. The function itself can be scaled by a factor (A) that is constant for each time step and summarizes all further dependencies as a product.

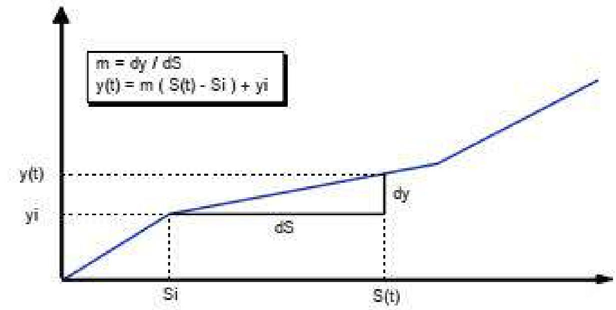


Figure 41: Section-wise linearized withdrawal function

The continuity equation can now be reformulated as:

$$\frac{dS}{dt} = \sum_{j=1}^{m} Q_{z,j}(t) + \sum_{k=1}^{m} y_{k,i} + \sum_{k=1}^{m} m_{k,i} \cdot \left(S(t) - S_i\right) \qquad \text{mit } C_2 = \sum_{k=1}^{m} m_{k,i}$$

$$\frac{dS}{dt} = \sum_{j=1}^{n} Q_{z,j}(t) + \sum_{k=1}^{m} y_{k,i} + C_2 \cdot \left(S(t) - S_i\right)$$

After expanding, the continuity equation becomes:

$$\frac{dS}{dt} + C_2 \cdot S(t) = C_1 \qquad \text{mit } C_1 = \sum_{j=1}^{n} Q_{z,j}(t) + \sum_{k=1}^{m} y_{k,i} + C_2 \cdot S_i$$

This equation is a non-homogeneous, linear first-order differential equation and has the following solution:

$$S(t) = \frac{C_2}{C_1} \cdot \left(1 - e^{-C_1 \cdot t}\right) + S_0 \cdot e^{-C_1 \cdot t} \qquad \text{with: } S_0 = S(t=0)$$

Thus, the storage can be determined at each time step. If within a time interval there is an exceedance of the section, the quantities C1 and C2 with the respective actual slopes and intercepts have to be recalculated. The simultaneous computation of the release function is achieved by inserting the storage equation in the respective linear equations.

For the average intensity of all releases the following generally applies:

$$\bar{y} = \frac{1}{\Delta t}\int_{t=0}^{\Delta t} A \cdot \left[y_i \cdot S_i + m_i \cdot \left(\frac{C_2}{C_1} \cdot \left(1 - e^{-C_1 \cdot t}\right) + S_o \cdot e^{-C_1 \cdot t} \right) \right]$$

$$\bar{y} = y_i + m_i \cdot \left[-S_i + \frac{C_2}{C_1} + \left(1 - e^{-C_1 \cdot \Delta t}\right) \cdot \left(\frac{S_o}{\Delta t \cdot C_1} - \frac{C_2}{\Delta t \cdot C_1^2} \right) \right]$$

With this computation scheme, all reservoirs can be calculated whose processes can be described from section to section by linear functions. With this module in TALSIM, the soil processes, the reservoirs, as well as the water transport elements are calculated.

<u>*Hydrologic response units (HRU)*</u>:

If the runoff generation is calculated by the soil moisture model, at the same time the concept of the hydrologic response units is applied. A sub-catchment element is thereby divided into any number of hydrologically homogeneous areas.

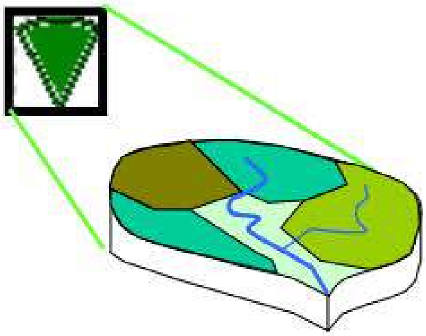


Figure 42: Division of a sub-catchment element into HRUs

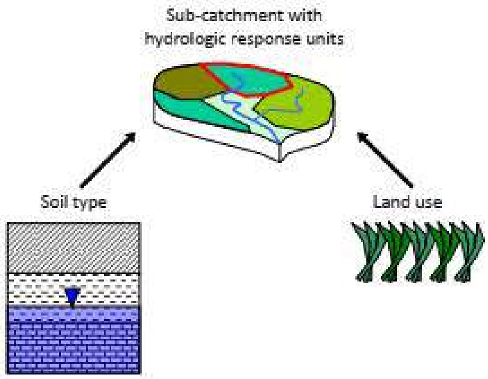


Figure 43: Assignation of soil type and land use to a HRU

To each HRU, a land use and soil type have to be assigned. The amount of water generated on a HRU is located at the element outlet, i.e. all HRUs deliver water with the same time delay independently of their location within the sub-catchment.

The computation of the soil moisture is computationally intensive and, thus, time consuming. This is especially the case if many HRUs are set per sub-catchment. In TALSIM, there is the option to let the program internally aggregate the HRUs, i.e. by specifying a threshold value, all HRUs whose area is smaller than the threshold value are aggregated into one HRU (weighted by area). This is particularly sensible if there are many HRUs with areas under 5%.

- ***Runoff concentration:***

The runoff concentration determines the retention of the surface runoff in the catchment. A parallel cascade of reservoirs is used with three reservoirs for permeable, and one cascade for impermeable areas. The runoff of the components interflow and base flow is released with a time delay by a linear reservoir to the outlet of the element.

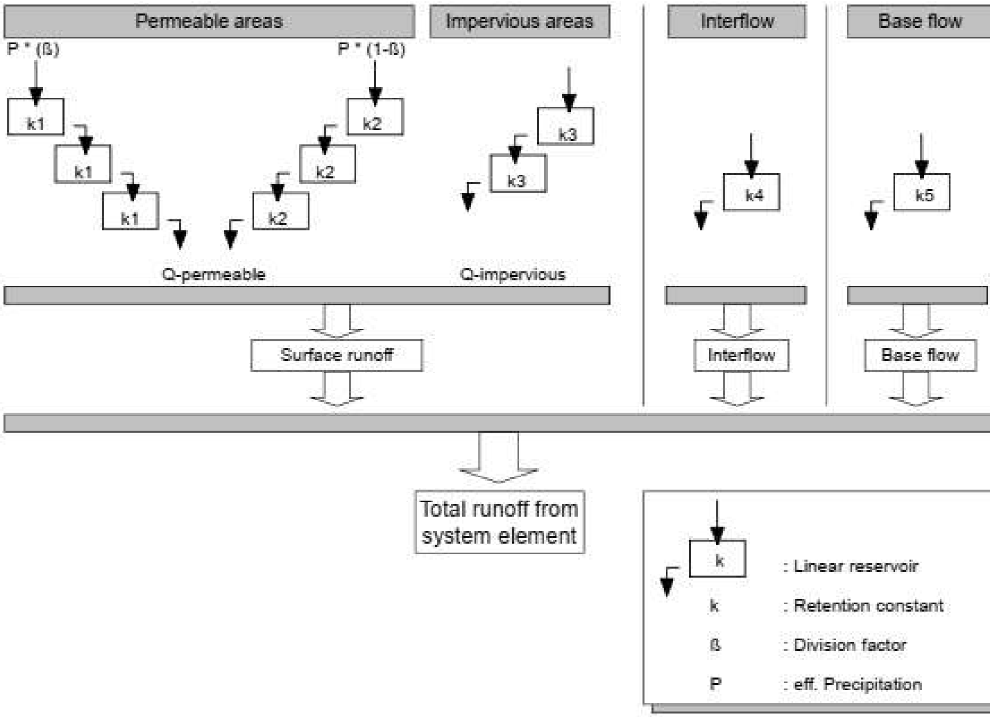


Figure 44: Computation of the runoff concentration in sub-catchments

3.5.2 Discharge elements

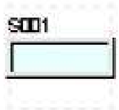
Discharge elements are the interfaces of the system to the outside. They provide stress on the hydrological system in the form of a constant hydrograph that can be composed by a mean value or by annual, weekly or daily patterns, or by a time series that is read in via the time series manager. In this manner it is possible to release measured or generated stresses into the hydrological system. An interface to other models is possible by the import of external data into the time series manger.

- ***Mode of discharge***

  Option 1) as a constant hydrograph that is repeated daily, monthly or yearly

  Option 2) as a measured or generated time series from the time series manager

3.5.3 Water transport elements



Water transport elements represent the translation and retention of natural river reaches or pipes. The approaches for pipes and natural channels differ.

The following options are implemented:

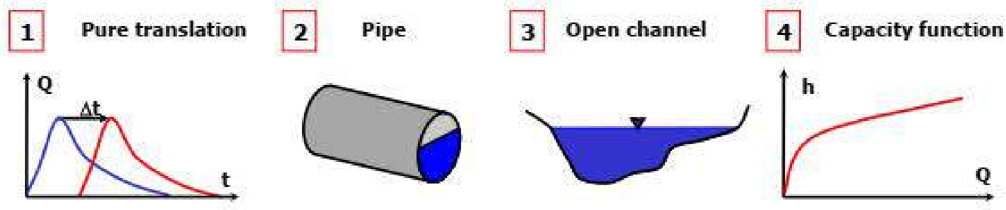


Figure 45: Calculation modes for the water transport element

- ***Translation (Option 1):***

  The inflow hydrograph is delayed to the outlet by a time shift which corresponds to the flow time. If the flow time is smaller than the computational time step, the translation is not visible in the simulation results.

- ***Gravity pipeline (Option 2):***

  The computation of flood routing in tubes by Kalinin-Miljukov is applied. The parameters of the Kalinin-Miljukov-method are estimated for circular tubes by the program according to /Euler, 1983/ or for non-circular profiles determined by specifying a hydrologic diameter and the cross sectional area in the case of complete filling.

Characteristic length: $L = 0.4 \cdot \frac{D}{I_s} [m]$

Retention constant: $K = 0.64 \cdot L \cdot \frac{D^2}{Q_v} [s]$

where D [m] = diameter of the circular pipe or hydraulic diameter

I_S [-] = bottom slope of the pipe

Q_v [m3/s] = discharge capacity of the pipe

The discharge capacity of the pipe is calculated according to the flow law by Prandtl-Colebrook:

$$Q_v = A_v \left[-2 \cdot \lg \left[\frac{2.51 \cdot \nu}{D\sqrt{2gDI_s}} + \frac{k_b}{3.71 \cdot D} \right] \cdot \sqrt{2gDI_s} \right]$$

where: A_v [m²] = Cross section area of the profile ν [m²/s] = kinematic viscosity

k_b [m] = working roughness

g [m/s²] = acceleration of gravity

According to the characteristic length, L, the total length, L_g, of the transport element is divided into n sections of the same length for calculation, with:

$n = L_g/L$ (where n is an integral number)

For the calculation of single sections, the following adapted parameters apply

$L^* = L_g/n$

$K^* = K \bullet L^*/L$

Based on these parameters, after running through the recursion formula n-times, the runoff at the lower end of the transport element is calculated.

$$Q_{out,i} = Q_{out,i-1} + C_1 \cdot (Q_{in,i-1} - Q_{out,i-1}) + C_2 \cdot (Q_{in,i} - Q_{in,i-1})$$

with: Q_{in} = inflow to the calculation section

Q_{out} = outflow from the calculation section

i = actual computational time step

i-1 = previous computational time step

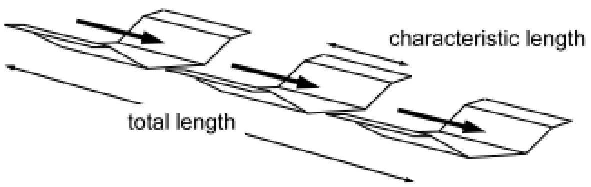
dt = computational time interval

$$C_1 = 1 - e^{-dt/K^*}, \qquad C_2 = 1 - \frac{K^*}{dt} / C_1$$

This approximation procedure derived by Kalinin-Miljukov is the same as the reservoir cascade used with the runoff concentration; i.e. the flood-routing in a water transport element can be simulated by a reservoir cascade consisting of n reservoirs with the storage constant, K*.

- ***Open channel with the specification of a cross section profile (option 3):***

Here too the translation and retention is reproduced by the flood-routing computation by Kalinin-Miljukov. From the normal runoff relation by Manning-Strickler, the characteristic length is derived as a parameter of the Kalinin-Miljukov method /Rosemann, 1970/.

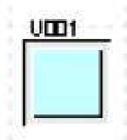


With this characteristic length, the channel is divided into separate segments. For each segment, the computation of the transfer is done by a non-linear reservoir computation (s. soil moisture simulation) with the help of the normal runoff relation.

- ***Using a characteristic curve (water level – cross section – runoff) (Option 4):***

  If the transport regime of the reach is known by former computations of the hydraulic heads, the result can be used in the form of a characteristic curve linking the water level, cross section and runoff.

3.5.4 User



Users can both withdraw from and release water into the system. They can be interpreted as municipal or industrial waterworks with a subsequent supply network which requires drinking or raw water, and then its release via the sewage system and wastewater treatment plant with a time-delay back into the river. The time delay specifies how long the water remains in the user element on average before it reappears as clarified wastewater in the river. The user substitutes a detailed simulation of an urban area with a sewage system. If a more sophisticated inspection of urban areas is necessary, this can be realised with the help of urban catchments, pipes and reservoirs as retention structures of the sewage system.

- ***Demand***

  The demand specifies the required amount of water. There are two options for defining these amounts.

  Option 1) as a constant hydrograph that is repeated daily, monthly or yearly

  Option 2) as a measured or synthetic time series from the time series manager

- ***Supply***

  A user can receive water from different water management systems or catchments to meet demand. If the user has a source of supply that is outside the system under consideration, this implies a discharge or supply into this system. The determination of the supply is done analogously to the demand via two options.

  Option 1) as a constant hydrograph that is repeated daily, monthly or yearly

  Option 2) as a measured or synthetic time series from the time series manager

- ***Release***

  In the same way a user can receive supplies from different areas, they can also release water to areas outside of the considered system. Such a situation occurs if a waterwork needs to serve different supply areas where at least one is not part of the simulated system. The discharge of a sewage system into an exterior area can be represented by this method in a simplified way. This corresponds to the simulation of diversions into other catchments.

  In such a case, a user acts like a diversion structure, where three different concepts are possible (a more detailed explication of the options can be found with the element *Diversion*)

Option 1) Threshold

If the water that flows back from the user towards the direction of the system exceeds a certain threshold, then the amount that lies over that threshold is cut off and not released back into the system.

Option 2) Percentage

A certain percentage of the water that flows from the user towards the direction of the system is treated as a deduction to another catchment and is not released back into the system.

Option 3) Function

The amount of the water discharged to other catchments and, thus, removed from the system, is defined by a function and depends on the current amount that flows back from the user.

The flows through a user are illustrated in the following figure.

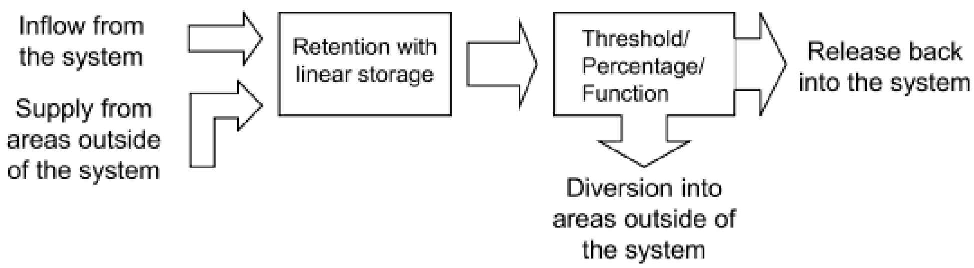
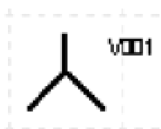
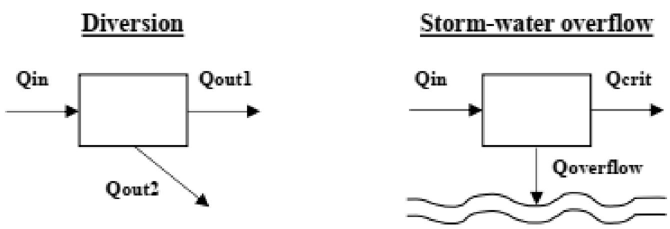


Figure 46: Volume flow of a user

3.5.5 Diversions



Diversions serve for separating an inflow into two outflows according to a specified rule. Possible forms are intakes into rivers that divert water for irrigation or water supply, storm-water overflows, junctions in pipelines, deductions in the inflow or outflow of dams, etc.



Three approaches are available as rules for the diversion:

- ***Threshold model (Option 1):***

Here, the second outflow (e.g. outlet channel) is only applied if the inflow is higher than a critical value, Q_{crit}, at which the first outflow (e.g. throttle) dams up to the sill. In reality, there is generally no perfect diversion of the outflows after reaching the threshold, so it is also possible to specify accuracy in form of a diversion coefficient for the structure.

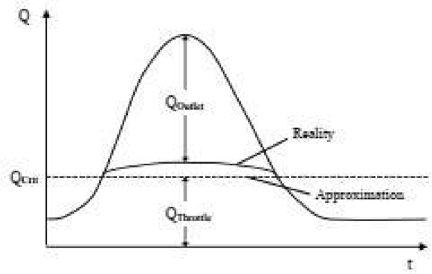


Fig. 1: Diversion after the Threshold model

It is defined by:

$$\text{Diversion coefficient} = \frac{Q_{out}(Q_{in} = 5 \cdot Q_{crit})}{Q_{crit}}$$

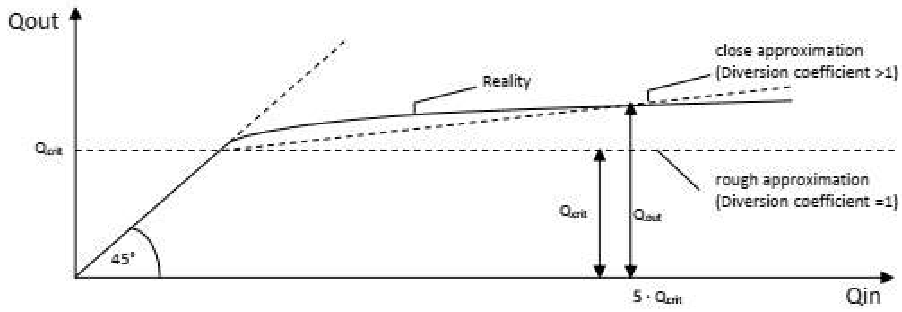


Figure 47: Definition of the parameter diversion coefficient in TALSIM

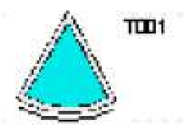
- ***Percentage (Option 2):***

  A constant partitioning into two outflows is done according to a specific percentage which is independent of the inflow. Here as well, there is the option to change the partitioning by scaling.

- ***Function (Option 3):***

  A dependency between outflow, Q_{out1}, and the inflow resulting from hydraulic computations or operation rules is used in form of a function. The second outflow, Q_{out2}, is determined as the residual between inflow and Q_{out1}.

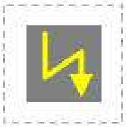
3.5.6 Reservoir



The reservoir module gets its operational instructions by functional dependencies that are defined between the different usages, the available storage and any other system states. In the case of combined operations or control cross sections, additional instructions exist which may influence the releases.

The computation of reservoirs is explained in detail in Chapter 2.3.

3.5.7 Reservoir with a hydroelectric power station



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Hydropower stations occur in conjunction with reservoirs. If a run-of-river power station shall be represented, the corresponding river reach has to be defined as a reservoir.

Depending on the priority of the hydropower compared to other usages, there are different concepts for the simulation of turbines. At the dams of the German Mittelgebirge, the production of hydropower is of secondary importance in most cases. There, the drop in elevation is used to gain another advantage from the construction of a reservoir apart from its primary purpose. One will try to start running the turbines every time enough water is available without impairing competing usages.

- ***Hydropower as a by-product:***

  An approximate computation is suitable which defines the turbine release as a function of the actual water level considering the effectiveness and the capacity of the turbine. As a simplification, a constant tailwater level is assumed. The necessary computational steps are given as follows:

  1. Specification of several sampling points along the storage element
  2. Iterative computation of the turbine release for all the nodes assuming a constant tailwater level
  3. Specification of a boundary storage below which the turbine release is reduced to zero in favour of other usages
  4. Assigned release function to the reservoir usage "hydropower"
  5. Simulation

  The *release function* for the turbine has to be determined beforehand.

  Example:

A turbine and its efficiency is given. If the required power is specified, the flow rate of the turbine has to be computed iteratively. The drop height, the efficiency and the head loss are related to the flow rate. If the tailwater level is assumed to be constant, then for any given water level in the reservoir, a power-dependent flow rate can be calculated. The assumption of a

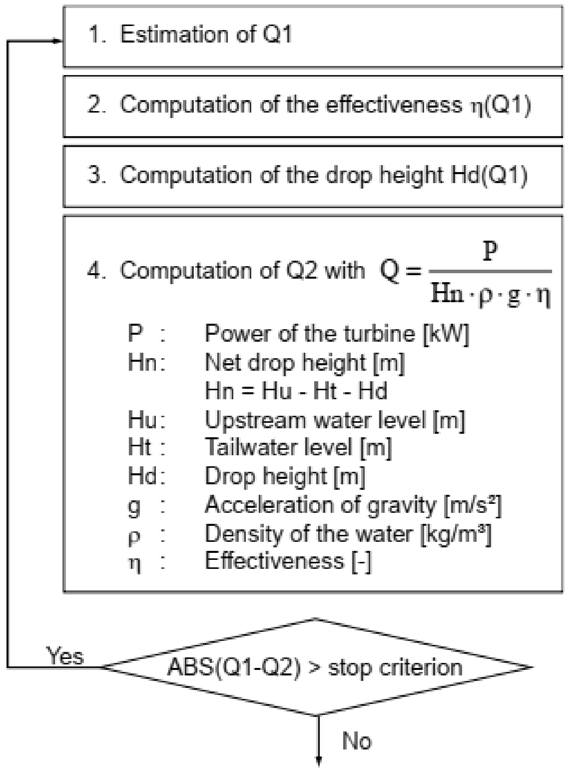


Figure 48: Iterative computation of the turbine release

constant tailwater level seems to be justified in the case of dams with their high and strongly variable upstream water levels, but only slightly varying tailwater levels.

The point at which the release function goes down to zero shows that this operation is subordinate to the main usages. The result of the pre-computation of the turbine output is an explicit function related to the storage volume.

By moving the point 'S1' to the right, the turbine release is more quickly reduced to zero. Thus, more reserves are available for the other usages. When defining the function, it is essential to consider the range of effectiveness of the turbine and, if necessary, to restrict the function based upon the storage volume.

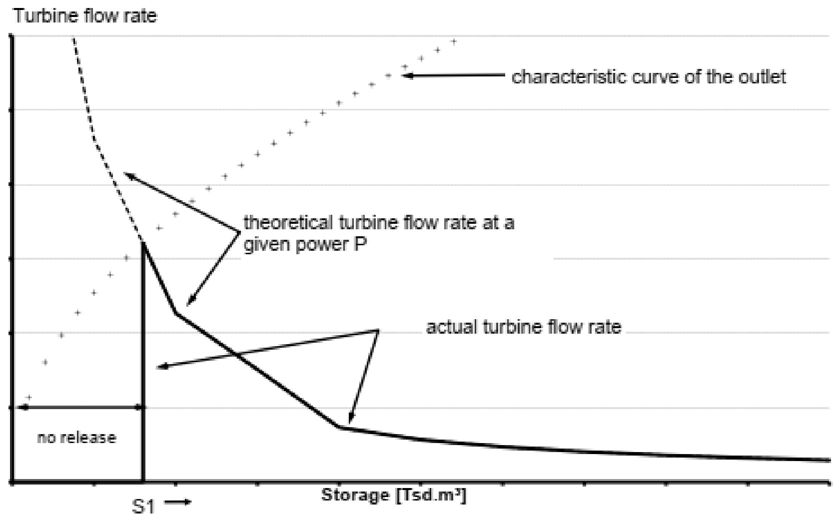


Figure 49: Example of a storage dependent turbine release with a constant tailwater level

- ***Hydropower as the main product:***

  If the hydropower production is the main target of the dam operation, the maximum turbine power output is the priority. For more precise results, it should be ensured that the tailwater level is accurate. The sequence of computational steps is as follows:

  1. Assessment/ specification of the characteristic properties of the turbine. This includes the performance, maximum absorption capacity, flow-dependent efficiency and the flow-dependent head-loss.

  During the simulation, the next computational steps are:

  2. Read out the last tailwater level
  3. Iterative computation of the turbine flow-through with an estimated water level of the reservoir
  4. For the reservoir, a storage and release computation according to Chapter 2.3, considering all the operative usages of the storage, follows. In doing so, the Q-turbine is kept constant
  5. Comparison of the new and old average water levels in the time interval
  6. If the water level criterion to stop is not reached, re-estimate the average water level in the reservoir and repeat the calculations starting from step 3.

  The turbine always achieves the required output, as long as the maximal flow rate of the outlet is not exceeded.

  If the hydropower generation is the main product, the turbine flow rate varies depending on the upstream water level and tailwater level. The fundamental difference to the hydropower generation as a by-product is in the variable tailwater level which causes net drop heights to be sometimes higher, sometimes lower and, thus, influences the optimal release of the turbine.

If it is intended to run the turbine only at certain storage levels for optimal performance, the turbine can operate using an additional storage-dependent *release function* or a *system state function* according to the factor concept of Chapter 2.4. This function is defined between zero and the maximum storage, and has a dimensionless y-axis with values between 0 and 1. The turbine flow serves as a factor.

4 EVALUATION OF THE WATER MANAGEMENT OPERATIONS

If there are regulatory interventions in the water cycle, this is done to achieve certain objectives. The evaluation on how successful an intervention was needs a clearly defined objective in the form of target quantities, and a rule on how to evaluate them; however, a satisfactory quantitative description of the targets, especially their mutual weighting, is complicated as the targets often compete with one another. Depending ones position and interests, a weighting can yield quite different results. In the end, it is a political decision as to which compromise represents the best solution for all parties involved.

4.1 Operation objectives

In general, the definition of operation objectives consists of minimizing failures and in maximising benefits- regardless of whether or not failures and benefits are defined monetarily.

The minimisation of failures requires that knowledge about an optimal or desirable state exists. The criteria to be fulfilled should be sufficiently differentiated and sophisticated, otherwise it can happen that insufficient operation strategies appear to be successful, yet cannot function with stricter conditions. Only with a sufficiently coherent specification of the boundary conditions can the best results be achieved.

A different problem is given if a maximization of benefits is demanded. Here, the performance and effectiveness of the water management system is crucial. The question of the management is- "How does the water management have to look in order to satisfy one or several usages to the maximum extent"? The difference with the above objective is that the demands are explicitly stated beforehand and not moulded organically during the model setup. The formulation of the objectives therefore automatically contains the search of an optimal solution.

The minimisation of failures can be translated into a maximisation of usages if the requirements are set so high that they are in effect unattainable. If the water management procedure is found which minimises the failures, the maximal performance regarding the usages or the system has also been found.

4.2 Definition of an ideal state space

For the definition of an ideal state space, the specification of desired state values or derived values is necessary. Derived values could be securities or frequency of failure which can be derived by the frequency of occurrences or non-occurrences, or by comparing volumes required with volumes that are actually supplied. An optimal operation is the one with the highest security or with the lowest level of failure. In the case of more than one target, the naming of priorities or weighting in value is inevitable.

When defining desired state values, it is essential to narrow down the area which will meet all the required boundary conditions or at least comes closest to meeting them. Two different types of boundary conditions exist:

1. boundary conditions based on physical laws
2. boundary conditions that are operationally required

Boundary conditions that are based on physical laws do not belong to the formulation of target objective functions, but have to be incorporated in the simulation program. Any computations have to take place within the physical boundaries.

Operationally required boundary conditions arise from the interest to organise the water operations as well as possible. For example, keeping maximum releases arises from the need for protection against floods, or meeting a minimum release arises from the requirements for maintaining an intact environment. Thus, these boundary conditions do not follow any physical law and can, in principle, be violated. This is why it is necessary not only to give thought to the required states, but also to their potential violation. In TALSIM, this is done in the form of penalty functions. Generally, the higher penalty value, the greater the discrepancy between the state and the ideal.

4.3 Evaluation with the model TALSIM

The model works with an ideal state space which is bounded by the specification of penalty functions. To this end, all the system states have to at first be selected which best characterise the performance of the water management system. These are generally the storages and usages of the reservoirs of the system as well as the runoff states of critical river reaches. In principle, there is no restriction considering the choice of the system states.

For each chosen system state, a penalty function has to be defined that contains both the range of value below and above the desired ideal conditions. In order to keep this as general as possible, the use of several parameters is required. If the parameters are assigned, operation plans can be changed, simulations can be run, and the results of the penalty functions can be compared with each other.

For each penalty function, the following parameters have to be defined:

A. <u>Lower boundary of the ideal state</u>

1. Smallest value that is still considered ideal → minimal target value; the value can vary in time
2. Dimensionless weighing factor
3. Shape of the penalty function for values below the minimal target value
4. Exponent of the penalty function
5. Normalised deviation

B. <u>Upper boundary of the ideal state</u>

1. Highest value that is still considered ideal → maximal target value; the value can vary in time
2. Dimensionless weighting factor

3. Shape of the penalty function for values below the minimal target value
4. Exponent of the penalty function
5. Normalised deviation

The points 3, 4 and 5 require an explanation:

Shape and exponent of the penalty function:

Investigations on several dams showed that the shape of a penalty function has a clear influence on the evaluation of an operation plan. The quadratic deviations from a target value proved to be particularly successful for meeting the standard releases during flood events. However, a feature of quadratic functions is that they accept many small deviations from the target value in order to avoid a few great deviations. This behaviour can generally be classified as suitable, but it implies that the safety in the form of a time period to meet a water supply is not as high as possible. Composite (S-shaped) functions, on the other hand, also return penalty points in the case of small discrepancies. In terms of high securities of duration, S-shaped functions produce better results.

Normalised deviation:

A normalised deviation ensures the comparability between the different penalty functions. It describes the deviation from a target value at which the penalty function reaches the value 1. Thereby, a uniform scheme of evaluation is created that can be also used to compare system states with different units. This means that the same standardized deviations lead to an adjustment of the penalties with different penalty functions. Through weighting, additional priorities can be set. Generally, a penalty function can be represented by the following Figure- a state should neither fall below nor exceed certain target values.

By defining weighting factors, single system states can be classified as superior.

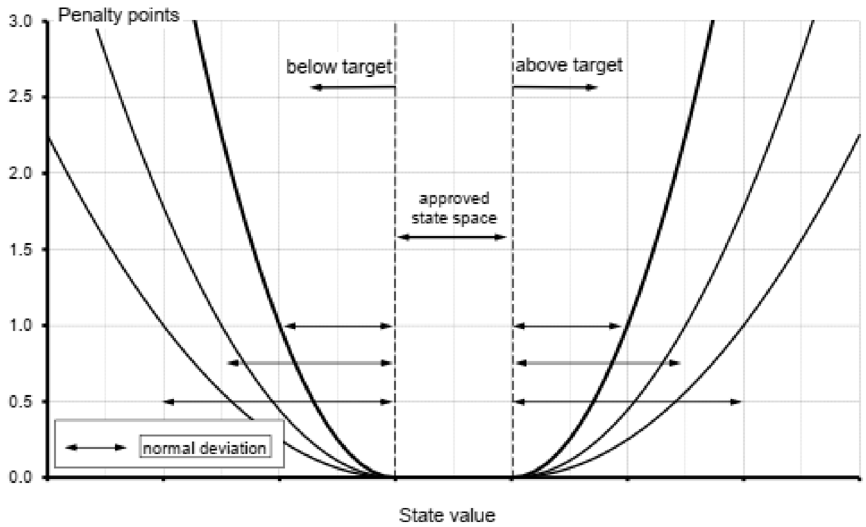


Figure 50: Example of quadratic penalty functions with different standard deviations

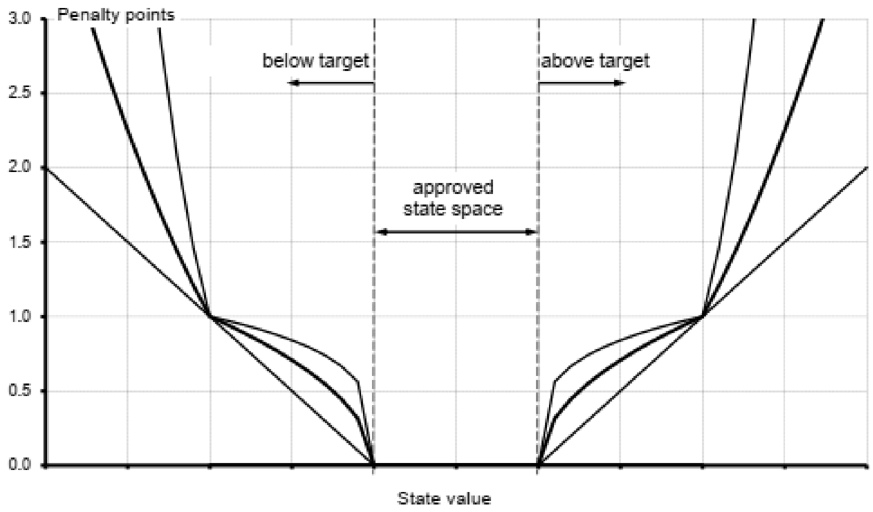


Figure 51: Example of composed penalty functions with different exponents

5 TYPES OF SIMULATIONS

In TALSIM, two types of simulations are distinguished:

a) Simulations with time series

b) Special simulations -> short term simulations (with designed storms)

In the first case, the stress on the water management system is read in as time series. On the other case, for the special simulations, the stress is defined in the shape of designed storms or flood hydrographs.

5.1 Simulation with time series

This type of simulation is suitable to run simulations over any chosen time horizon. The time series needs to exist in the proper TALSIM time series management. The stress can be given either in the form of precipitation or inflow or both. It is essential that precipitation time series are only assigned to sub-catchment elements and inflow only to the discharge elements.

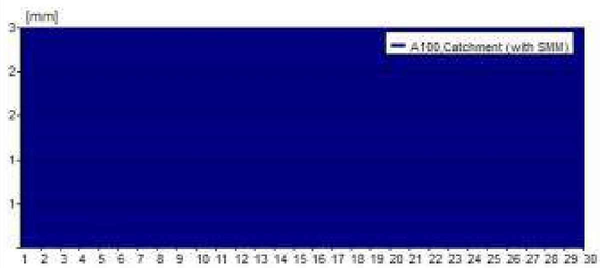
A restriction regarding the simulation time period is only given by the time period in which the data in the connected time series is available.

The time period is only limited by the available data of the time series to which it is associated.

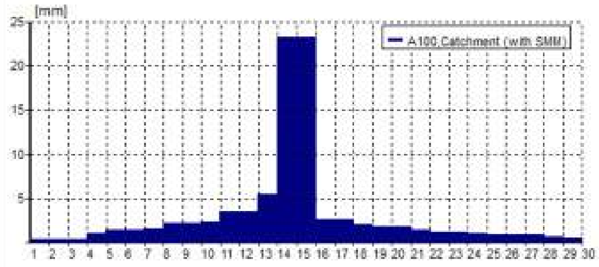
5.2 Special simulations -> Short-term simulation

A short term simulation offers the possibility to assess the system behaviour during stress with a designed storm, one or more flood hydrographs, or a combination of both. The specification of a design storm often serves for dimensioning.

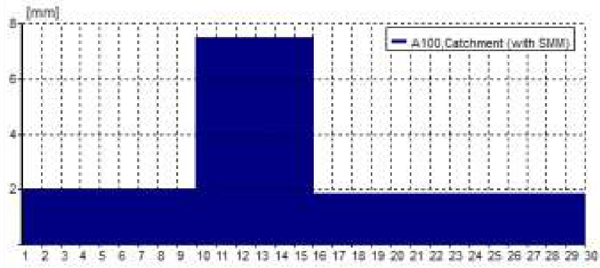
The following designed storms can be selected in TALSIM:

Uniform designed storm	

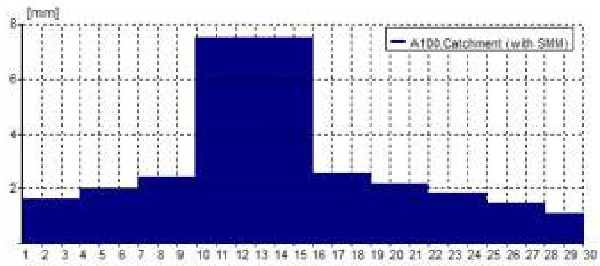
Mallet (Max: centre)



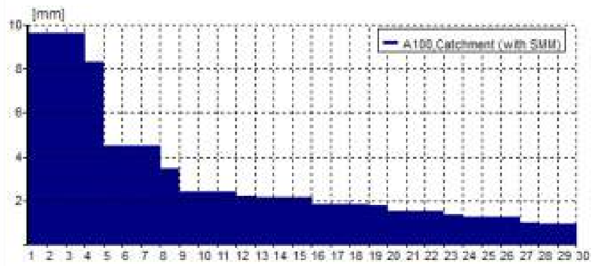
German Water Assocation definition

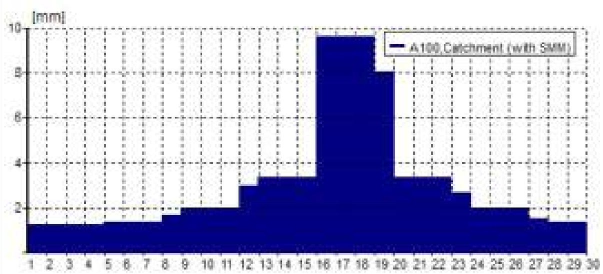
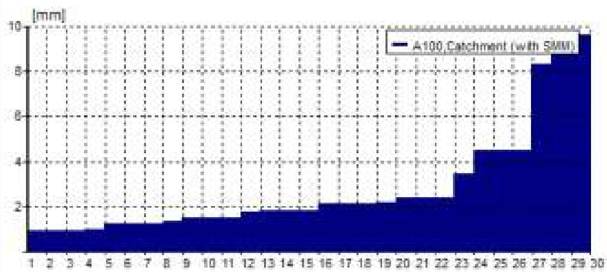
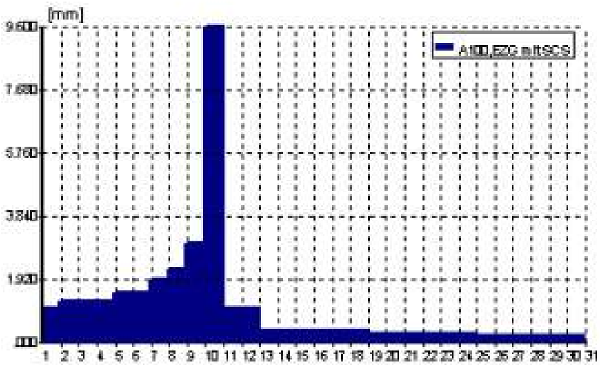


DVWK (smoothed)



Pecher 1
(Max: onset of storm)



Pecher 2 (Max: centre of storm)	
Pecher 3 (Max: end of storm)	
Euler - Type 2	

The central specifications for the short-term simulations in relation to precipitation are the precipitation depth [mm] as well as the duration [min].

For the designed storm Euler – Type 2, the precipitation depth [mm] for durations of 5 min to 4320 min have to be specified.

Furthermore, for each sub-catchment, the start of the precipitation event can be shifted. The temperature and potential evaporation can also be specified separately on a sub-catchment basis. As default values, 10°C and no evaporation are set.

There is also the possibility to scale the precipitation for each sub-catchment in order to represent different precipitation amounts within the system that has a uniform distribution of the intensity.

Specifications of the inflow relate to the assignment of flood hydrographs from the flood administration to the discharge elements.

Here a scaling of the peak flow and of the time to peak are possible both globally for all the discharge elements as well as separately for each element. For each element, further parameters such as the start of the flood wave and the base flow in [m³/s] have to be specified. As a default, the immediate start of the event and no base flow is set.

For the definition of flood waves one can refer to the several Water Management publications (see Wasserwirtschaft 7/8 2004).

5.3 Active Simulation

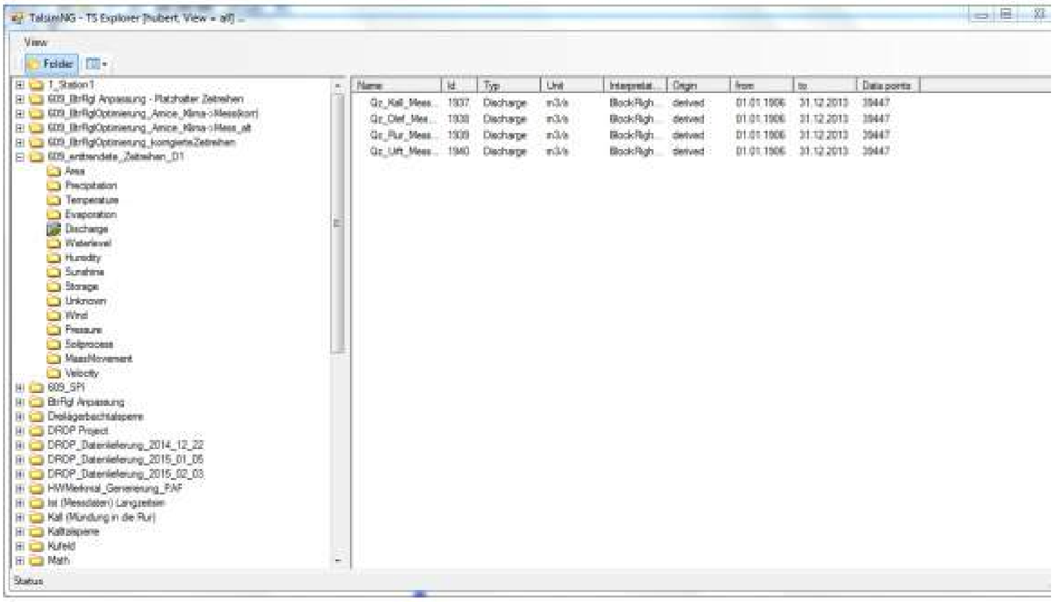
The project administration permits any number of simulations per scenario. To each simulation run and, thus, to each result, exactly one simulation is assigned. This can be seen by the structure of the project administration.

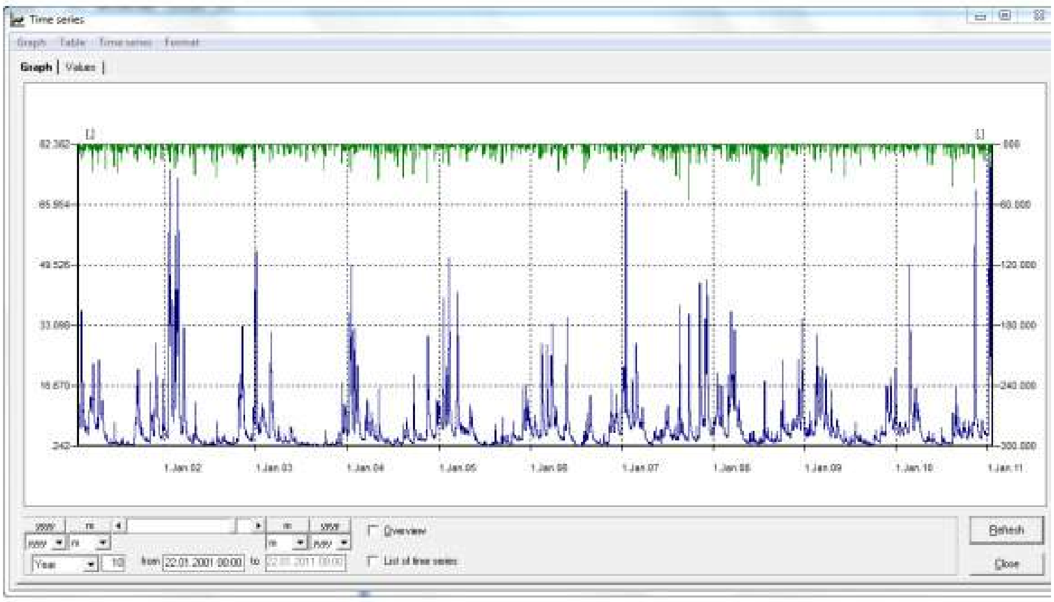
The simulation that is set as "active simulation" is ready for the simulation, i.e. its simulation settings are used when starting the next *simulation with time series* or the next *special simulation*. If the simulation start or the number of time steps are modified in the settings for the special simulation, these settings are taken for the simulation and the old settings are overwritten. This is the reason why it is recommended to create a separate simulation for each special simulation.

Note: If a simulation is run and the results are saved, this is done with the current settings of the elements. The consequence of a subsequent modification of characteristic values or parameters of the elements is that these adjusted settings no longer match the results. Here, great care and attention is required as well as a thorough documentation of the modifications.

6 TIME SERIES MANAGER

The time-series manager is the interface of TALSIM to stresses that are given in the form of time series. Generally, there are stations that time series can be assigned to according to their type (area, precipitation, temperature, evaporation, discharge, water level, humidity, sun intensity, storage, unknown, wind, pressure, soil process, mass movement, velocity).





Each time series can be statistically processed, displayed or exported. The time series manager can be used in the client-server environment of Taslim-NG.

Before the program can work with time series values, they need to be imported into the manager. The following formats are available for import:

- WEL-Format (Results from TALSIM)
- ZRE-Format (SYDRO Format)
- UVF-Format
- ZRX-Format (WISKI, Fa. Kisters)
- AQZ-Format (Aquacoup, Fa. Aquaplan)

The ZRE is a simple line-based format which requires date (14 character) a blank and a value. Details about the time series manager are given in the basic and advanced training documents.

6.1 Interpretation of time series

An essential piece of information about the stored time series values is given by the attribute interpretation, i.e. how the time stamp and its corresponding values should be read.

In total, there are five different types of interpretation which are depicted in the following graphic:

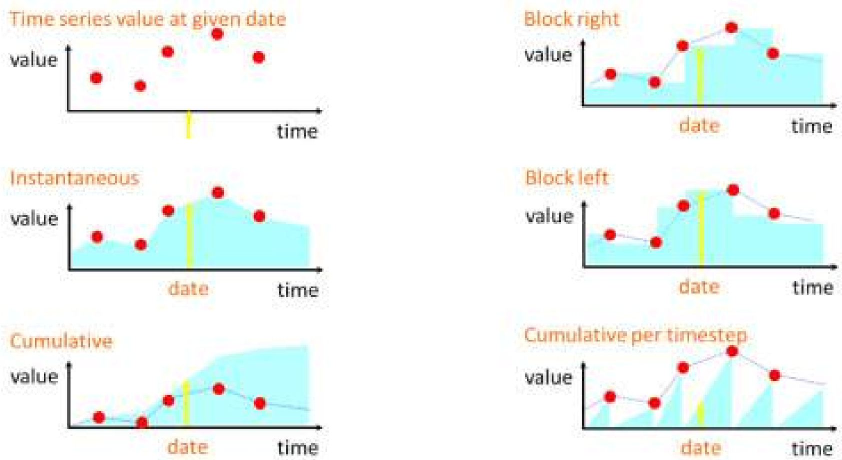


Figure 52: Interpretation of time series

If the interpretation is not set correctly, this will lead to erroneous results. Precipitation [mm] is normally given as cumulative values per time step. Discharge data at a gauge depends on the method by which it was recorded and is usually an average over a period of time.


TALSIM
Basic Course
TALSIM
Generic model for water resources management, reservoir operation and rainfall-runoff modelling
developed by
SYDRO CONSULT
Consulting Engineers: Hydrosystems, Water Resources Management and Hydro-Informatics
&
TECHNISCHE UNIVERSITAT DARMSTADT
Institute for Engineering Hydrology and Water Management
On behalf of the Environmental Agency NRW
SYDRO
Systemhydrologie, Wasserwirtschaft, Informationssysteme


TALSIM
Basic Course
TALSIM – Basic Course
Content – Day 1
1. Introduction to the program
2. Basic concepts of reservoir operations
3. System setup in TALSIM
4. Long-term simulation and presentation of results
Content – Day 2
1. RR-Modelling with TALSIM
2. System states and short-term storm simulations
3. Interface: Import/Export
4. Summary and additional questions

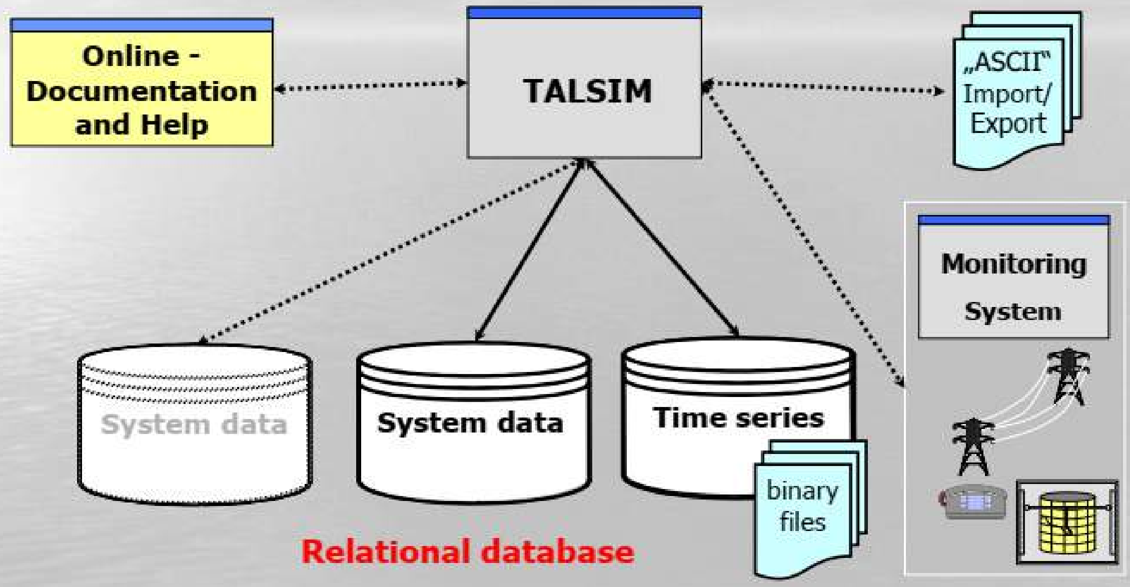
TALSIM Basic Course

Introduction and Basic Concepts- Theory

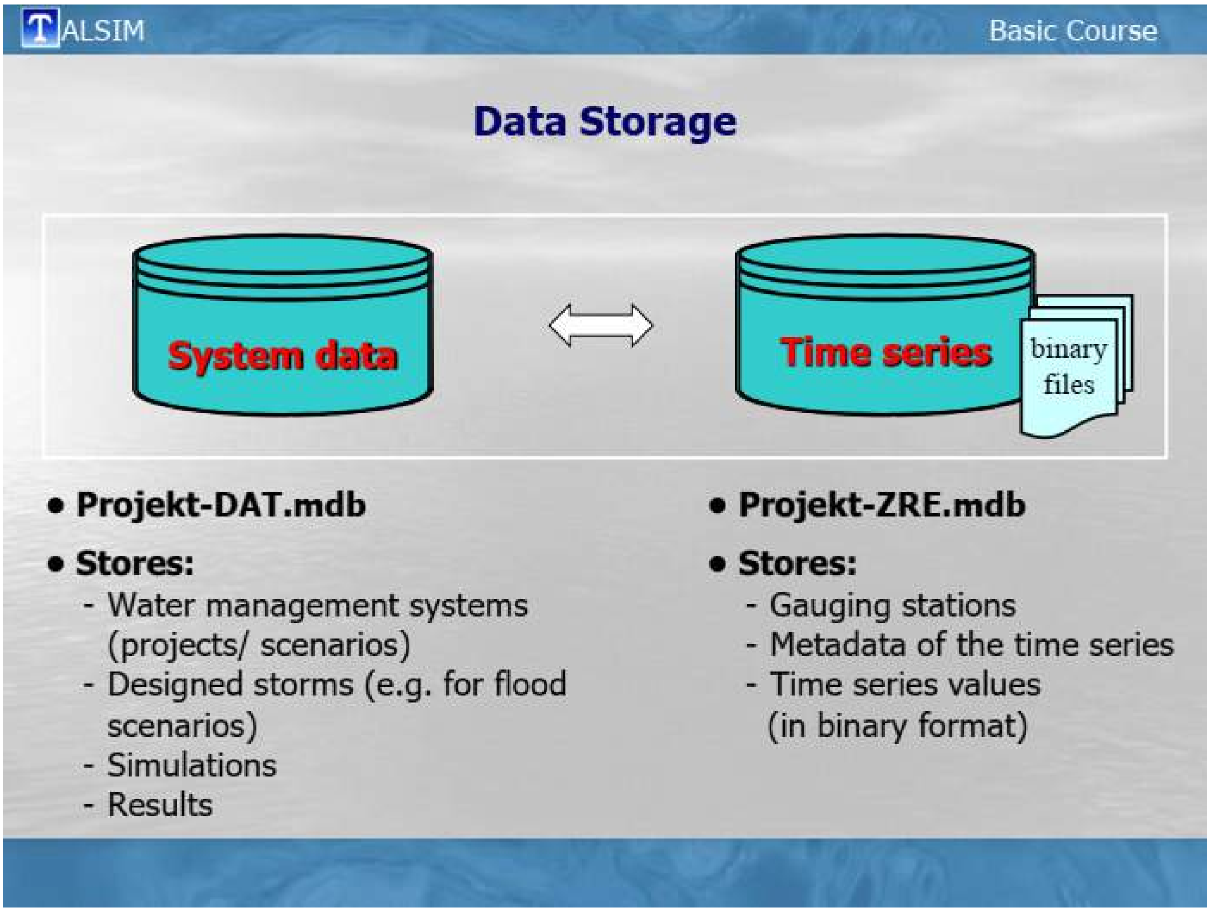
- **Program structure and data management**
- **Setup of a river basin management system**
- **Hydrological model components**
- **Definition of system states**
- **Fundamentals of time series management**

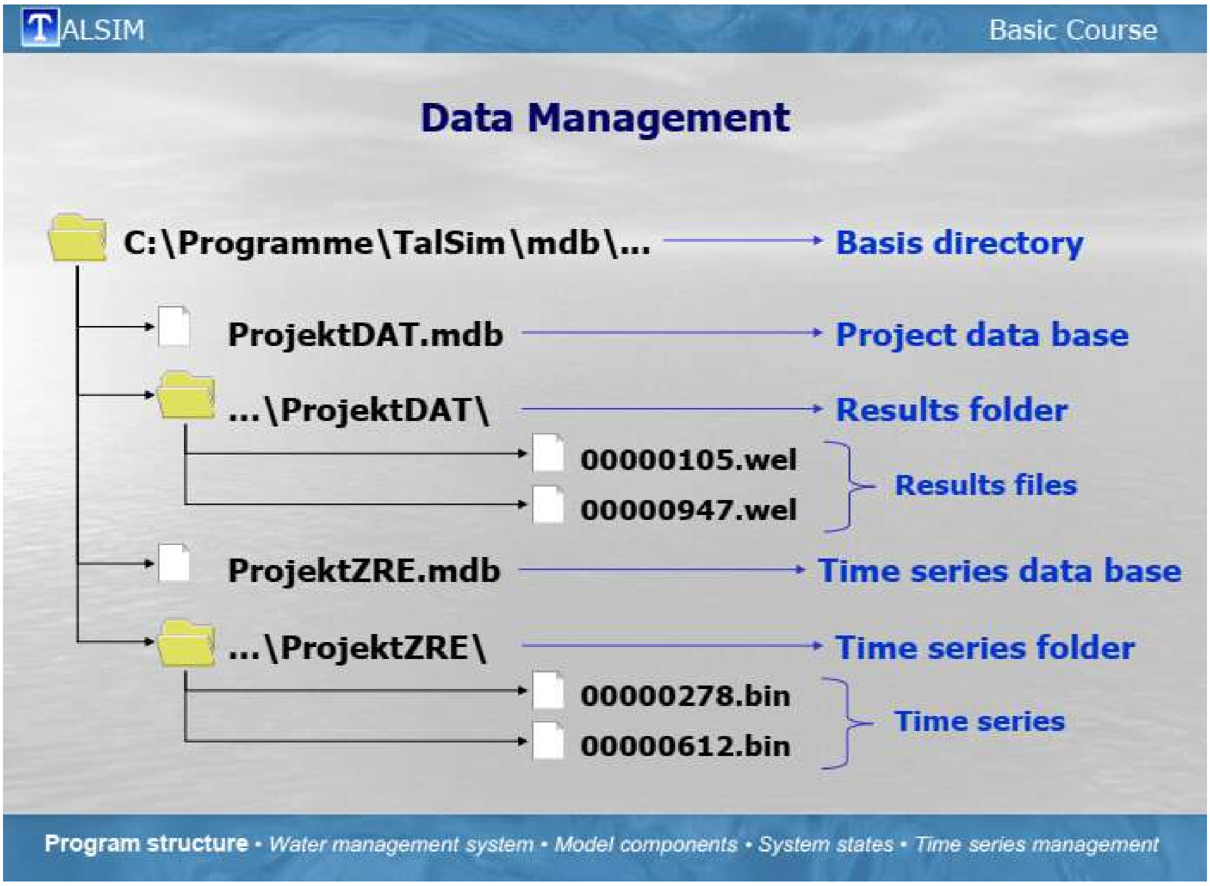
TALSIM Basic Course

Program Structure



Program structure • *Water management system • Model components• System states • Time series management*


TALSIM
Basic Course
Data Storage
System data
Time series
binary files
• Projekt-DAT.mdb
• Stores:
- Water management systems (projects/ scenarios)
- Designed storms (e.g. for flood scenarios)
- Simulations
- Results
• Projekt-ZRE.mdb
• Stores:
- Gauging stations
- Metadata of the time series
- Time series values (in binary format)


TALSIM
Basic Course
Data Management
C:\Programme\TalSim\mdb\...
Basis directory
ProjektDAT.mdb
Project data base
...\ProjektDAT\
Results folder
00000105.wel
00000947.wel
Results files
ProjektZRE.mdb
Time series data base
...\ProjektZRE\
Time series folder
00000278.bin
00000612.bin
Time series
Program structure • Water management system • Model components • System states • Time series management

TALSIM Basic Course

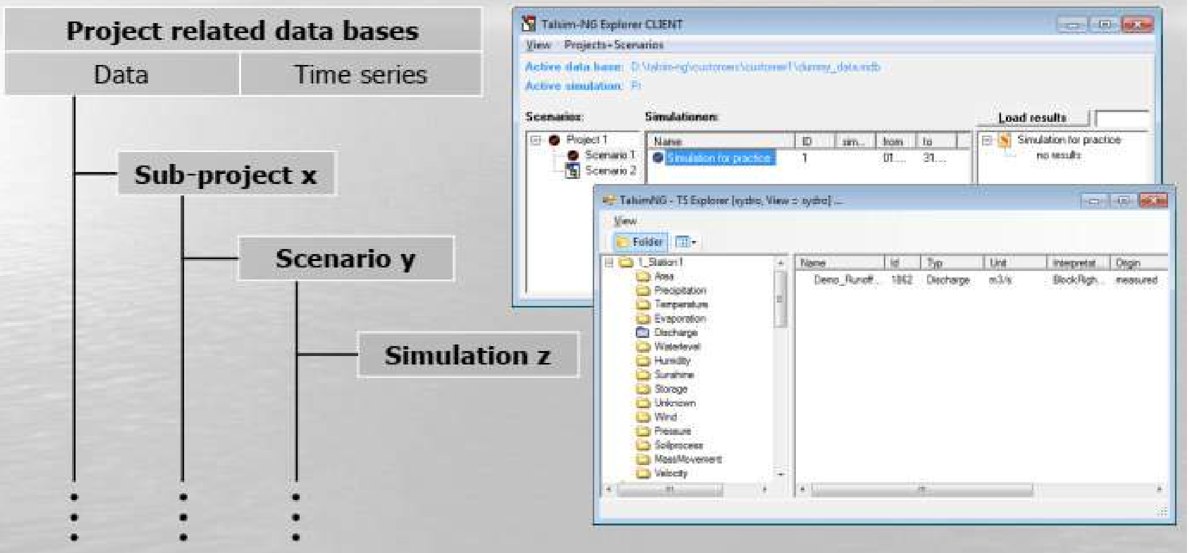
Data Management - Tip

1. **For each project create new databases:**
   - **Copy and rename the demonstration files from the standard directory (*TalsimDat.mdb, WelleZre.mdb*)**
   - **Use the project name and the corresponding abbreviations *Dat* or *Wel*, respectively, to distinguish the type of database**
2. **Create directories with the same names as the databases for results and time series**
3. **Delete superfluous sub-projects and scenarios**

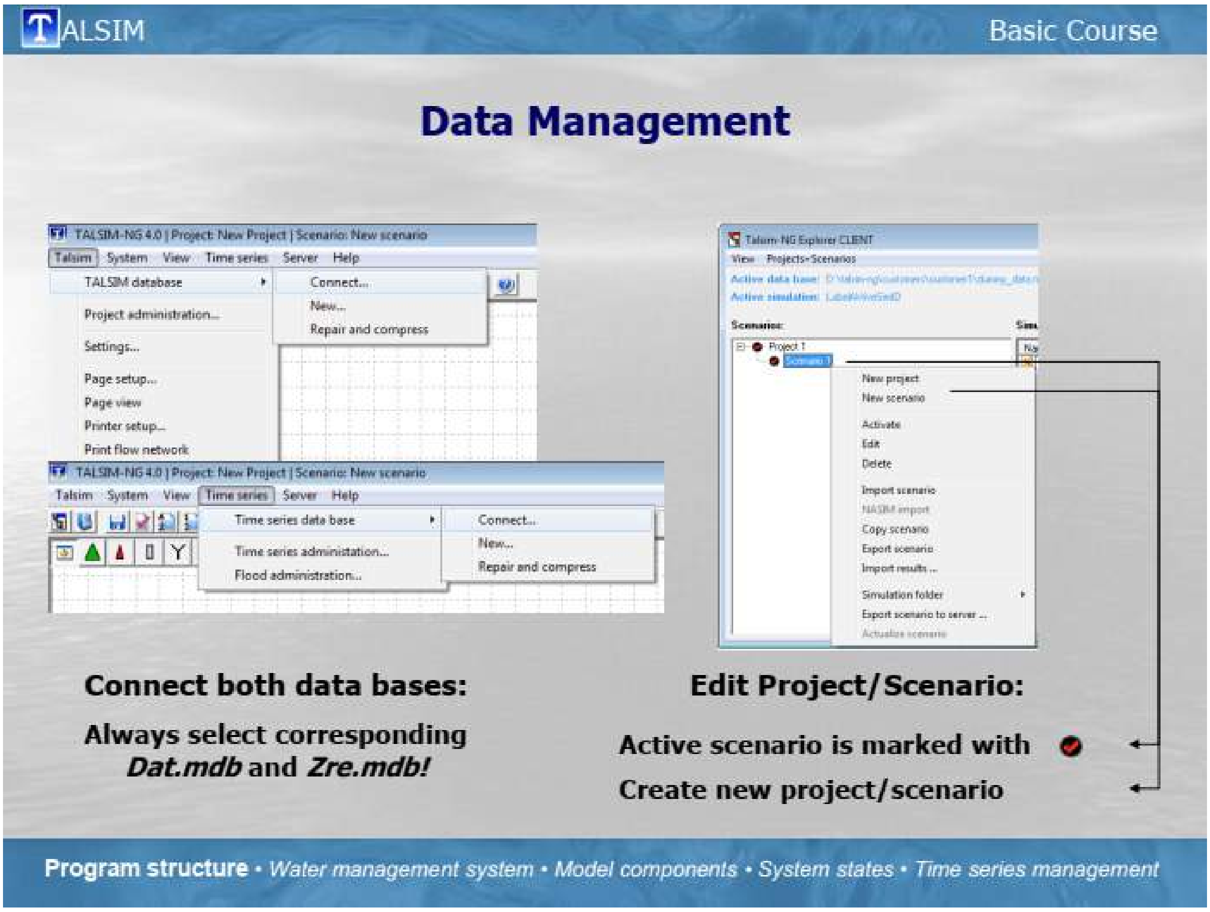
Program structure • *Water management system • Model components • System states • Time series management*

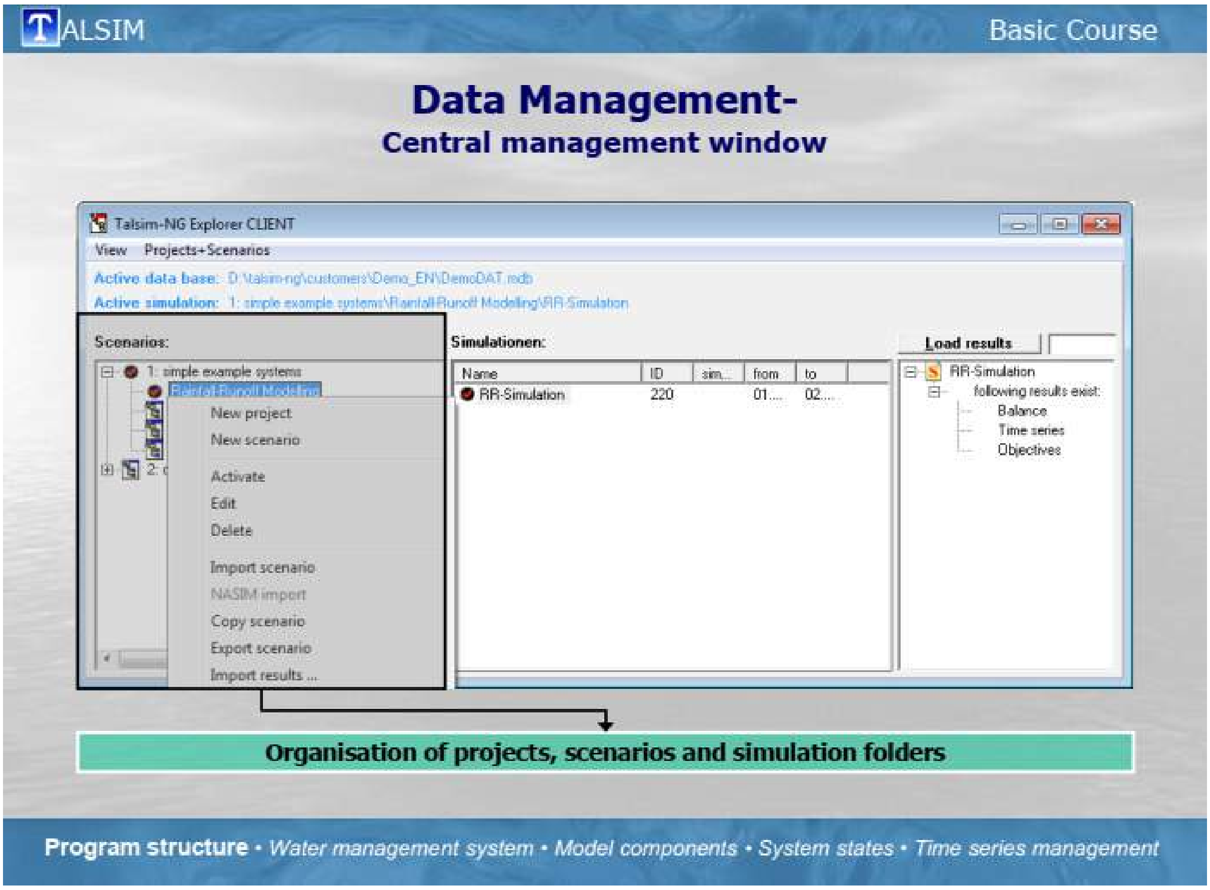
TALSIM Basic Course

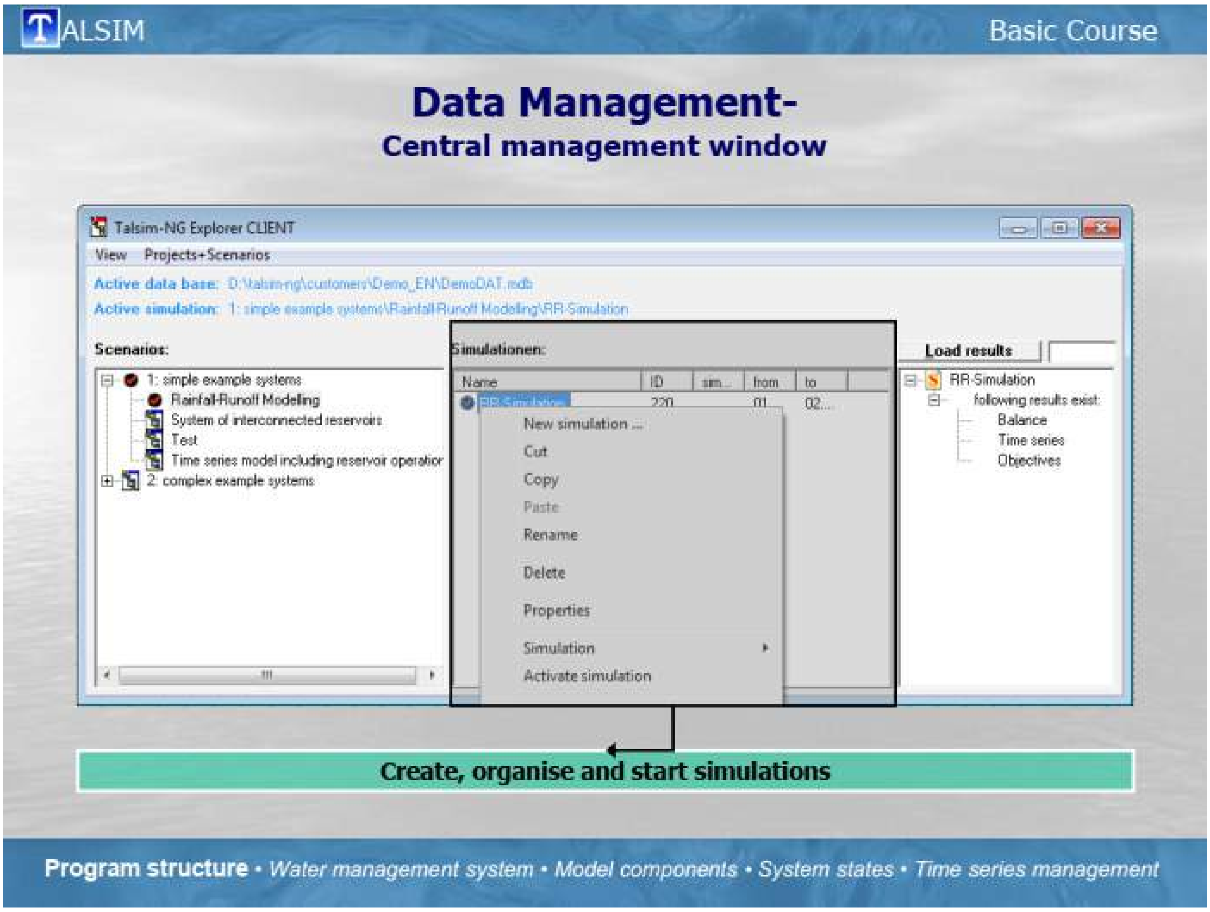
Project Organisation

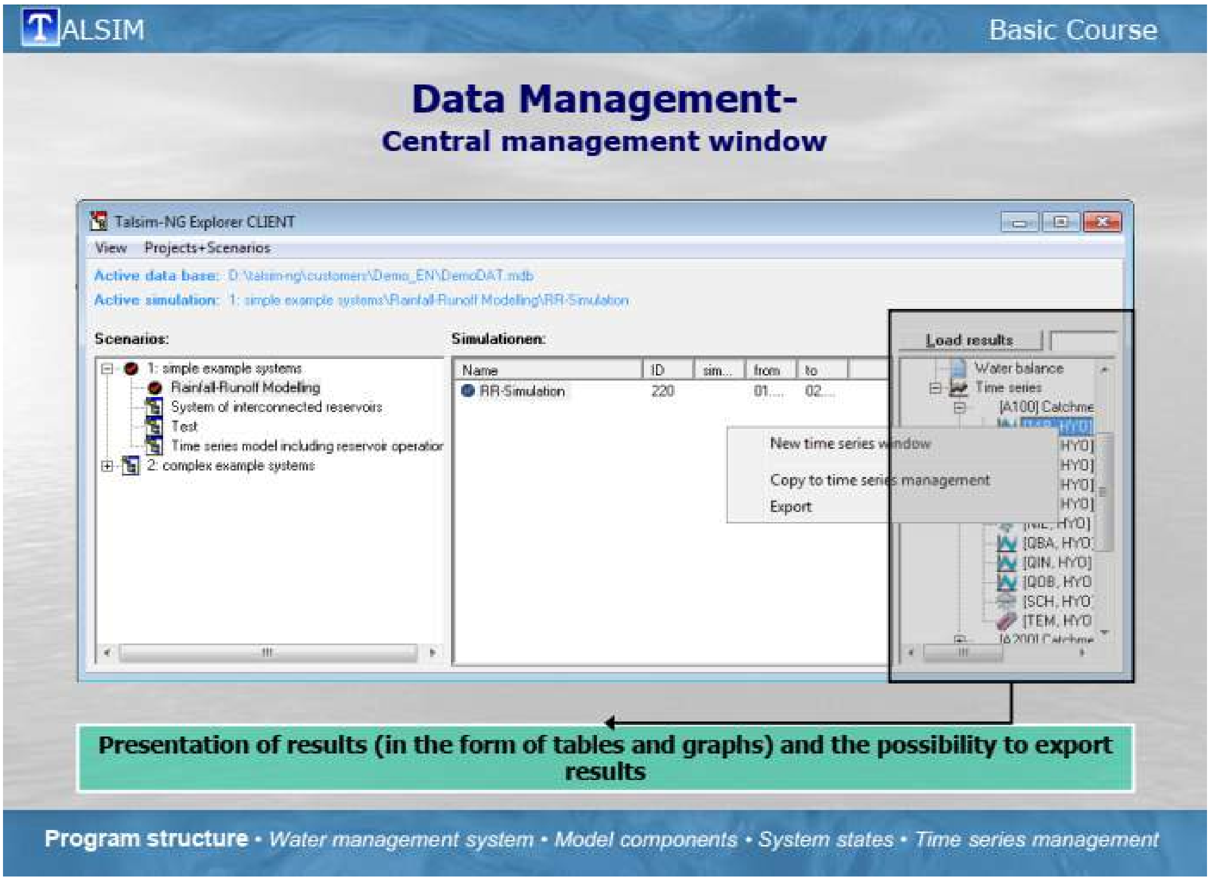


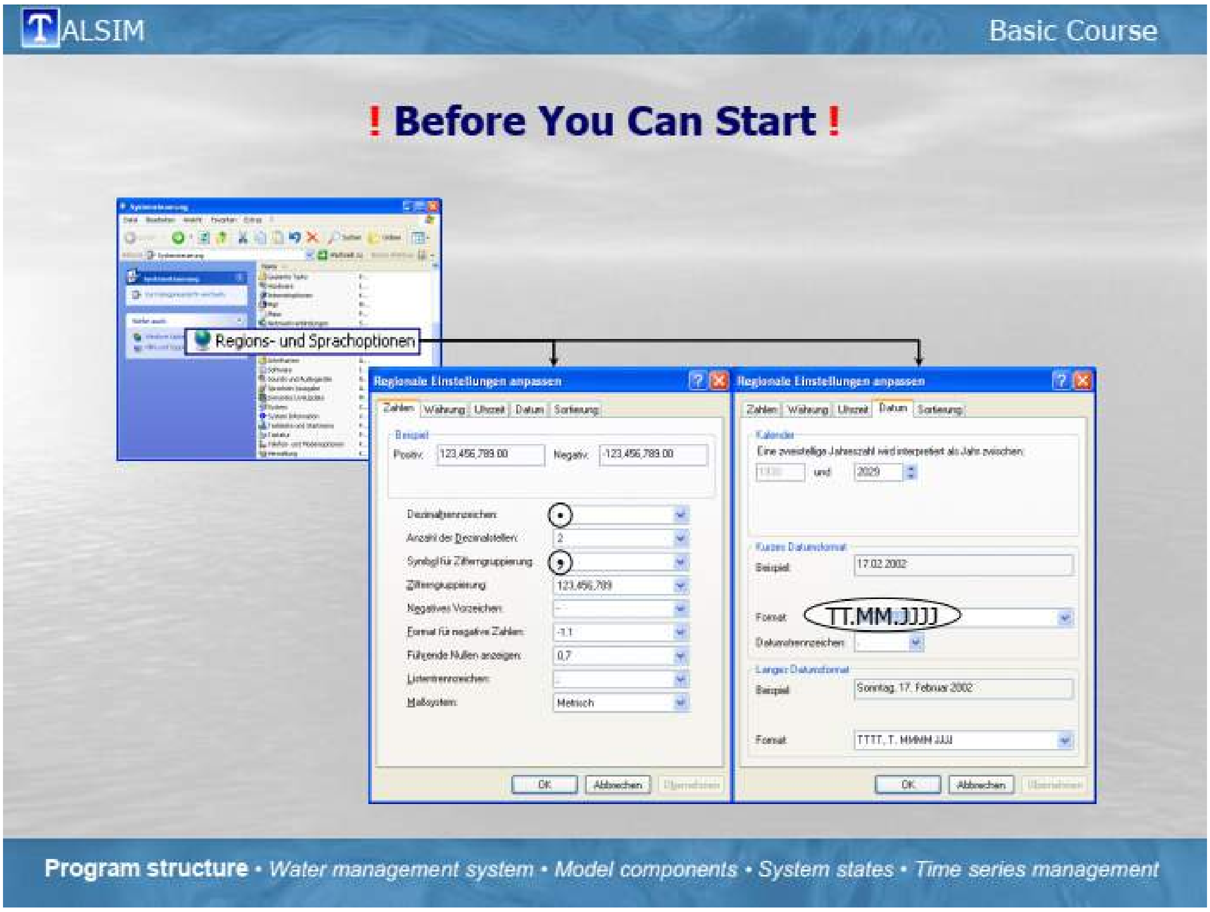
Program structure • *Water management system • Model components • System states • Time series management*

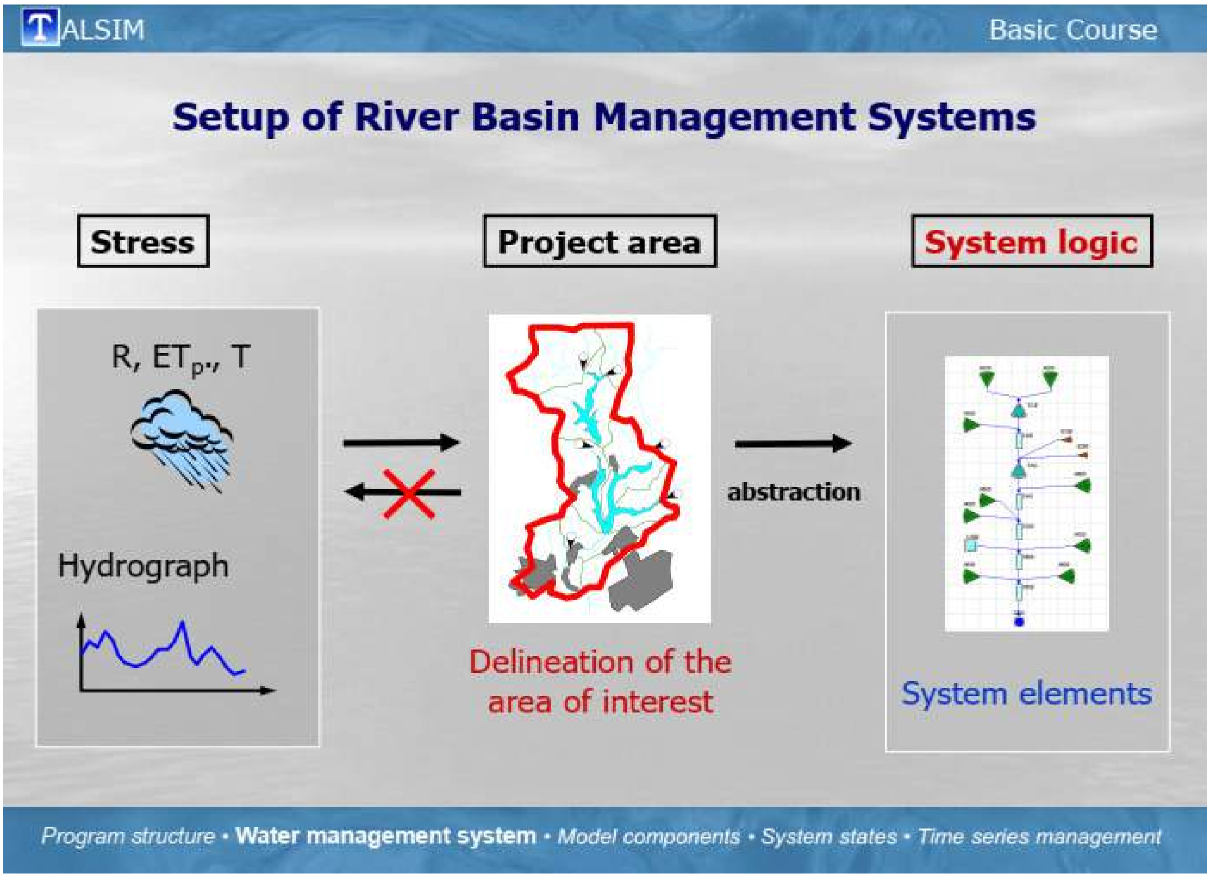

TALSIM
Basic Course
Data Management
TALSIM-NG 4.0 | Project: New Project | Scenario: New scenario
Talsim System View Time series Server Help
TALSIM database
Connect...
New...
Repair and compress
Project administration...
Settings...
Page setup...
Page view
Printer setup...
Print flow network
Time series data base
Time series administration...
Flood administration...
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Scenarios:
Project 1
New project
New scenario
Activate
Edit
Delete
Import scenario
NASIM import
Copy scenario
Export scenario
Import results ...
Simulation folder
Export scenario to server ...
Connect both data bases:
Always select corresponding
Dat.mdb and Zre.mdb!
Edit Project/Scenario:
Active scenario is marked with
Create new project/scenario
Program structure • Water management system • Model components • System states • Time series management


TALSIM
Basic Course
Data Management-
Central management window
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Active data base: D:\talsim-ng\customers\Demo_EN\DemoDAT.mdb
Active simulation: 1: simple example systems\Rainfall-Runoff Modelling\RR-Simulation
Scenarios:
1: simple example systems
Rainfall-Runoff Modelling
New project
New scenario
Activate
Edit
Delete
Import scenario
NASIM import
Copy scenario
Export scenario
Import results ...
Simulationen:
Name
ID
sim...
from
to
RR-Simulation
220
01....
02....
Load results
RR-Simulation
following results exist:
Balance
Time series
Objectives
Organisation of projects, scenarios and simulation folders
Program structure • Water management system • Model components • System states • Time series management


TALSIM
Basic Course
Data Management-
Central management window
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Active data base: D:\talsim-ng\customers\Demo_EN\DemoDAT.mdb
Active simulation: 1: simple example systems\Rainfall-Runoff Modelling\RR-Simulation
Scenarios:
1: simple example systems
Rainfall-Runoff Modelling
System of interconnected reservoirs
Test
Time series model including reservoir operation
2: complex example systems
Simulationen:
Name
ID
from
to
New simulation ...
Cut
Copy
Paste
Rename
Delete
Properties
Simulation
Activate simulation
Load results
RR-Simulation
following results exist:
Balance
Time series
Objectives
Create, organise and start simulations
Program structure • Water management system • Model components • System states • Time series management


TALSIM
Basic Course
Data Management-
Central management window
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Active data base: D:\talsim-ng\customers\Demo_EN\DemoDAT.mdb
Active simulation: 1: simple example systems\Rainfall-Runoff Modelling\RR-Simulation
Scenarios:
1: simple example systems
Rainfall-Runoff Modelling
System of interconnected reservoirs
Test
Time series model including reservoir operation
2: complex example systems
Simulationen:
Name
ID
from
to
RR-Simulation
220
Load results
Water balance
Time series
New time series window
Copy to time series management
Export
Presentation of results (in the form of tables and graphs) and the possibility to export results
Program structure • Water management system • Model components • System states • Time series management


TALSIM
Basic Course
! Before You Can Start !
Regions- und Sprachoptionen
Regionale Einstellungen anpassen
Regionale Einstellungen anpassen
TT.MM.JJJJ
Program structure • Water management system • Model components • System states • Time series management

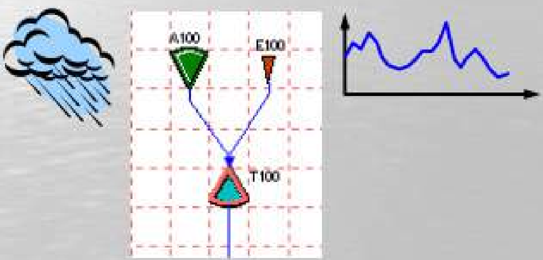

TALSIM
Basic Course
Setup of River Basin Management Systems
Stress
Project area
System logic
R, ETp., T
Hydrograph
abstraction
Delineation of the area of interest
System elements
Program structure • Water management system • Model components • System states • Time series management

TALSIM Basic Course

Model Setup-
System elements

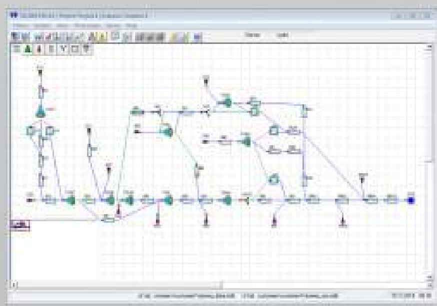
Model input: **Stress**

The **scope of tasks** and the **data available** provide an indication of how to specify the stress.



RR-Modelling ↔ Hydrograph

Model structure: **System logic**



Is composed of **system elements** (hydrological components)
→ **flow network**

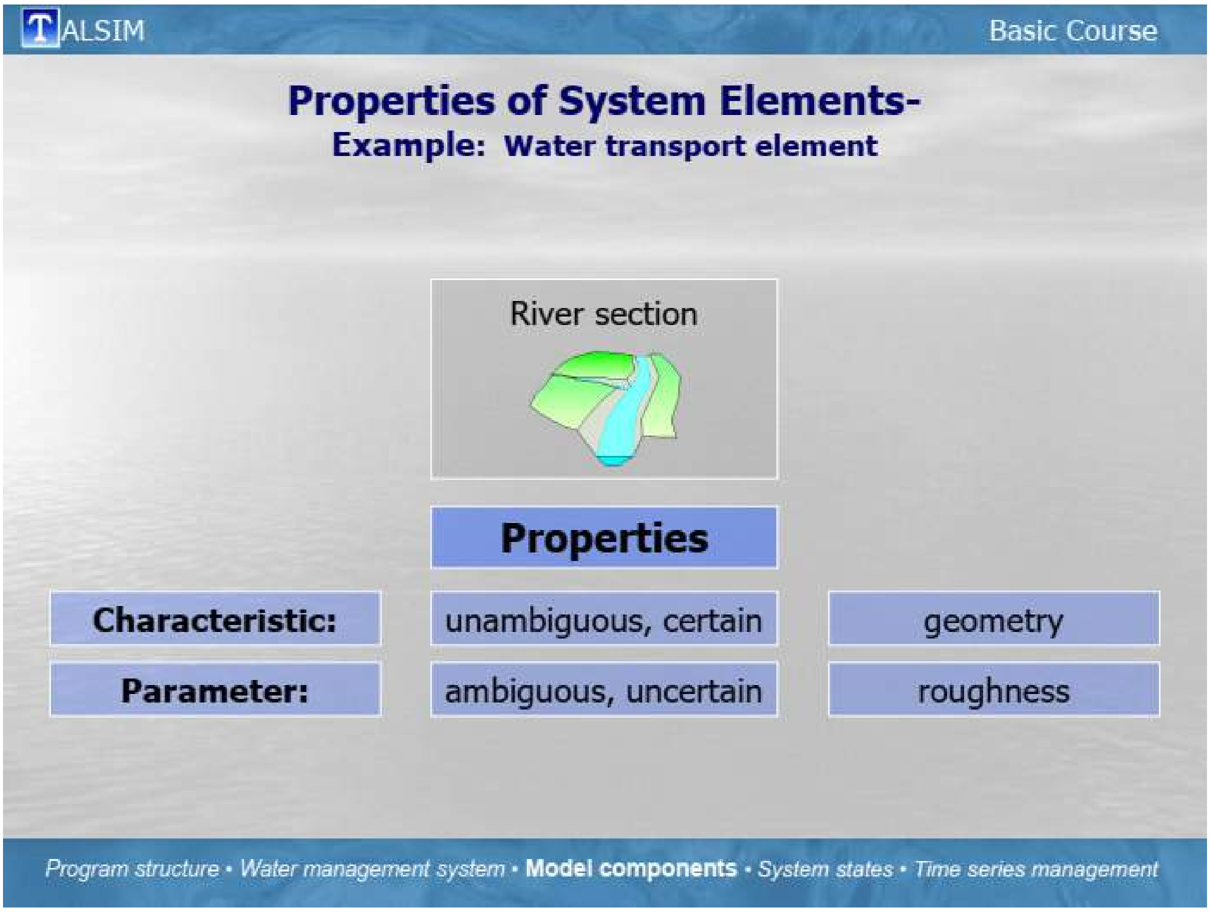
Program structure • **Water management system** • *Model components* • *System states* • *Time series management*

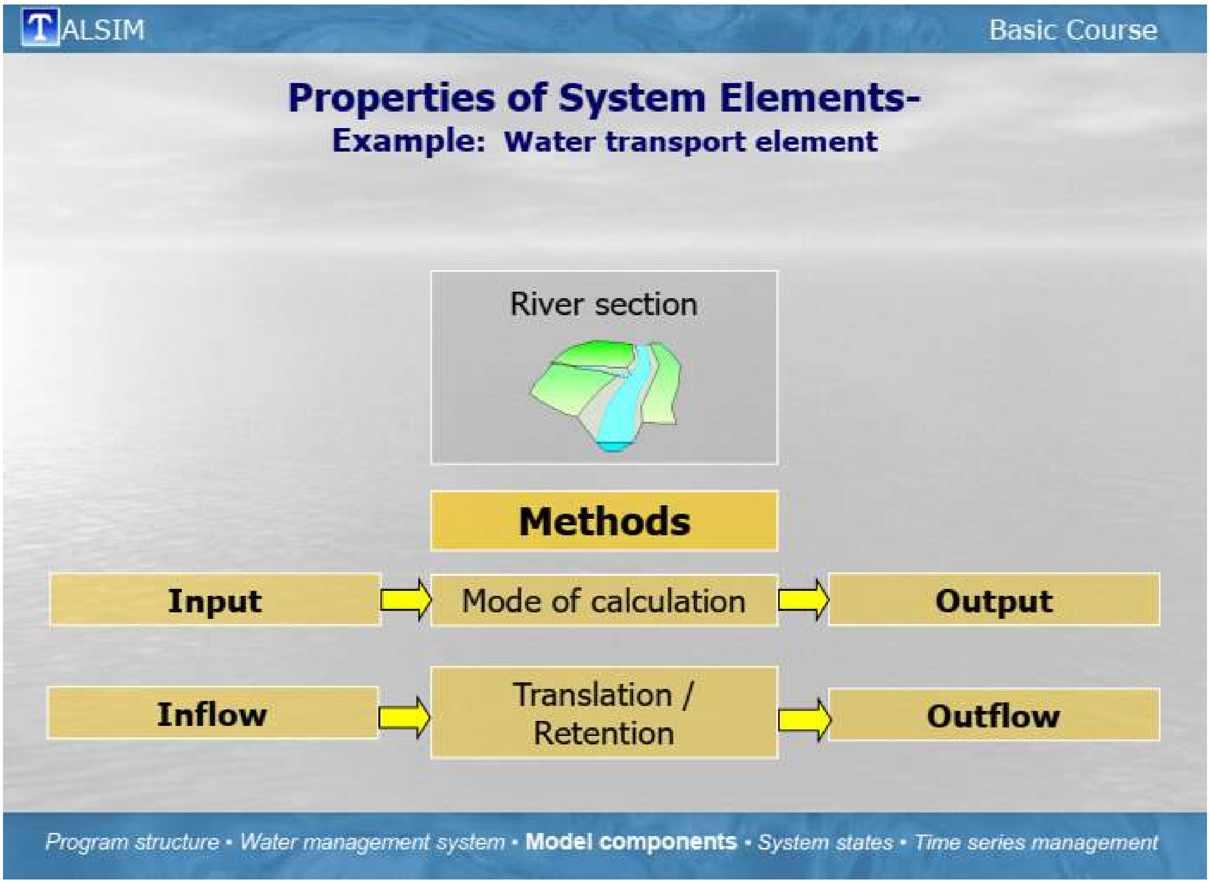
TALSIM Basic Course

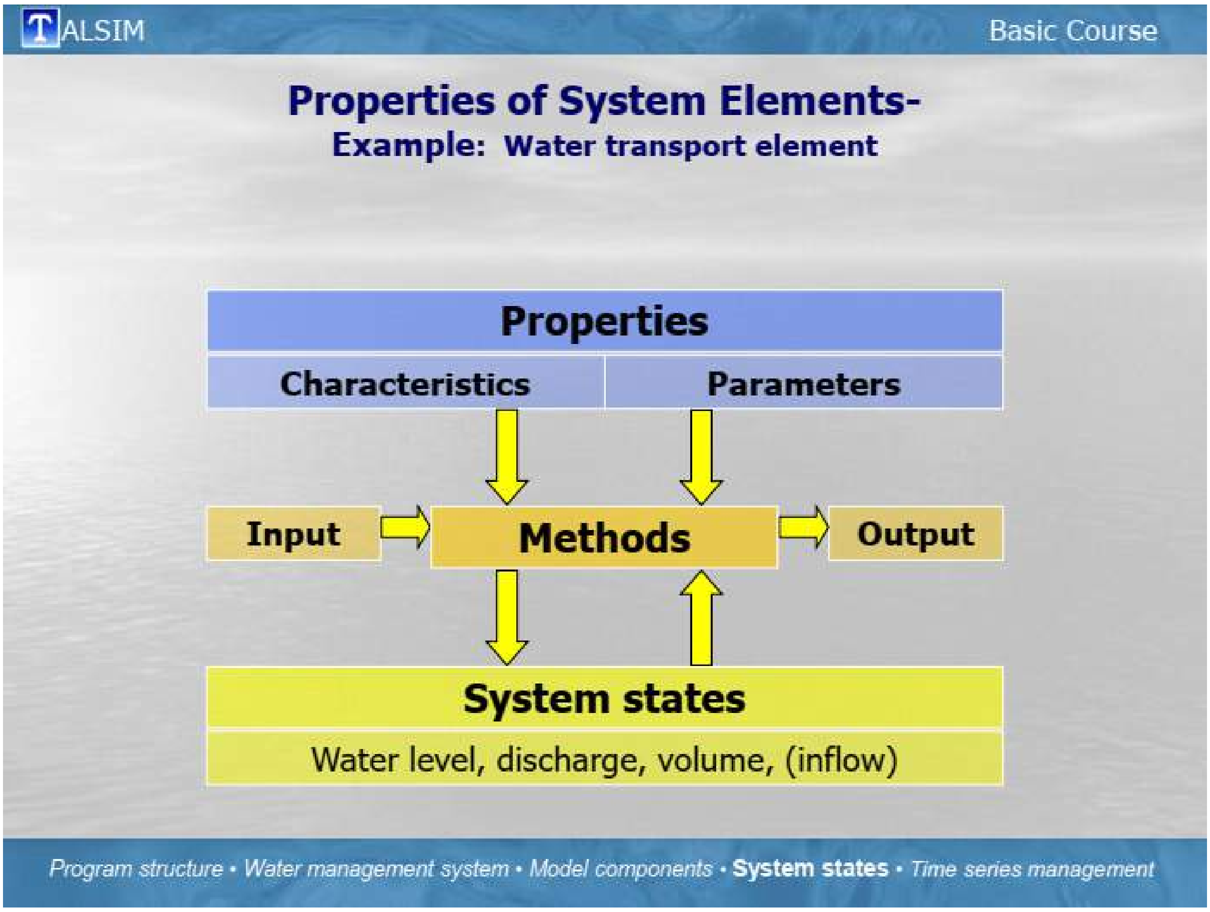
Hydrological Components-
System elements

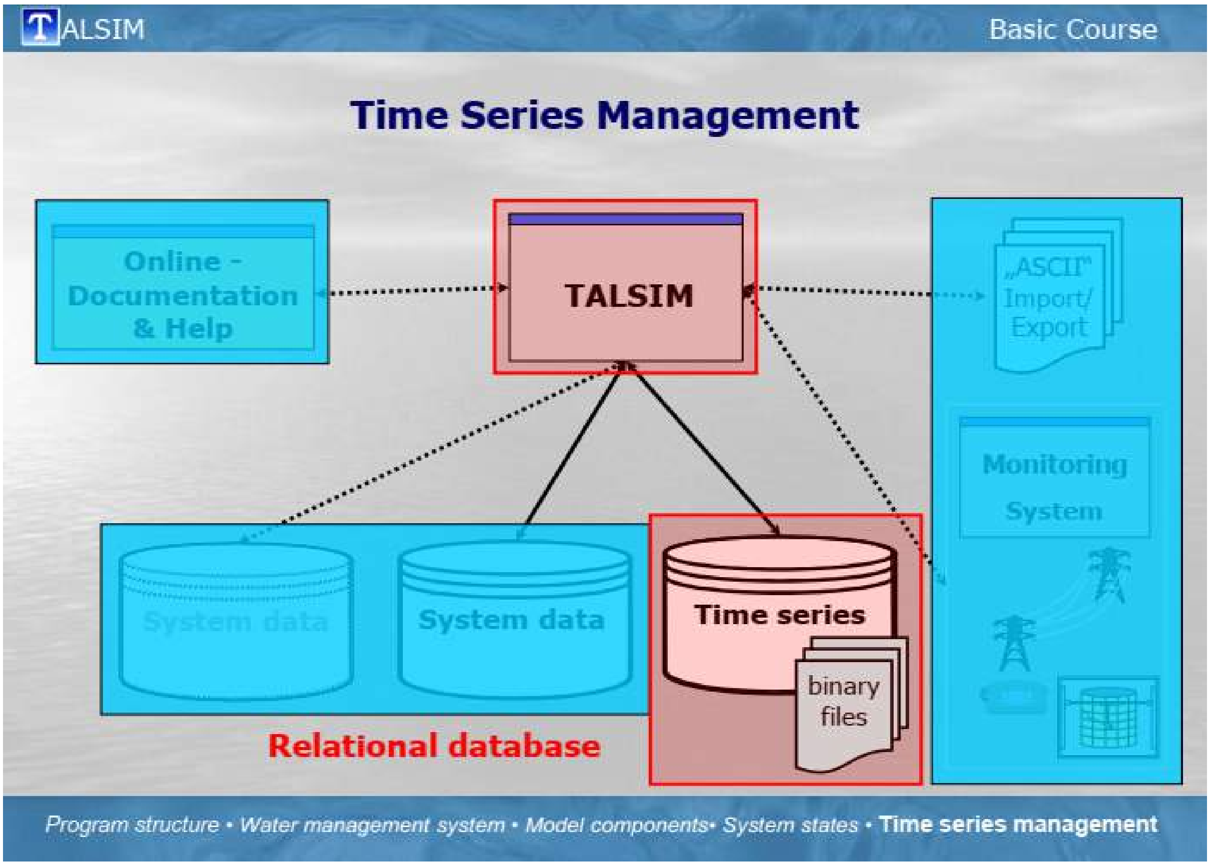
E10	**Discharge element**	→ Connects time series of discharge
A50	**Sub-catchment**	→ Transforms precipitation into runoff (→ RR-Modell)
S10	**Water transport**	→ Computes runoff transport in tubes and open channels
V10	**Diversion**	→ Splits one inflow into two outflows
U50	**Consumer**	→ Computes transport in water works or supply lines (also input)
T70	**Reservoir**	→ Computes releases and withdrawals; Lake retention

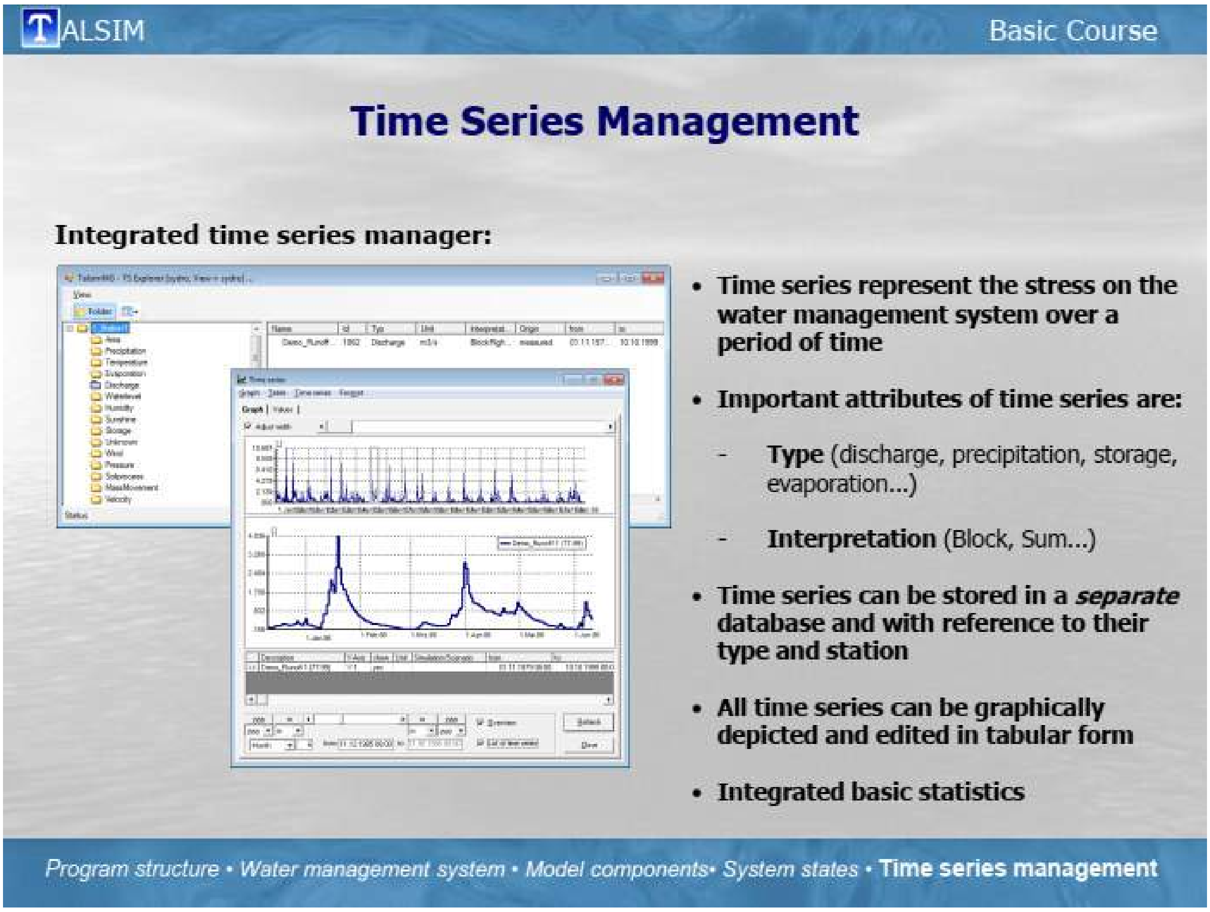
Program structure • **Water management system** • *Model components* • *System states* • *Time series management*

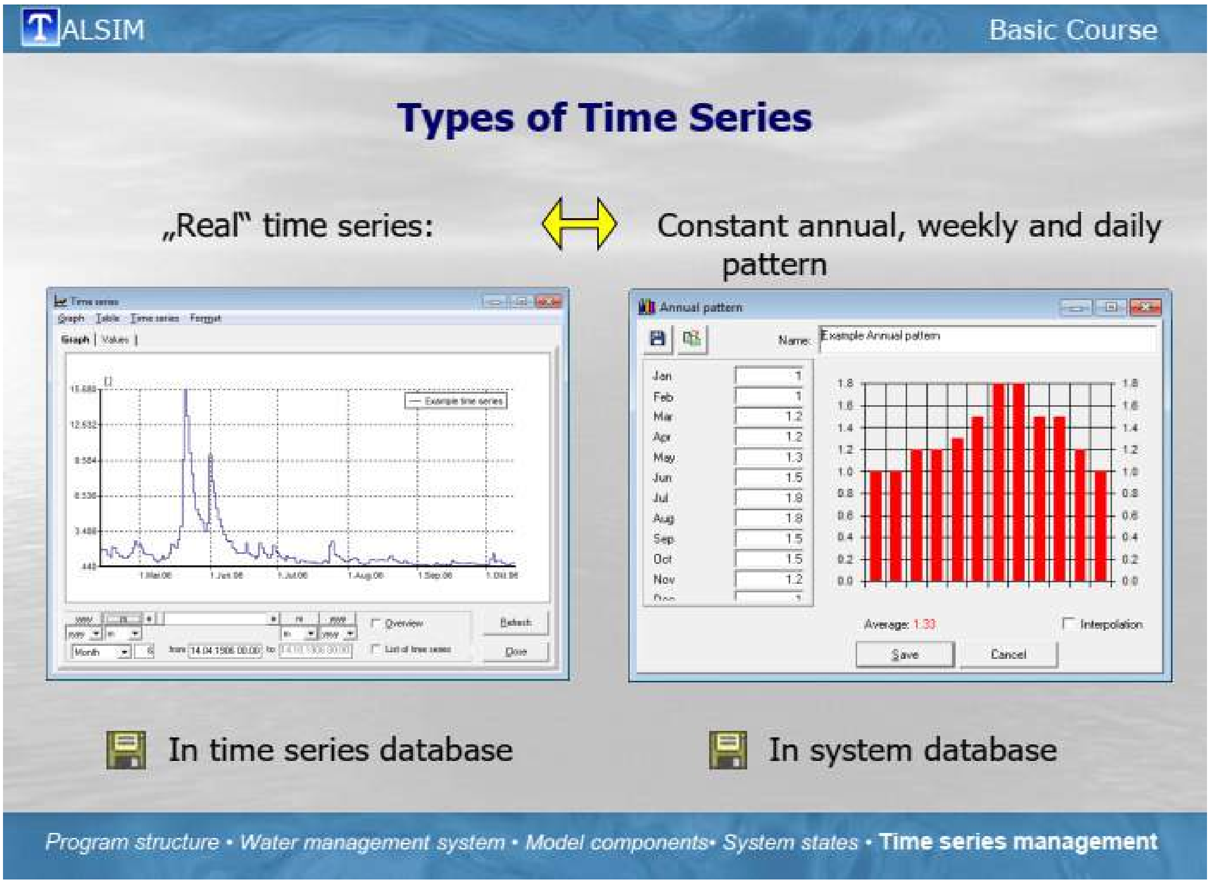

TALSIM
Basic Course
Properties of System Elements-
Example: Water transport element
River section
Properties
Characteristic:
unambiguous, certain
geometry
Parameter:
ambiguous, uncertain
roughness
Program structure • Water management system • Model components • System states • Time series management

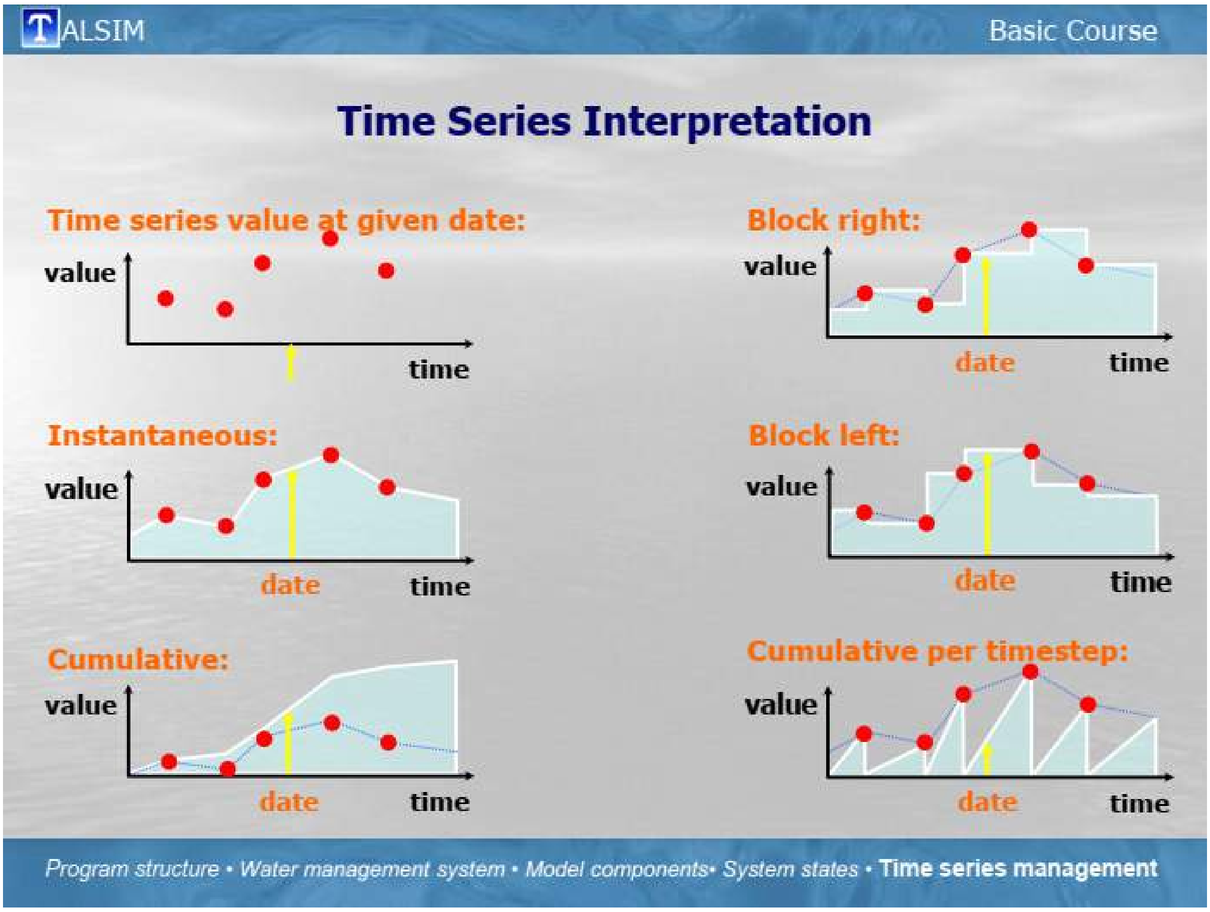

TALSIM
Basic Course
Properties of System Elements-
Example: Water transport element
River section
Methods
Input
Mode of calculation
Output
Inflow
Translation / Retention
Outflow
Program structure • Water management system • Model components • System states • Time series management

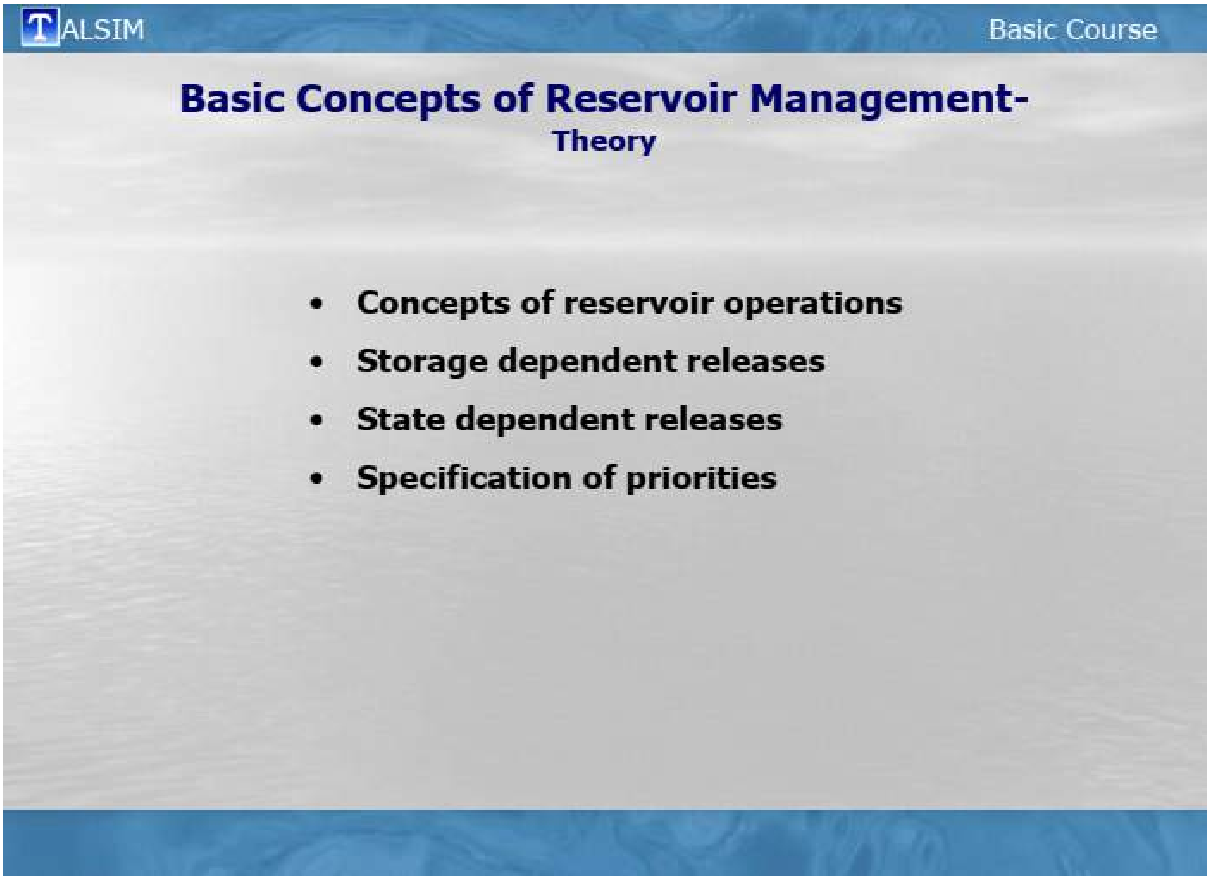

TALSIM
Basic Course
Properties of System Elements-
Example: Water transport element
Properties
Characteristics
Parameters
Input
Methods
Output
System states
Water level, discharge, volume, (inflow)
Program structure • Water management system • Model components • System states • Time series management


TALSIM
Basic Course
Time Series Management
Online - Documentation & Help
TALSIM
„ASCII" Import/ Export
Monitoring System
System data
System data
Time series
binary files
Relational database
Program structure • Water management system • Model components• System states • Time series management


TALSIM
Basic Course
Time Series Management
Integrated time series manager:
• Time series represent the stress on the water management system over a period of time
• Important attributes of time series are:
- Type (discharge, precipitation, storage, evaporation...)
- Interpretation (Block, Sum...)
• Time series can be stored in a separate database and with reference to their type and station
• All time series can be graphically depicted and edited in tabular form
• Integrated basic statistics
Program structure • Water management system • Model components• System states • Time series management


TALSIM
Basic Course
Types of Time Series
„Real" time series:
Constant annual, weekly and daily pattern
Annual pattern
Name: Example Annual pattern
Average: 1.33
Interpolation
Save
Cancel
In time series database
In system database
Program structure • Water management system • Model components• System states • Time series management


TALSIM
Basic Course
Time Series Interpretation
Time series value at given date:
value
time
Block right:
value
date
time
Instantaneous:
value
date
time
Block left:
value
date
time
Cumulative:
value
date
time
Cumulative per timestep:
value
date
time
Program structure • Water management system • Model components• System states • Time series management


TALSIM
Basic Course
Basic Concepts of Reservoir Management-
Theory
• Concepts of reservoir operations
• Storage dependent releases
• State dependent releases
• Specification of priorities

TALSIM Basic Course

Reservoir Operations-
Fundamentals

Operation rules are regulations which define releases depending on system states and the time.

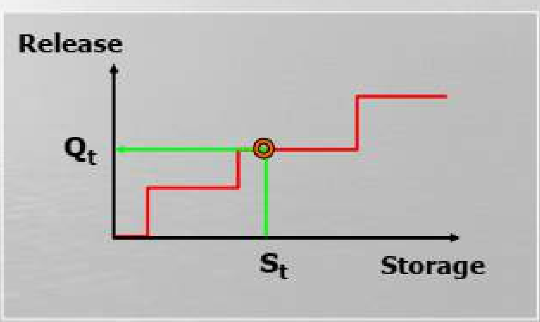
To almost all operation rules, a few basic principles apply:

- Releases *depend on storage*
- Releases can be *influenced by system states* (scaled)
- Several releases of a reservoir can be *interdependent on one another* → prioritisation possibly required
- All releases can *vary with time*

Concepts of reservoir operations • *Storage dependent releases* • *State dependent releases* • *Priorities*

TALSIM Basic Course

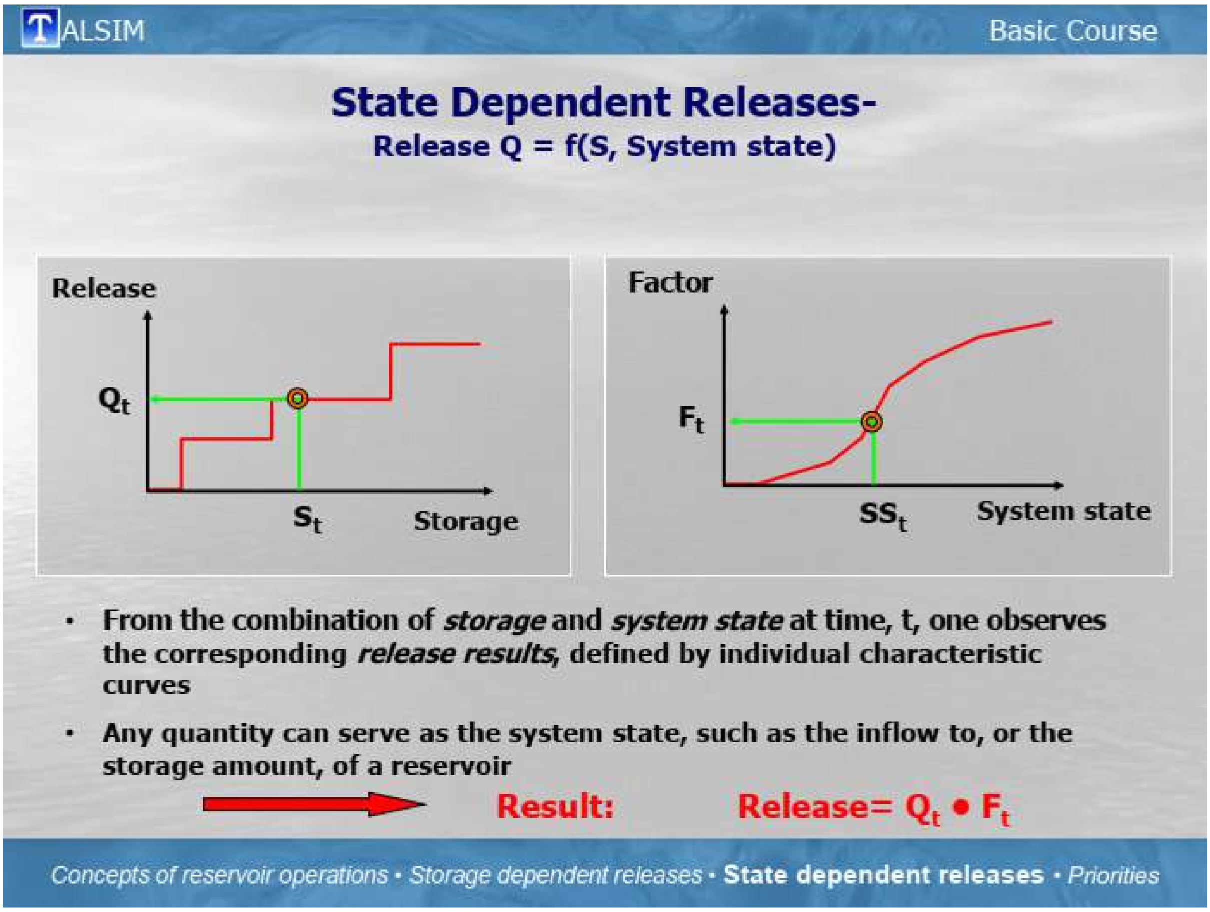
Storage Dependent Releases-
Release Q = f(S)

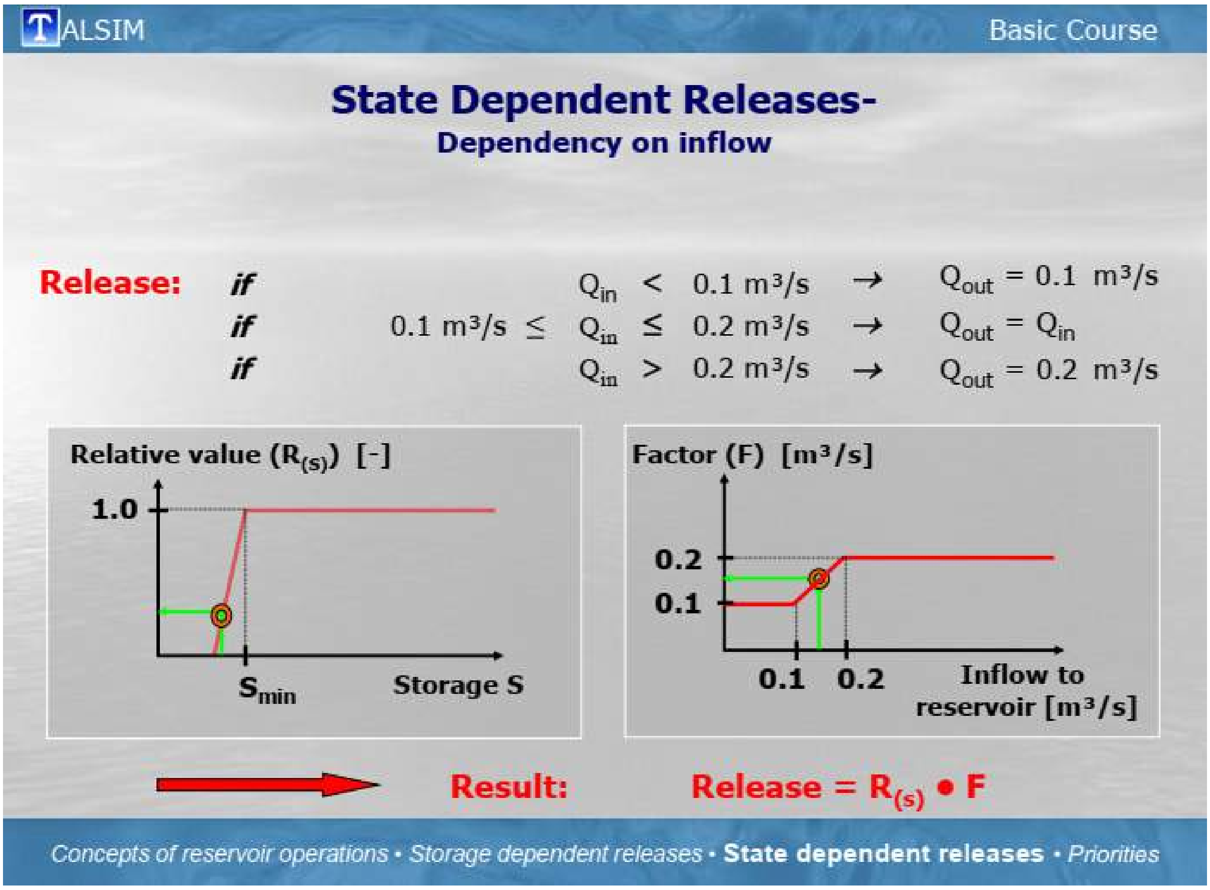


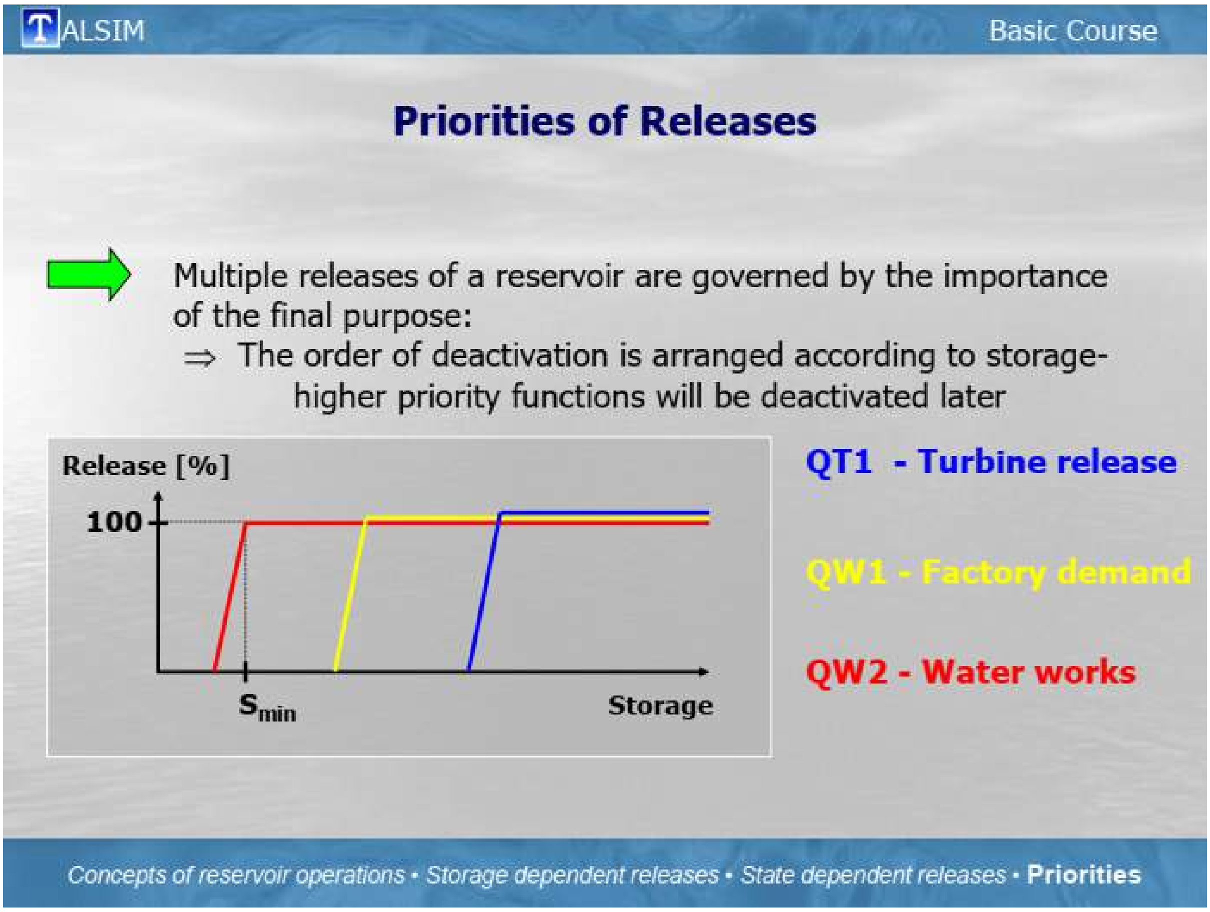
Most operation rules are grounded on this principle:

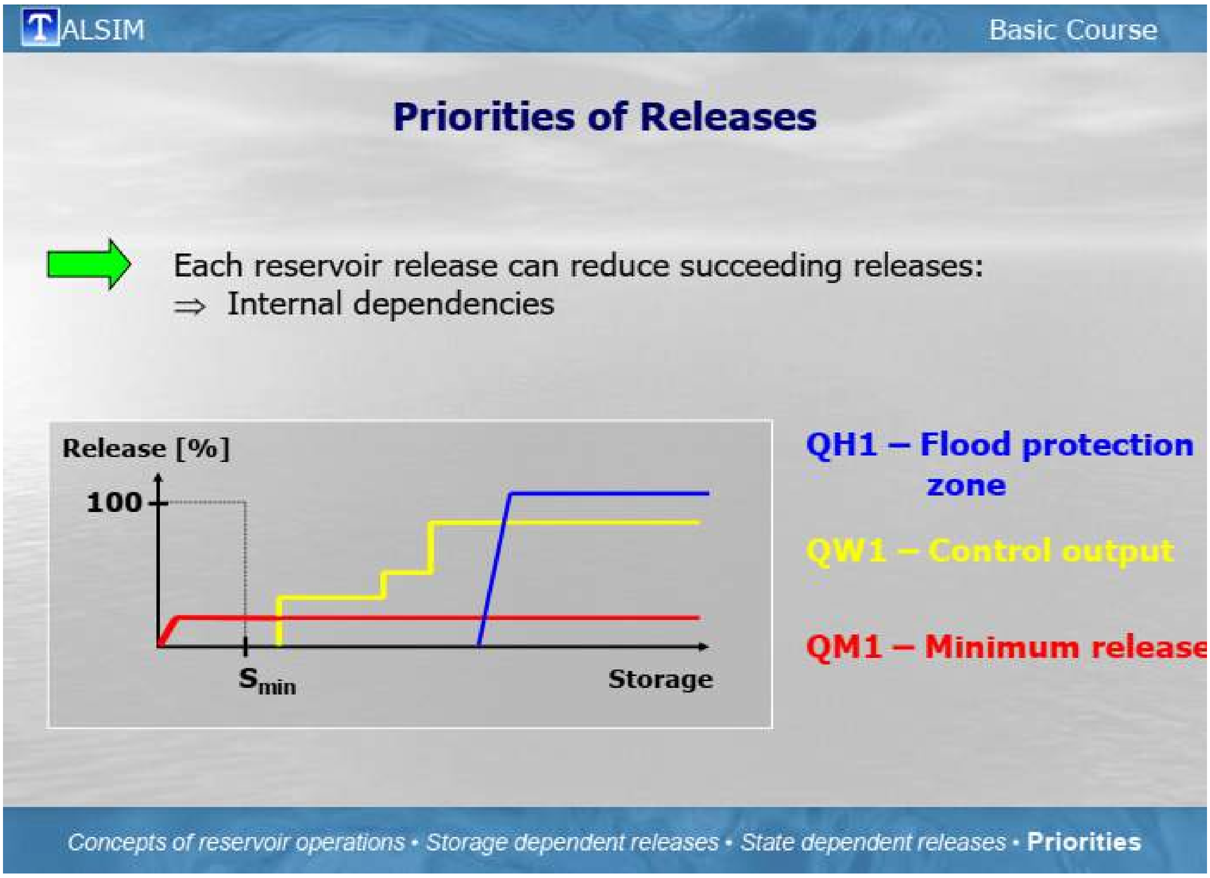
- **Storage-elevation curve**
- **Flood protection storage space**
- **Time dependent zoning plan**
- **...**

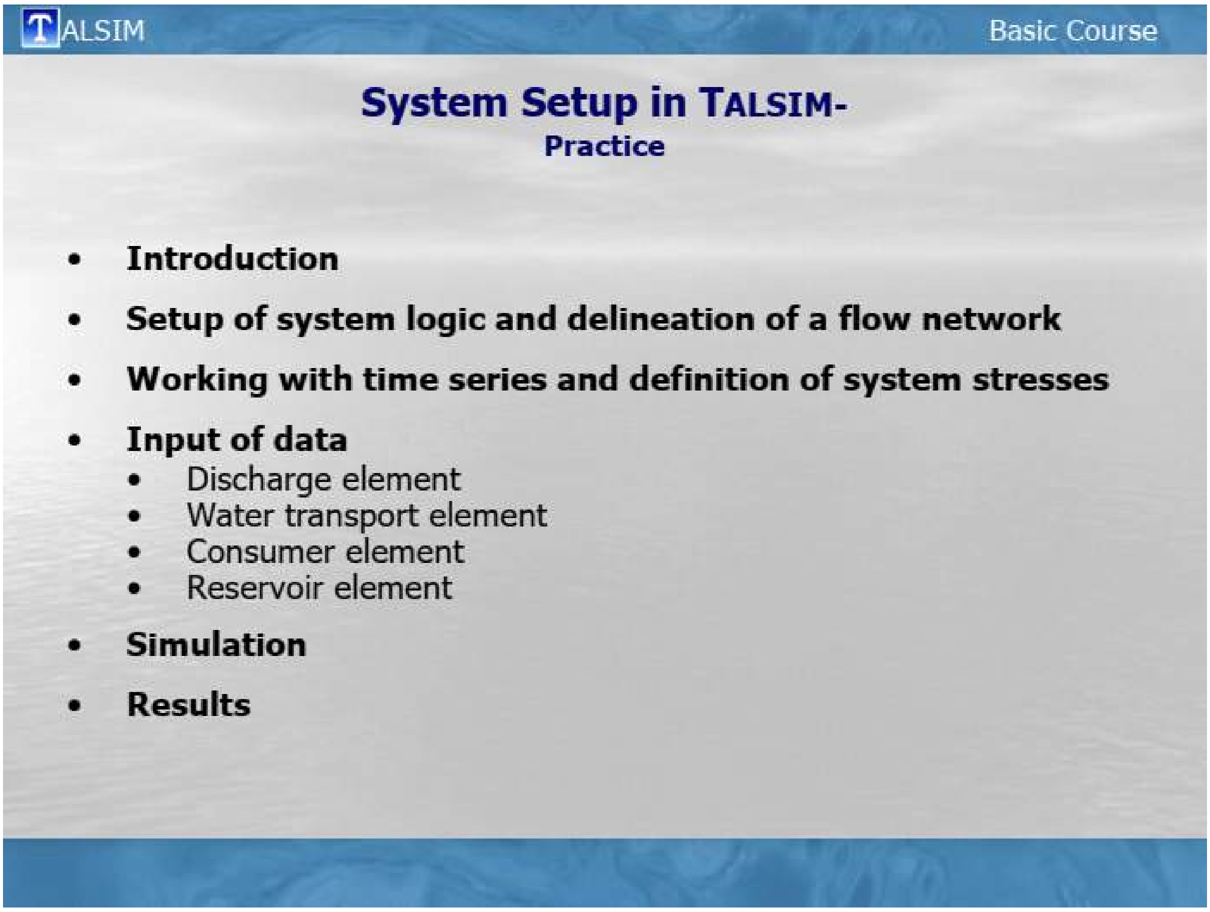
Concepts of reservoir operations • **Storage dependent releases** • *State dependent releases* • *Priorities*

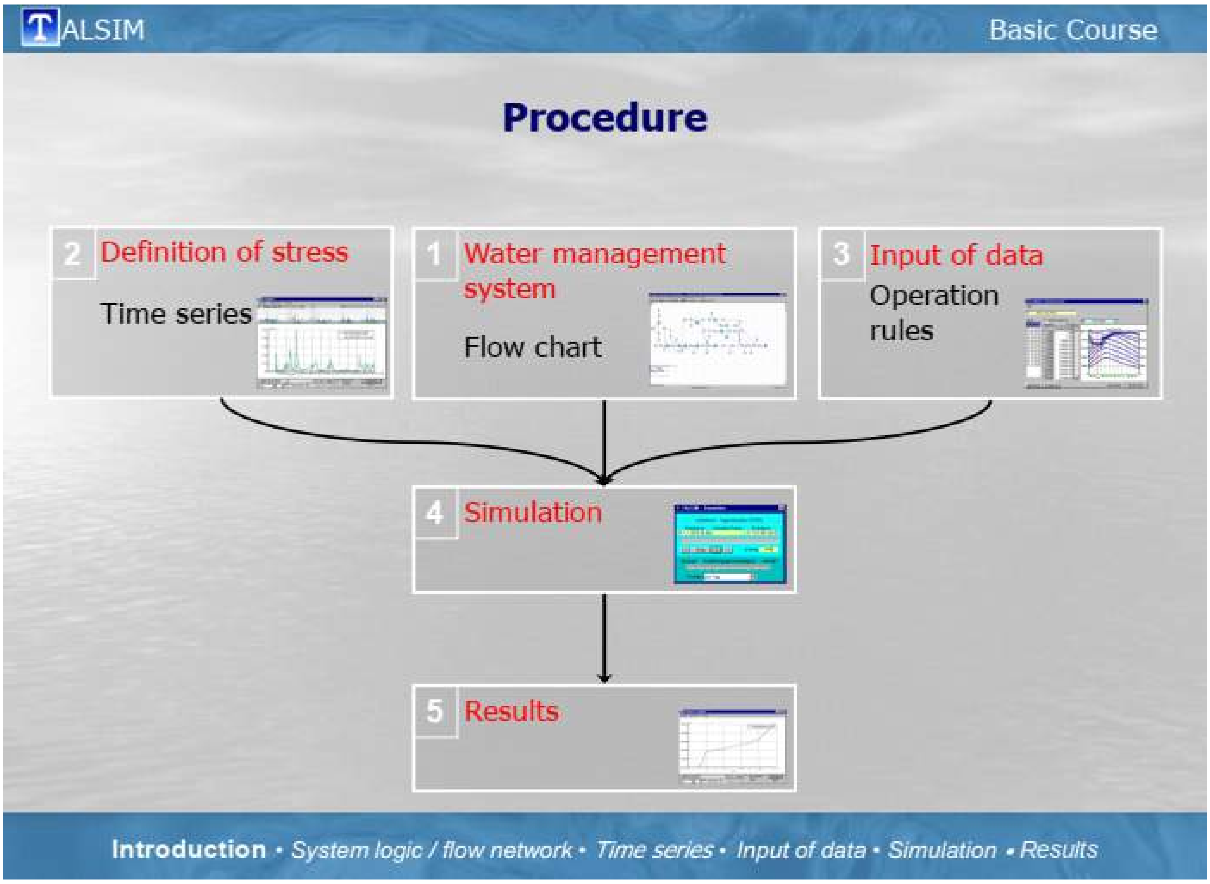

TALSIM
Basic Course
State Dependent Releases-
Release Q = f(S, System state)
Release
Qt
St
Storage
Factor
Ft
SSt
System state
• From the combination of storage and system state at time, t, one observes the corresponding release results, defined by individual characteristic curves
• Any quantity can serve as the system state, such as the inflow to, or the storage amount, of a reservoir
Result:
Release= Qt • Ft
Concepts of reservoir operations • Storage dependent releases • State dependent releases • Priorities

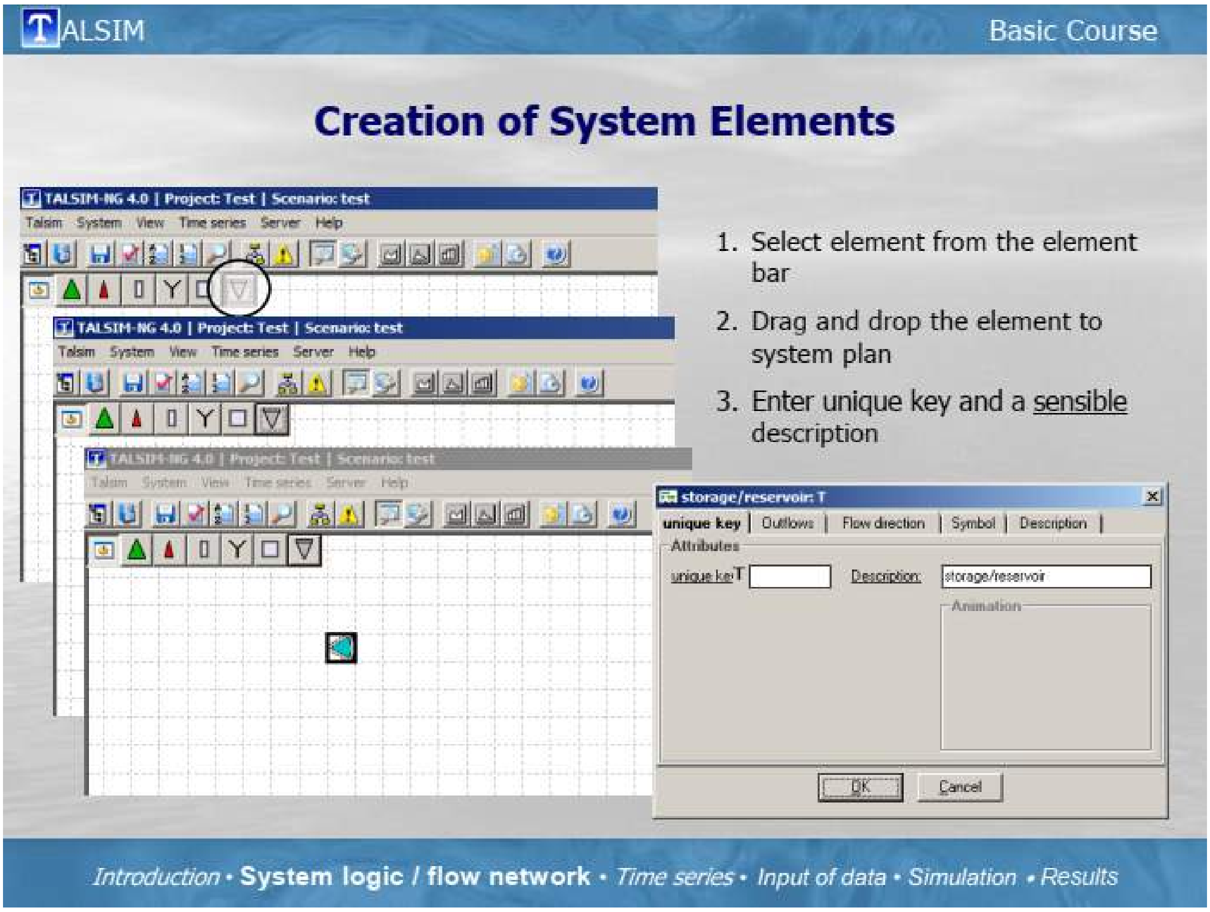

TALSIM
Basic Course
State Dependent Releases-
Dependency on inflow
Release: if Qin < 0.1 m³/s → Qout = 0.1 m³/s
if 0.1 m³/s ≤ Qin ≤ 0.2 m³/s → Qout = Qin
if Qin > 0.2 m³/s → Qout = 0.2 m³/s
Relative value (R(s)) [-]
1.0
Smin
Storage S
Factor (F) [m³/s]
0.2
0.1
0.1 0.2
Inflow to reservoir [m³/s]
Result:
Release = R(s) • F
Concepts of reservoir operations • Storage dependent releases • State dependent releases • Priorities

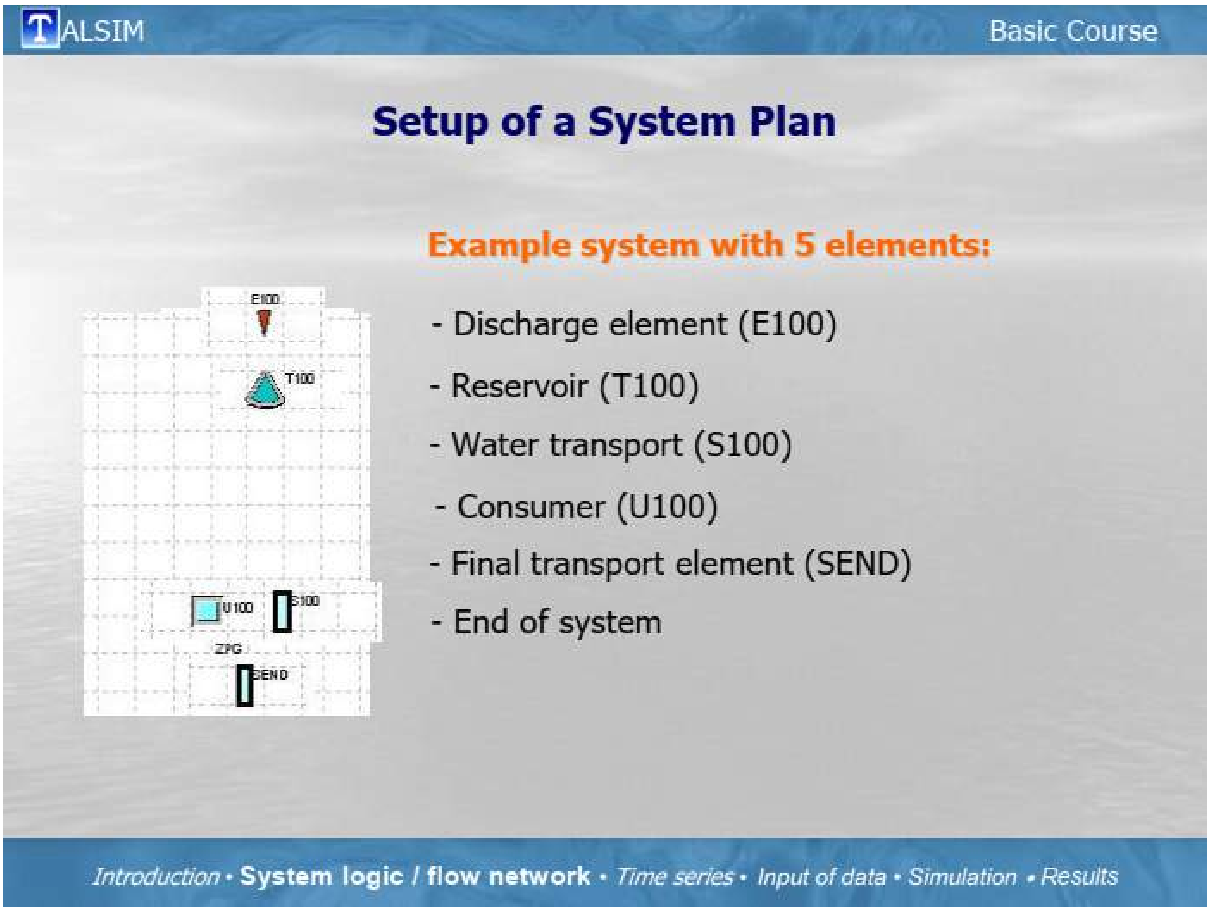

TALSIM
Basic Course
Priorities of Releases
Multiple releases of a reservoir are governed by the importance of the final purpose:
⇒ The order of deactivation is arranged according to storage- higher priority functions will be deactivated later
Release [%]
100
Smin
Storage
QT1 - Turbine release
QW1 - Factory demand
QW2 - Water works
Concepts of reservoir operations • Storage dependent releases • State dependent releases • Priorities

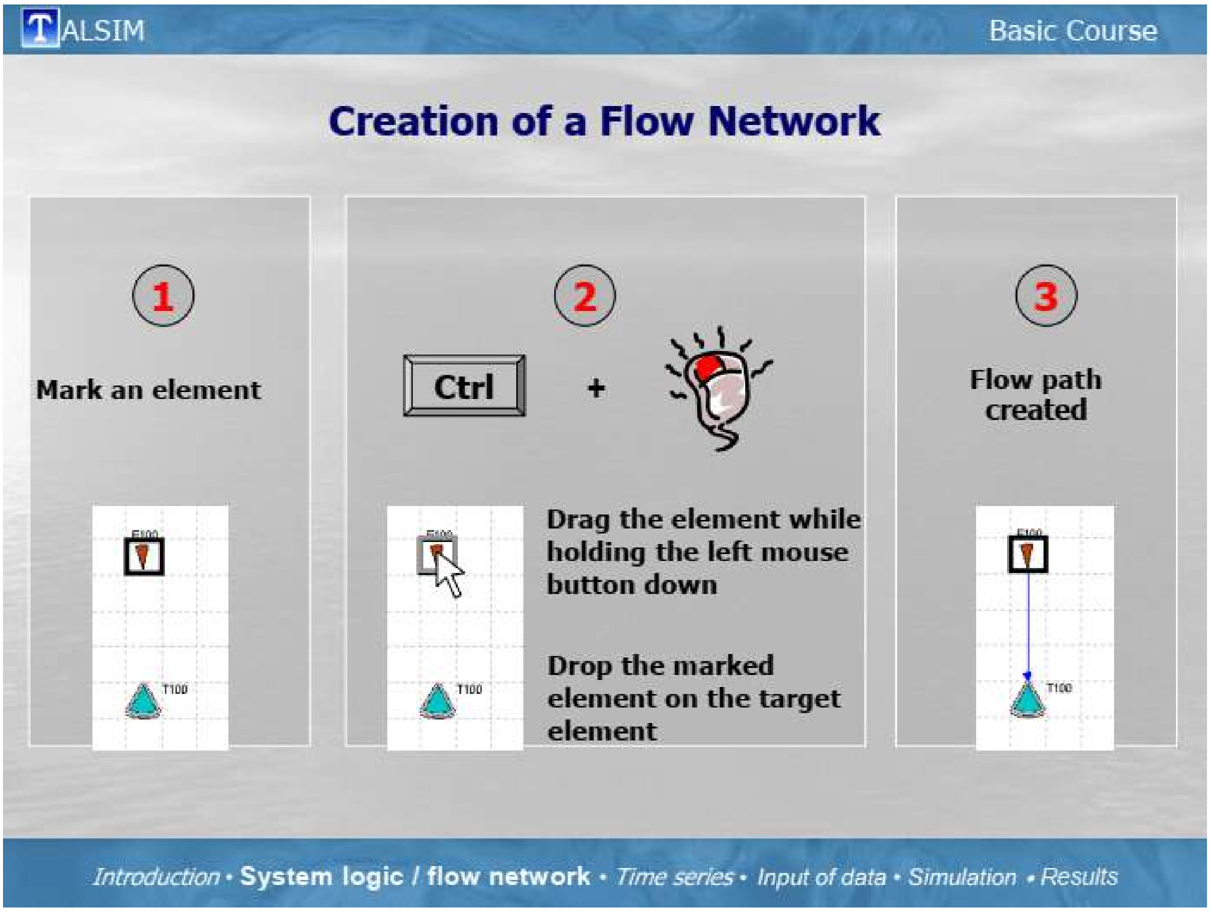

TALSIM
Basic Course
Priorities of Releases
Each reservoir release can reduce succeeding releases:
⇒ Internal dependencies
Release [%]
100
Smin
Storage
QH1 – Flood protection zone
QW1 – Control output
QM1 – Minimum release
Concepts of reservoir operations • Storage dependent releases • State dependent releases • Priorities

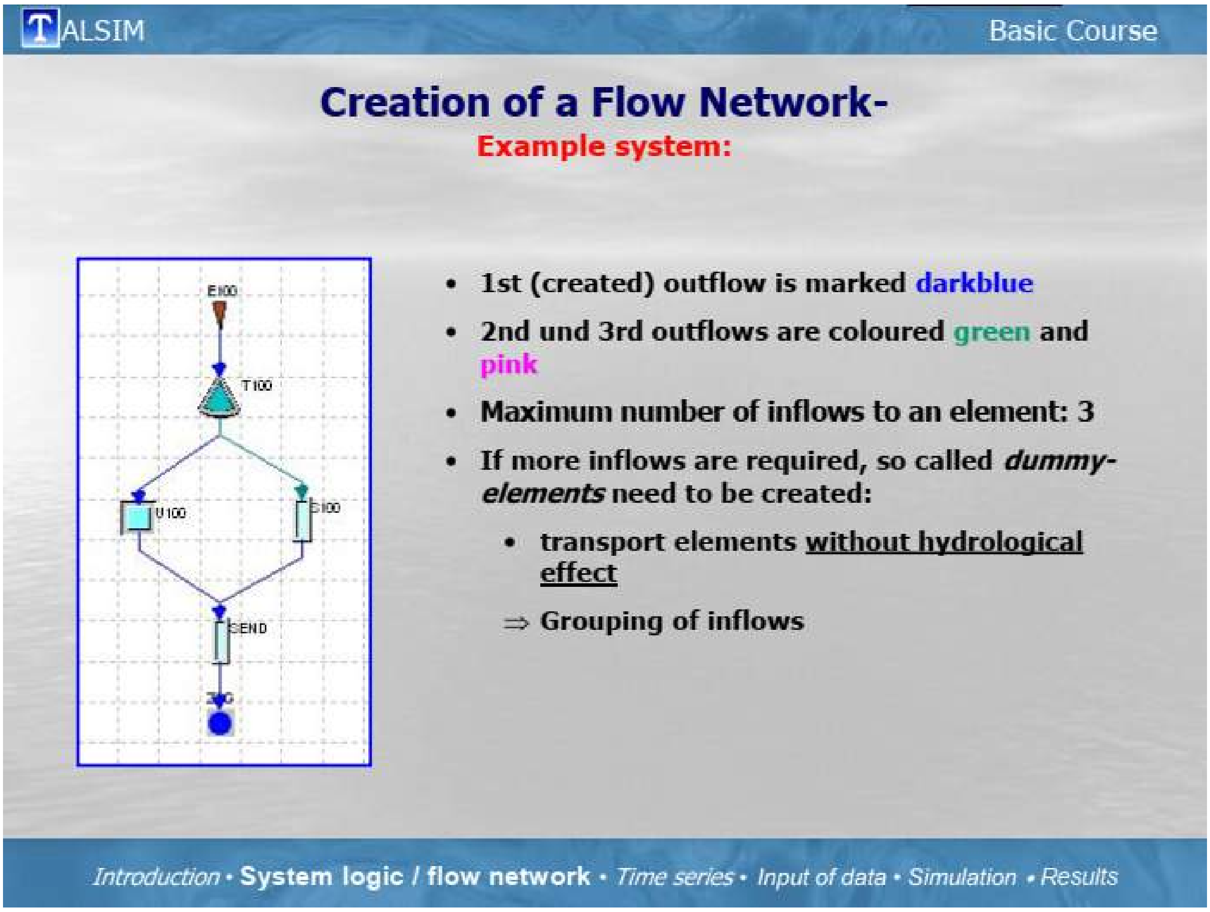

TALSIM
Basic Course
System Setup in TALSIM-
Practice
Introduction
Setup of system logic and delineation of a flow network
Working with time series and definition of system stresses
Input of data
Discharge element
Water transport element
Consumer element
Reservoir element
Simulation
Results

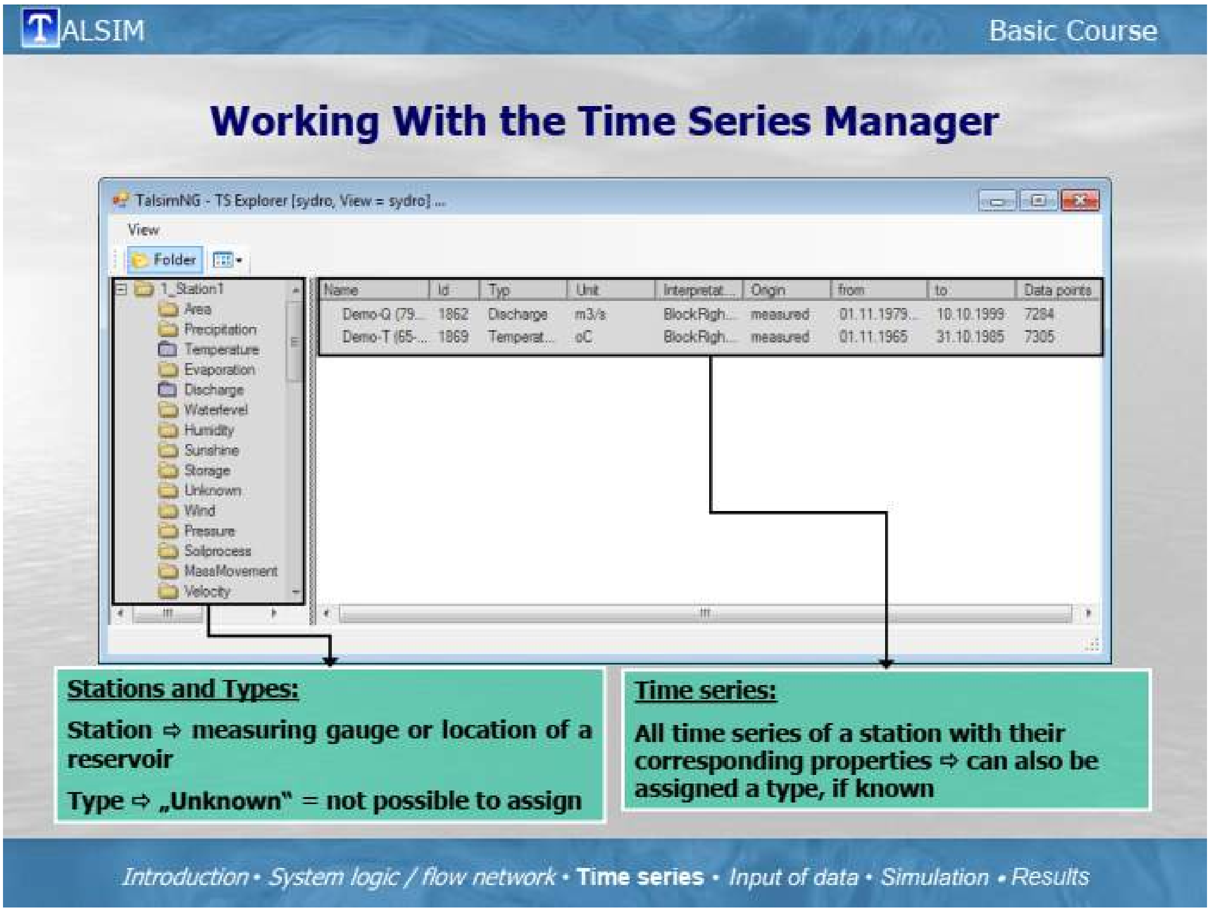

TALSIM
Basic Course
Procedure
2 Definition of stress
Time series
1 Water management system
Flow chart
3 Input of data
Operation rules
4 Simulation
5 Results
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

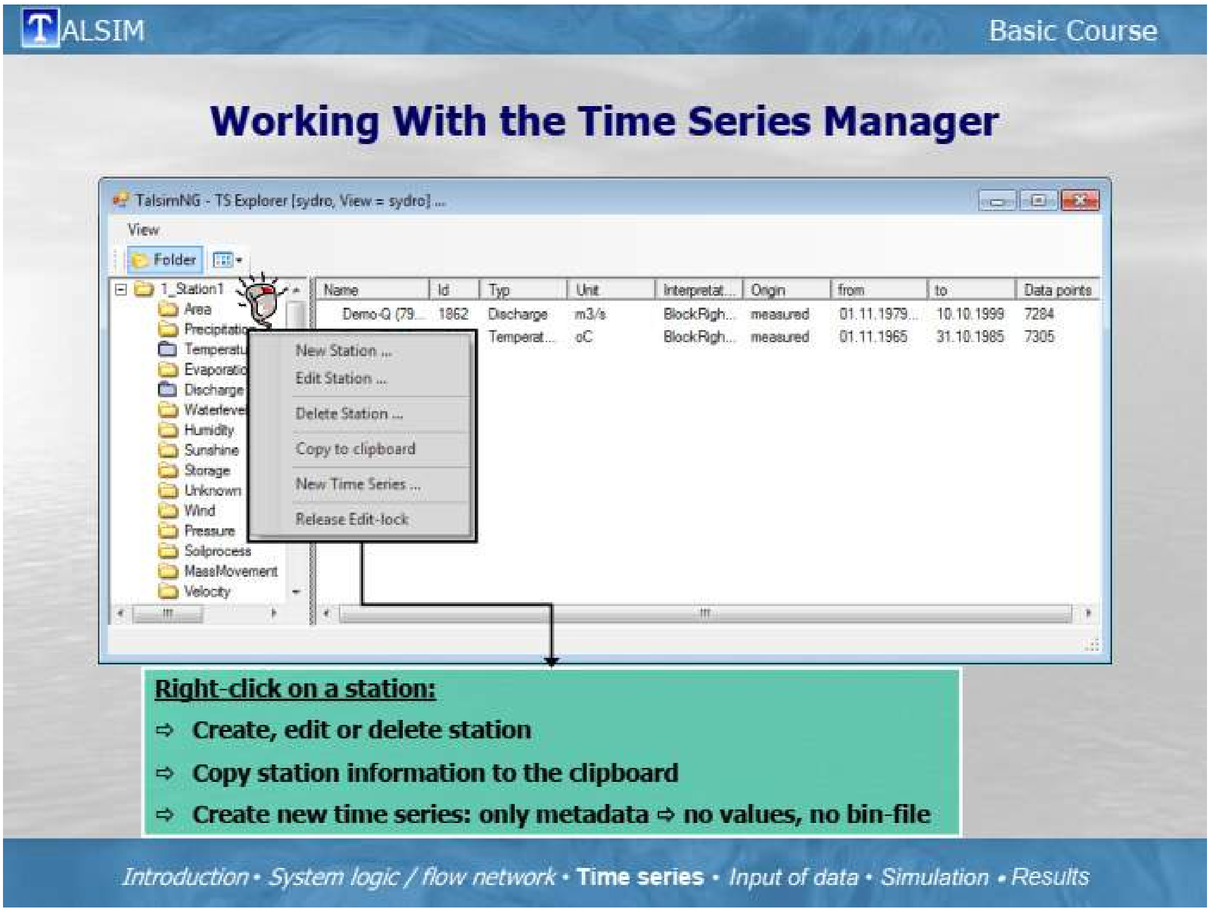

TALSIM
Basic Course
Creation of System Elements
TALSIM-NG 4.0 | Project: Test | Scenario: test
Talsim System View Time series Server Help
1. Select element from the element bar
2. Drag and drop the element to system plan
3. Enter unique key and a sensible description
storage/reservoir: T
unique key | Outflows | Flow direction | Symbol | Description
Attributes
unique key T
Description: storage/reservoir
Animation
OK
Cancel
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Setup of a System Plan
Example system with 5 elements:
E100
T100
U100
S100
ZPG
SEND
- Discharge element (E100)
- Reservoir (T100)
- Water transport (S100)
- Consumer (U100)
- Final transport element (SEND)
- End of system
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Creation of a Flow Network
1
Mark an element
2
Ctrl
+
Drag the element while holding the left mouse button down
Drop the marked element on the target element
3
Flow path created
T100
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

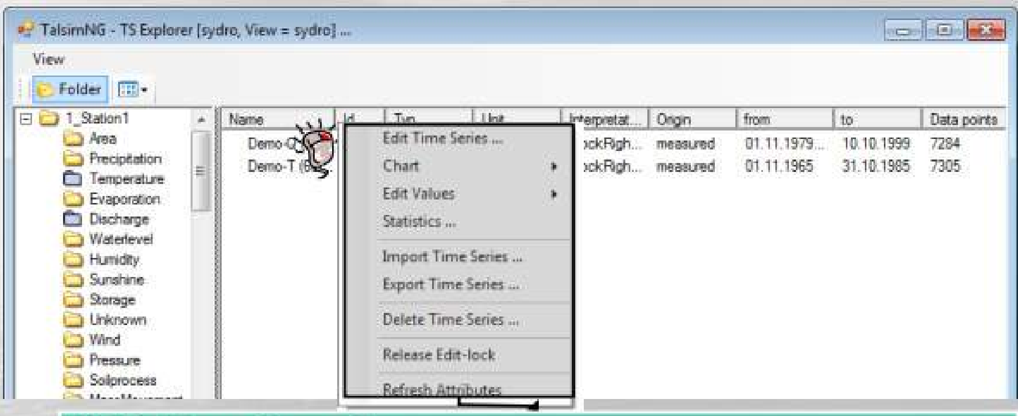

TALSIM
Basic Course
Creation of a Flow Network-
Example system:
E100
T100
U100
END
• 1st (created) outflow is marked darkblue
• 2nd und 3rd outflows are coloured green and pink
• Maximum number of inflows to an element: 3
• If more inflows are required, so called dummy-elements need to be created:
• transport elements without hydrological effect
⇒ Grouping of inflows
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Working With the Time Series Manager
TalsimNG - TS Explorer [sydro, View = sydro] ...
View
Folder
1_Station1
Area
Precipitation
Temperature
Evaporation
Discharge
Waterlevel
Humidity
Sunshine
Storage
Unknown
Wind
Pressure
Soilprocess
MassMovement
Velocity
Name Id Typ Unit Interpretat... Origin from to Data points
Demo-Q (79... 1862 Discharge m3/s BlockRigh... measured 01.11.1979... 10.10.1999 7284
Demo-T (65-... 1869 Temperat... oC BlockRigh... measured 01.11.1965 31.10.1985 7305
Stations and Types:
Station ⇨ measuring gauge or location of a reservoir
Type ⇨ „Unknown" = not possible to assign
Time series:
All time series of a station with their corresponding properties ⇨ can also be assigned a type, if known
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Working With the Time Series Manager
TalsimNG - TS Explorer [sydro, View = sydro] ...
View
Folder
1_Station1
Name Id Typ Unit Interpretat... Origin from to Data points
Demo-Q (79... 1862 Discharge m3/s BlockRigh... measured 01.11.1979... 10.10.1999 7284
Temperat... oC BlockRigh... measured 01.11.1965 31.10.1985 7305
New Station ...
Edit Station ...
Delete Station ...
Copy to clipboard
New Time Series ...
Release Edit-lock
Right-click on a station:
⇨ Create, edit or delete station
⇨ Copy station information to the clipboard
⇨ Create new time series: only metadata ⇨ no values, no bin-file
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

TALSIM Basic Course

Working With the Time Series Manager



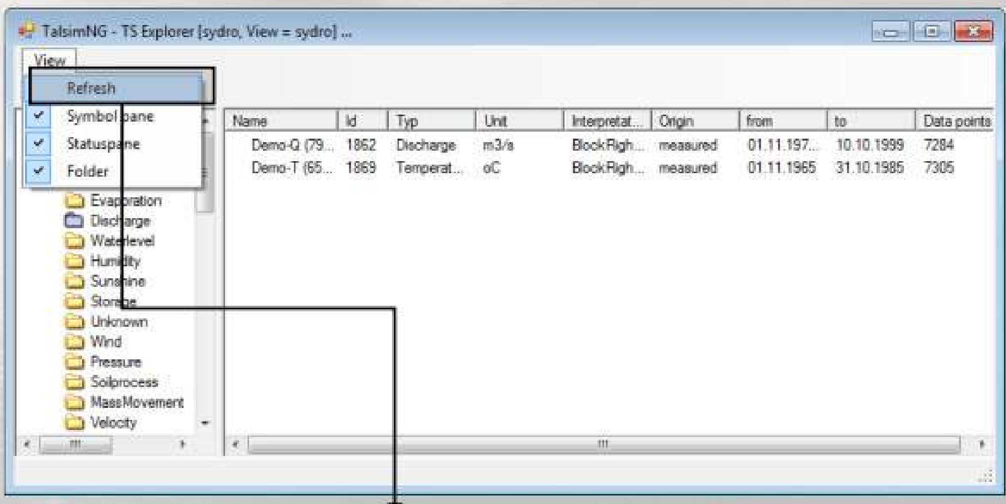
Right-click on a time series:

- ⇨ **Edit metadata of the time series and refresh attributes**
- ⇨ **Plot time series and its duration curve**
- ⇨ **Edit values (edit, add, delete)**
- ⇨ **Compute statistics: standard moments, low/high flow analysis**
- ⇨ **Import, export or delete time series**

Introduction • System logic / flow network • **Time series** *• Input of data • Simulation • Results*

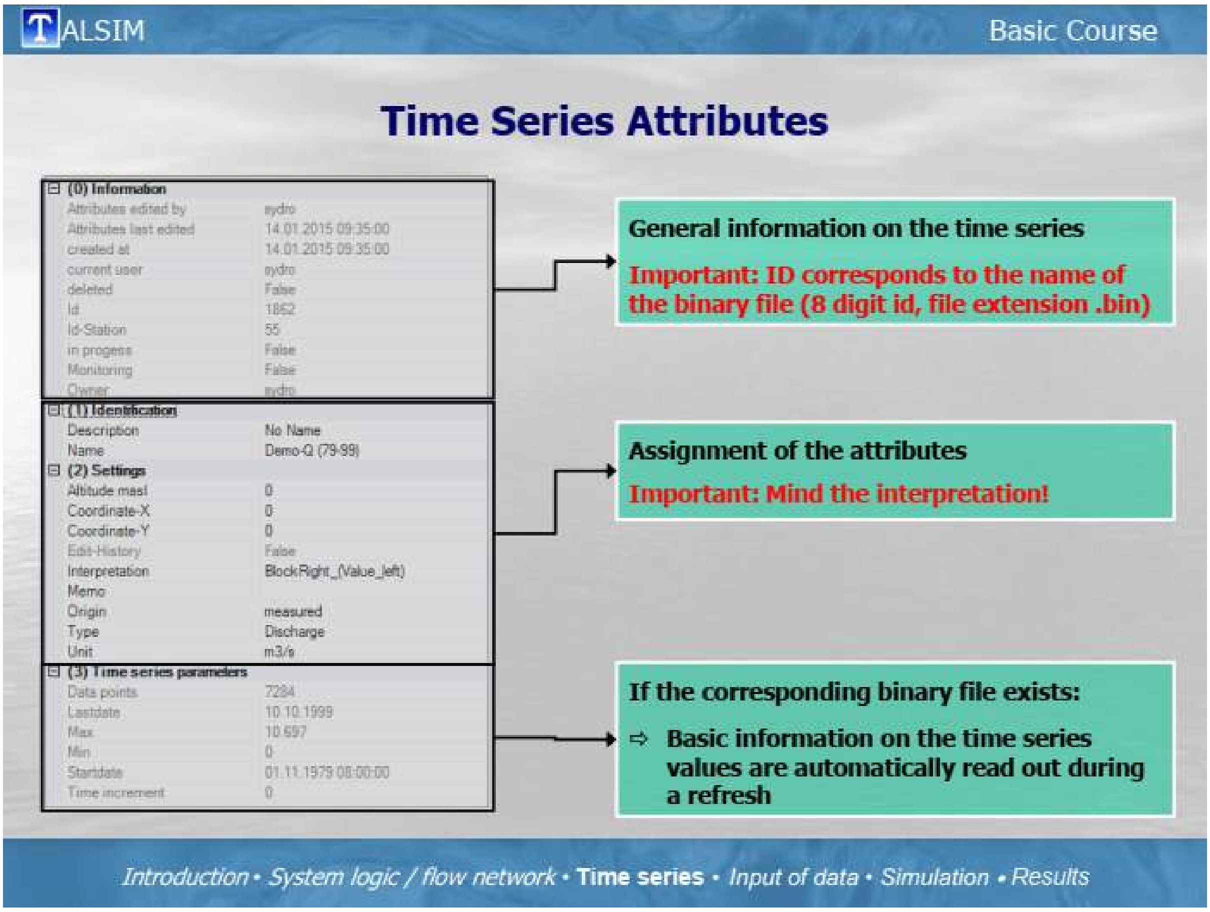
TALSIM Basic Course

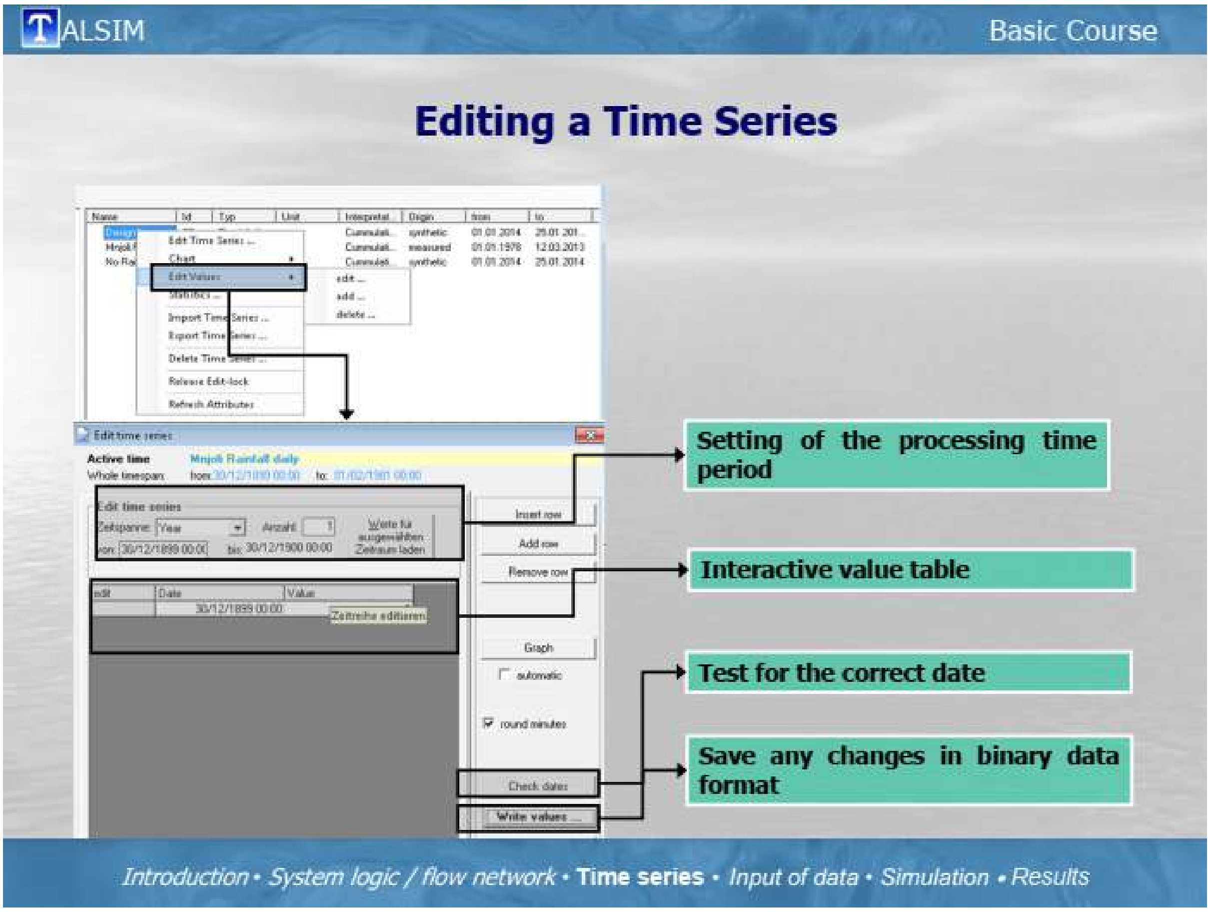
Working With the Time Series Manager

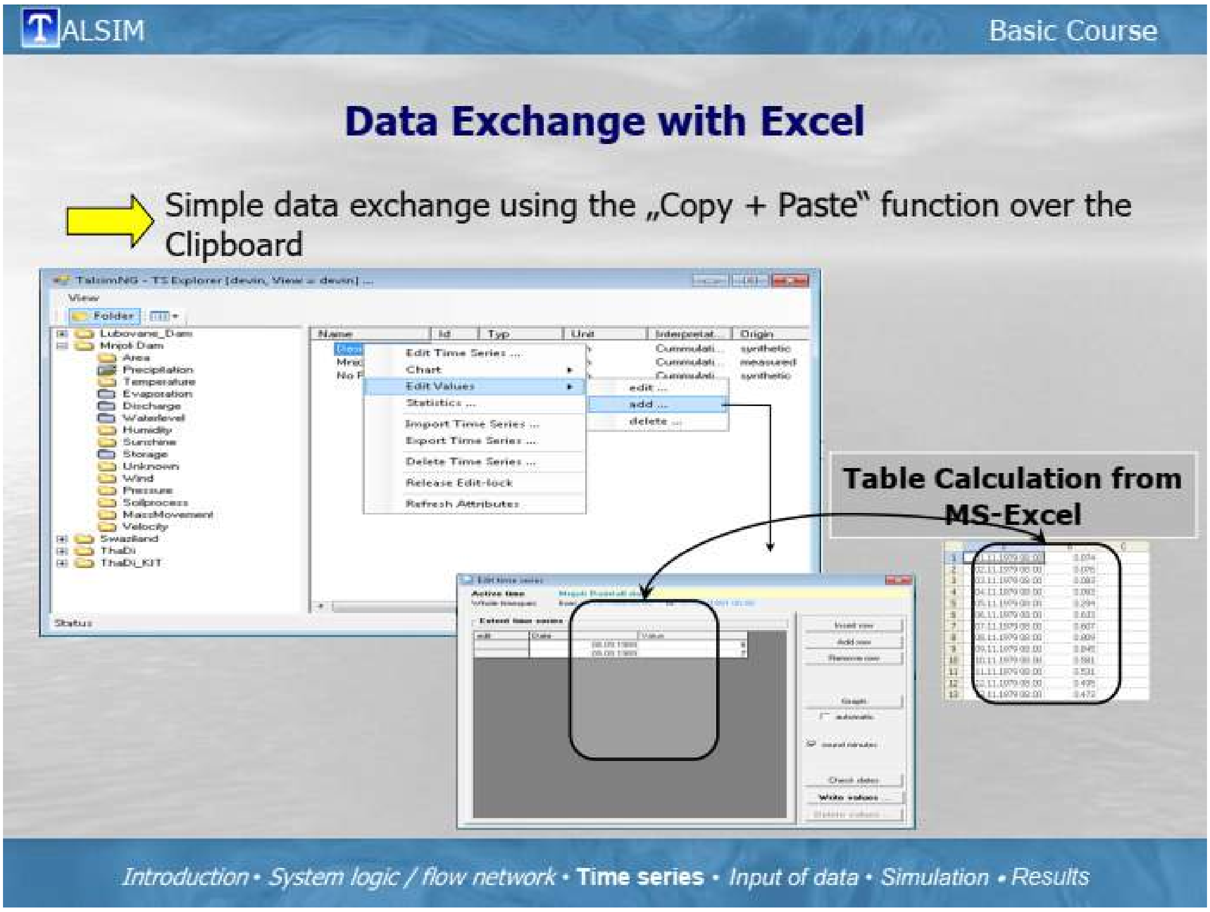


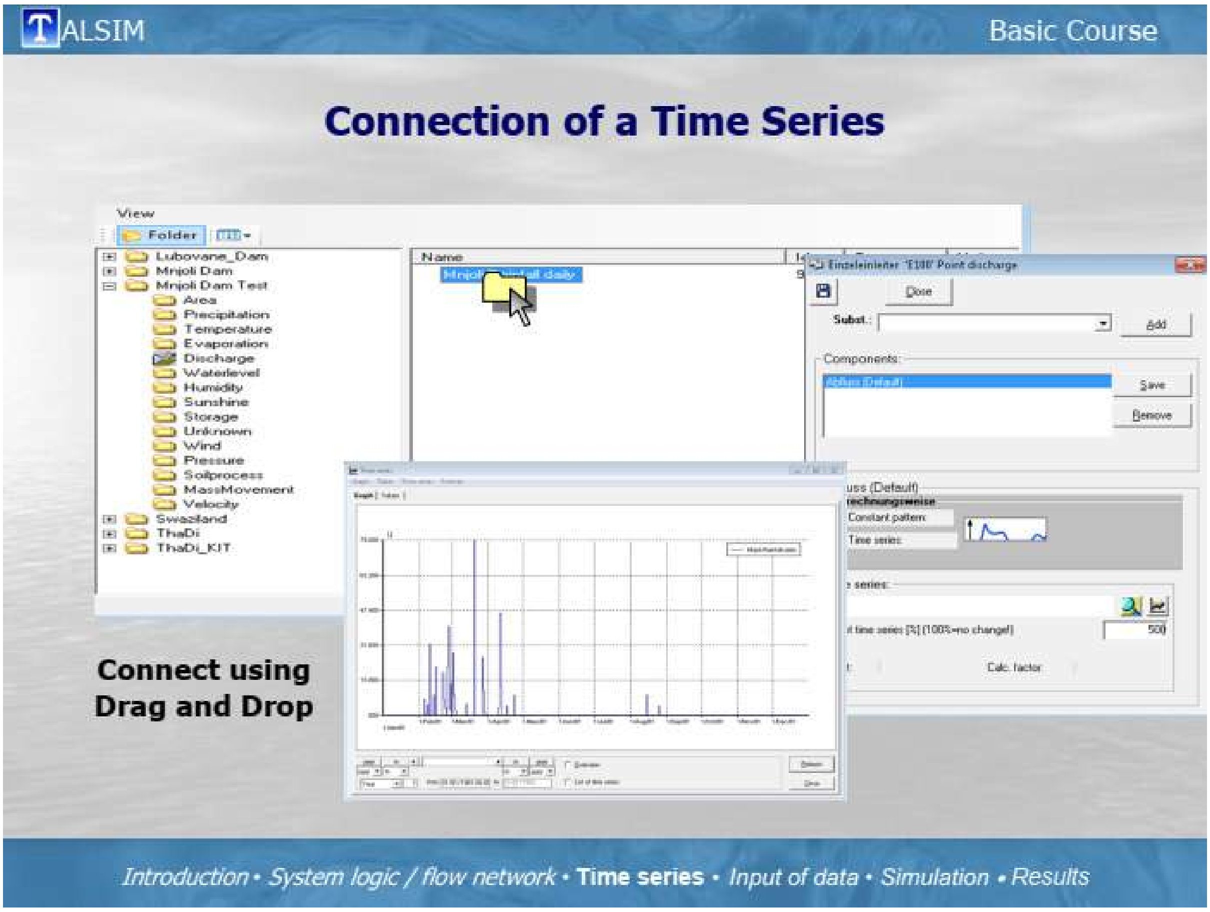
⇨ **Refresh the window to show newly created stations and time series**

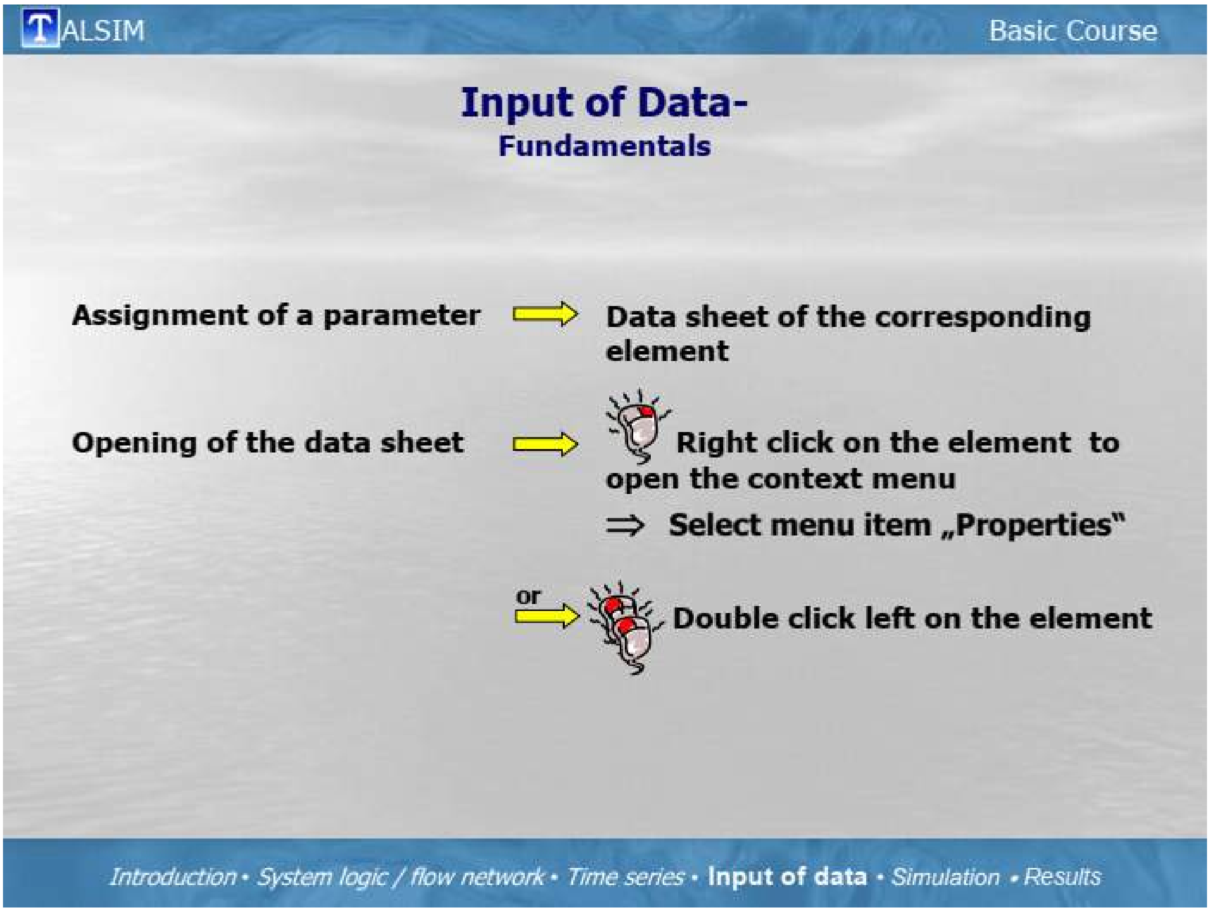
Introduction • System logic / flow network • **Time series** *• Input of data • Simulation • Results*

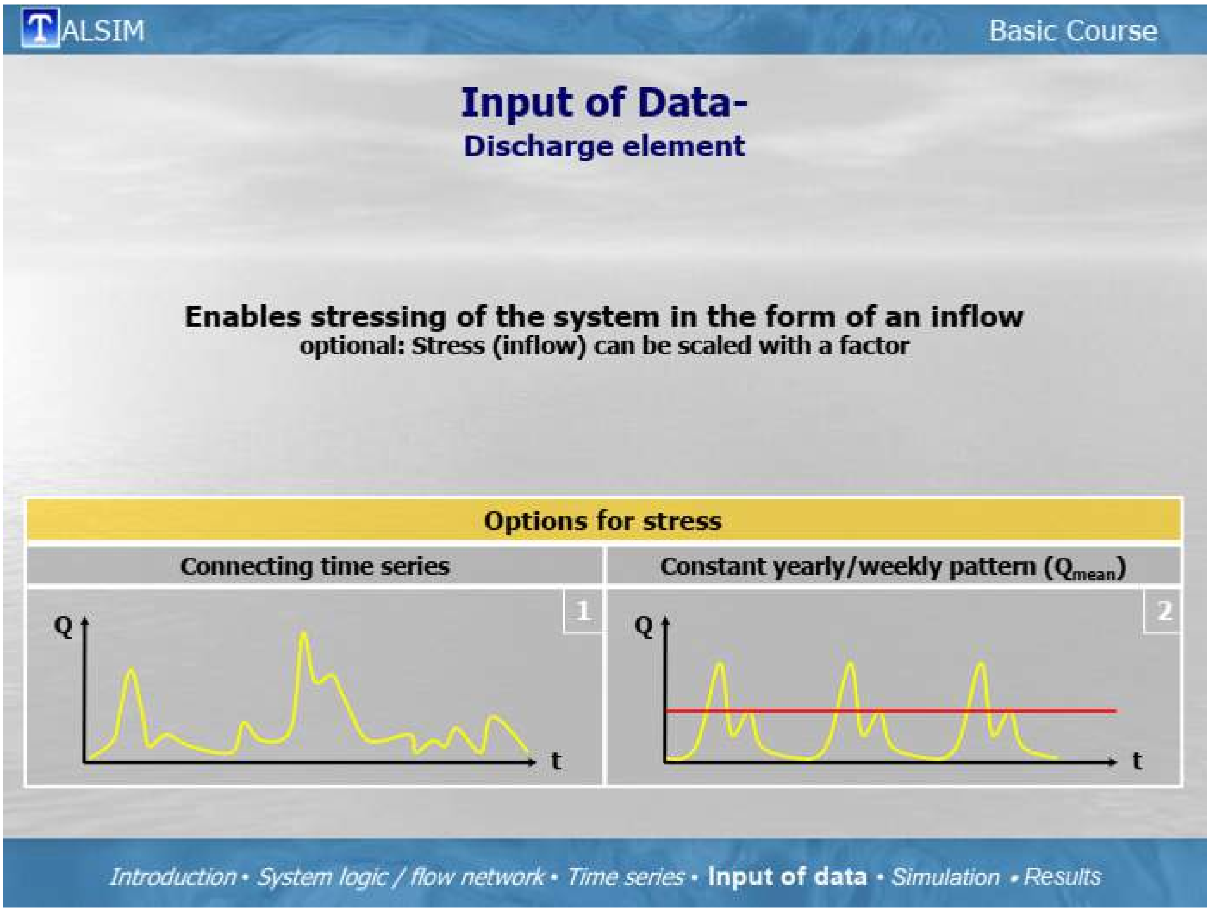

TALSIM
Basic Course
Time Series Attributes
(0) Information
Attributes edited by
Attributes last edited
created at
current user
deleted
Id
Id-Station
in progress
Monitoring
Owner
(1) Identification
Description
Name
(2) Settings
Altitude masl
Coordinate-X
Coordinate-Y
Edit-History
Interpretation
Memo
Origin
Type
Unit
(3) Time series parameters
Data points
Lastdate
Max
Min
Startdate
Time increment
General information on the time series
Important: ID corresponds to the name of the binary file (8 digit id, file extension .bin)
Assignment of the attributes
Important: Mind the interpretation!
If the corresponding binary file exists:
⇨ Basic information on the time series values are automatically read out during a refresh
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

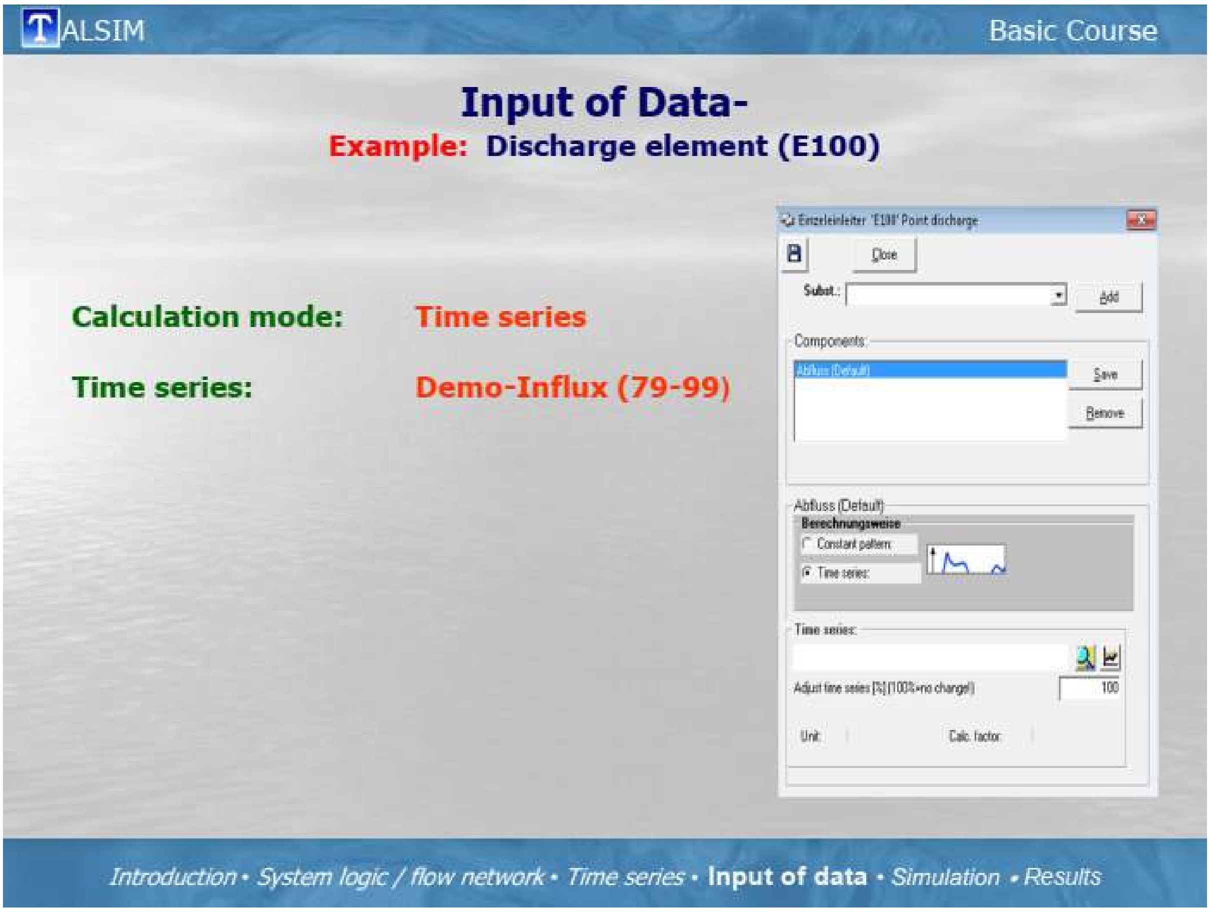

TALSIM
Basic Course
Editing a Time Series
Setting of the processing time period
Interactive value table
Test for the correct date
Save any changes in binary data format
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

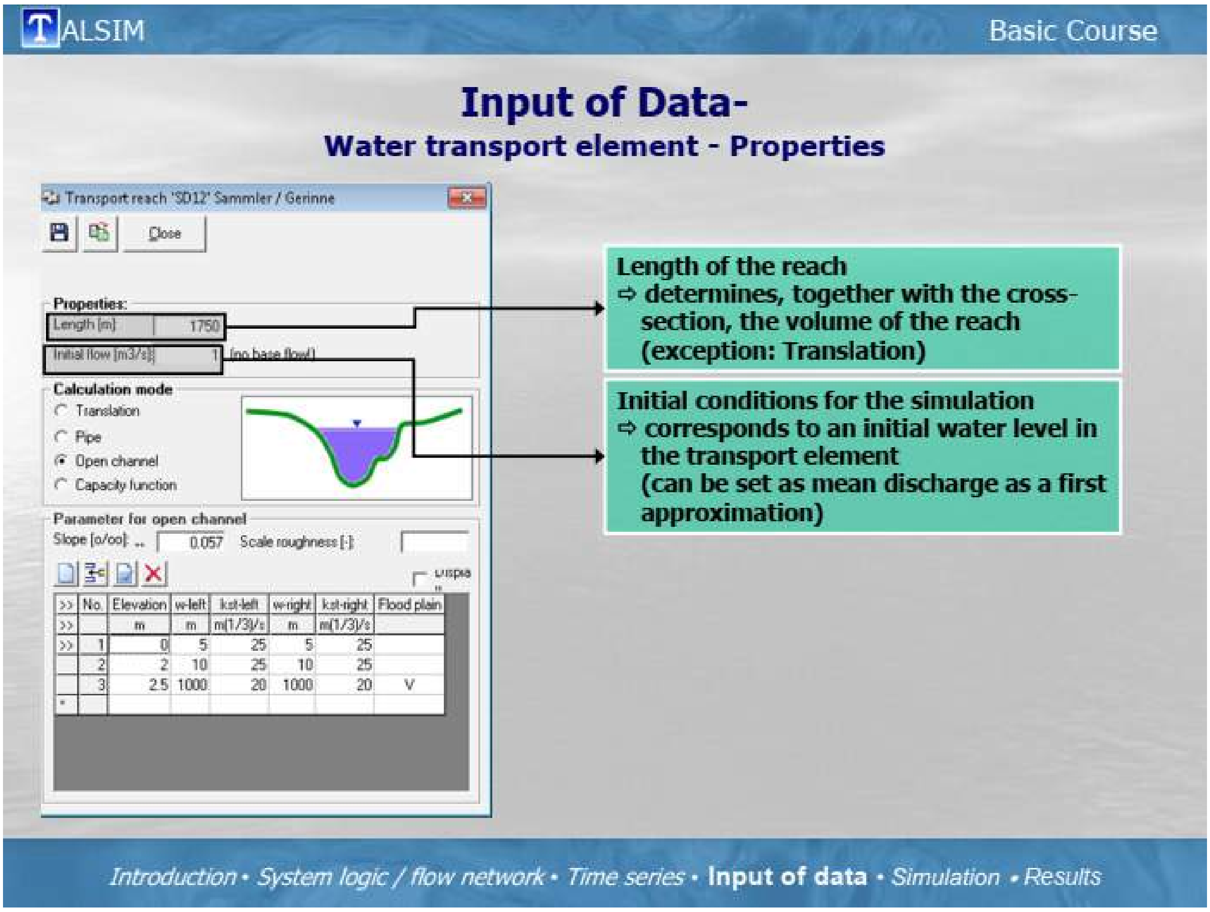

TALSIM
Basic Course
Data Exchange with Excel
Simple data exchange using the „Copy + Paste" function over the Clipboard
Table Calculation from MS-Excel
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

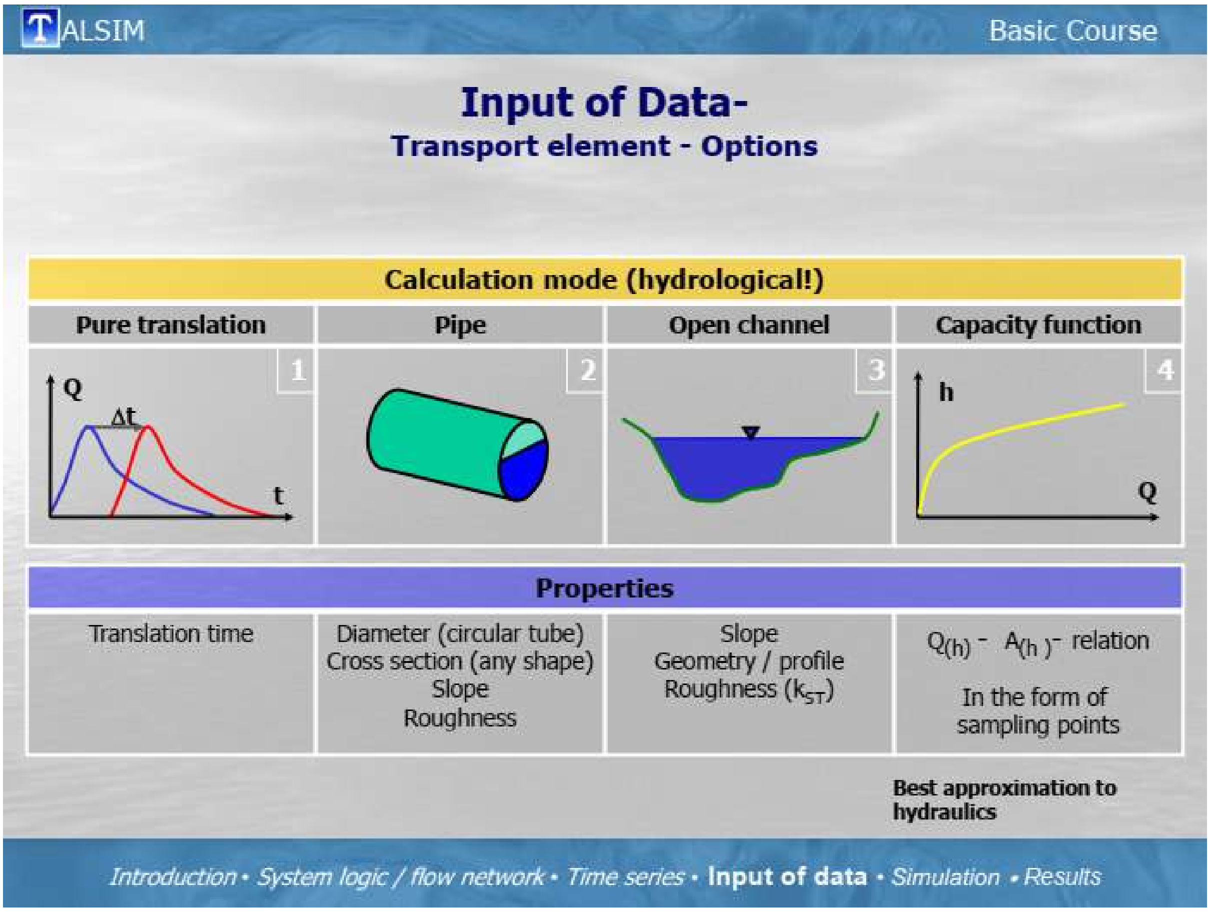

TALSIM
Basic Course
Connection of a Time Series
Connect using Drag and Drop
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

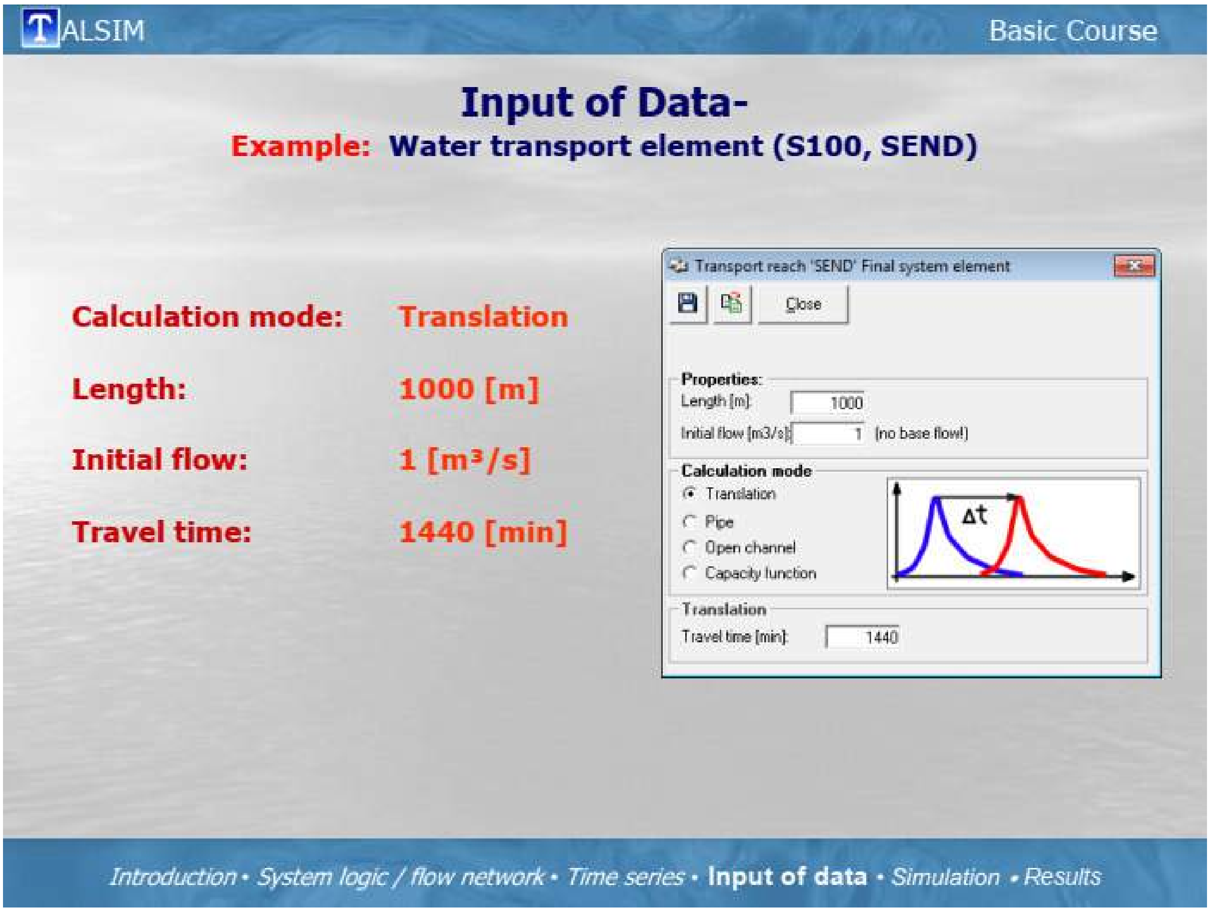

TALSIM
Basic Course
Input of Data-
Fundamentals
Assignment of a parameter
Data sheet of the corresponding element
Opening of the data sheet
Right click on the element to open the context menu
⇒ Select menu item „Properties"
or
Double click left on the element
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Discharge element
Enables stressing of the system in the form of an inflow
optional: Stress (inflow) can be scaled with a factor
Options for stress
Connecting time series
Constant yearly/weekly pattern (Q_{mean})
1
2
Q
t
Q
t
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Example: Discharge element (E100)
Calculation mode: Time series
Time series: Demo-Influx (79-99)
Einzeleinleiter 'E100' Point discharge
Close
Subset:
Add
Components:
Abfluss (Default)
Save
Remove
Abfluss (Default)
Berechnungsweise
Constant pattern:
Time series:
Time series:
Adjust time series [%] (100%=no change!)
100
Unit:
Calc. factor:
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Water transport element - Properties
Transport reach 'SD12' Sammler / Gerinne
Close
Properties:
Length [m] 1750
Initial flow [m3/s]: 1 (no base flow!)
Calculation mode
Translation
Pipe
Open channel
Capacity function
Parameter for open channel
Slope [o/oo]: 0.057
Scale roughness [-]:
No. Elevation w-left kst-left w-right kst-right Flood plain
m m m(1/3)/s m m(1/3)/s
1 0 5 25 5 25
2 2 10 25 10 25
3 2.5 1000 20 1000 20 V
Length of the reach
⇨ determines, together with the cross-section, the volume of the reach (exception: Translation)
Initial conditions for the simulation
⇨ corresponds to an initial water level in the transport element
(can be set as mean discharge as a first approximation)
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Transport element - Options
Calculation mode (hydrological!)
Pure translation
Pipe
Open channel
Capacity function
1
2
3
4
Q
Δt
t
h
Q
Properties
Translation time
Diameter (circular tube)
Cross section (any shape)
Slope
Roughness
Slope
Geometry / profile
Roughness (kST)
Q(h) - A(h) - relation
In the form of sampling points
Best approximation to hydraulics
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Example: Water transport element (S100, SEND)
Calculation mode: Translation
Length: 1000 [m]
Initial flow: 1 [m³/s]
Travel time: 1440 [min]
Transport reach 'SEND' Final system element
Close
Properties:
Length [m]: 1000
Initial flow [m3/s]: 1 (no base flow!)
Calculation mode
Translation
Pipe
Open channel
Capacity function
Δt
Translation
Travel time [min]: 1440
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

TALSIM Basic Course

Input of Data-
Consumer element

Calculation groups and modes		
Consumption (withdrawal from system)	**Demand**	**Supply**
1 Definition of a Q_{loss}: • Threshold • Percentage • Function	2 Definition of a demand. Required flow to consumer ⇒ control of meeting the demand: demand as a system state	3 Definition of a Q_{in}. Discharge from outside into the system
Properties		
Retention for re-discharge • Threshold and Diversion coeff • Ratio [%] • Q_{in} – Q_{out} – relation • For $Q_{re\text{-}injection}$	Demand in the form of: • fixed patterns • time series	Supply in the form of: • fixed patterns • time series

Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

TALSIM Basic Course

Input of Data-
Example: Consumer element (U100)

Retention: 48 [h]

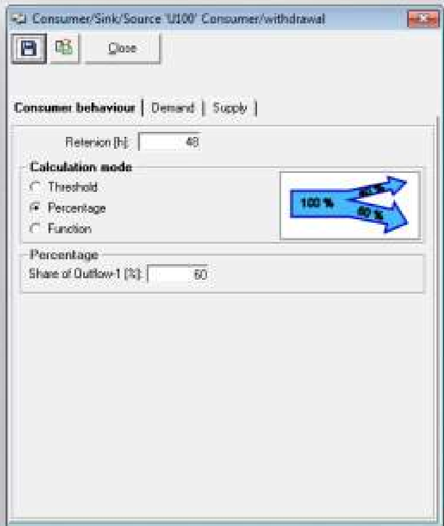
Consumer behaviour

Calculation mode: Percentage

Share of Outflow-1: 60 [%]

Demand

Average demand: 0.6 [m³/s]

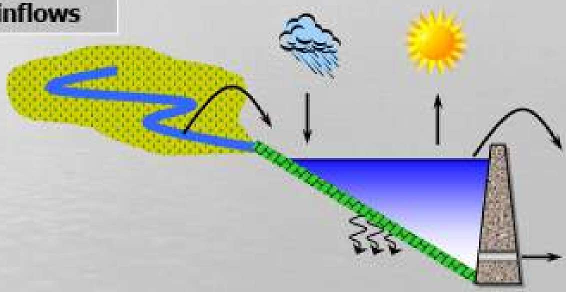


Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

TALSIM Basic Course

Input of Data-
Reservoir element

Stress input
Time series
RR-simulated inflows



Releases
Flood discharge
Control output
Raising of low water level
Water supply

Local losses and yield
Precipitation
Evaporation
Percolation

to be defined at the reservoir

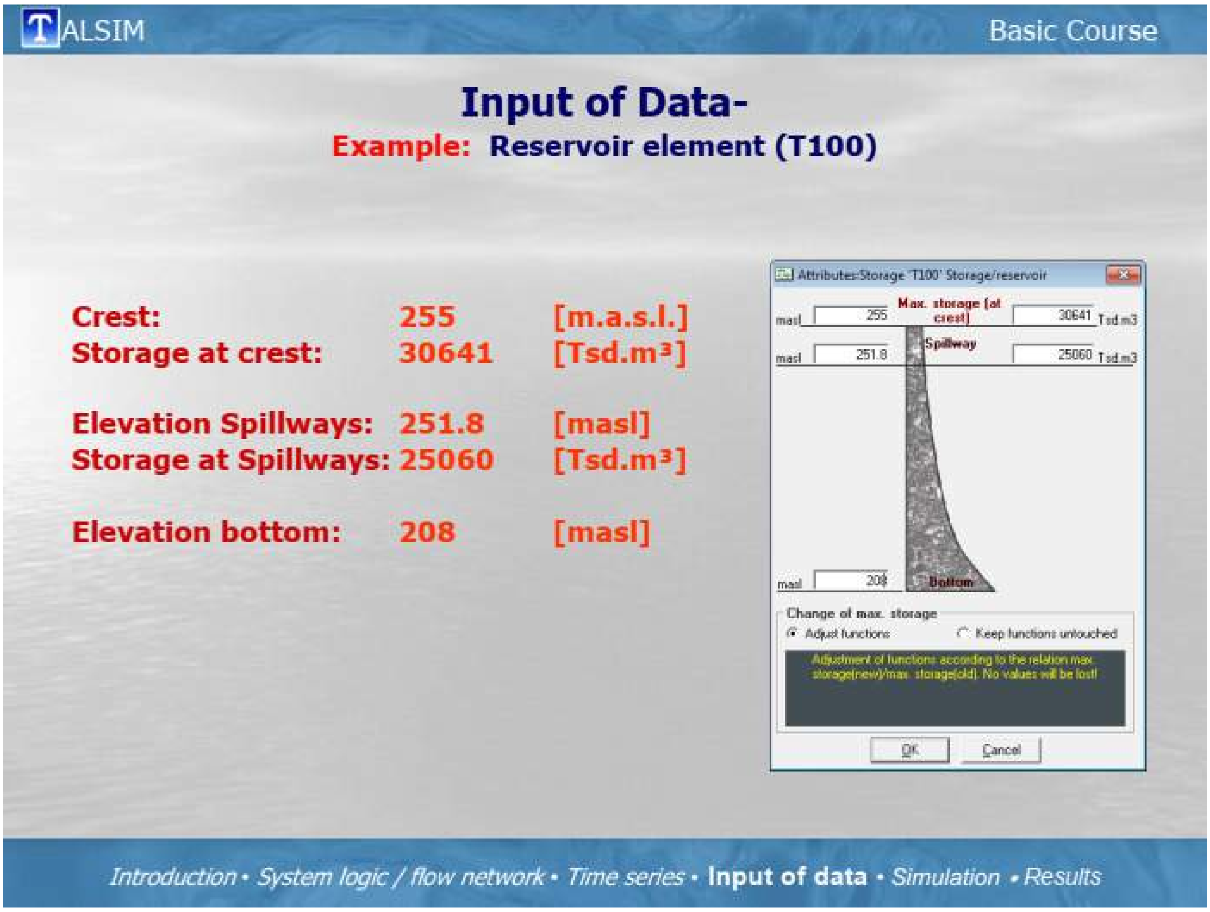
Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

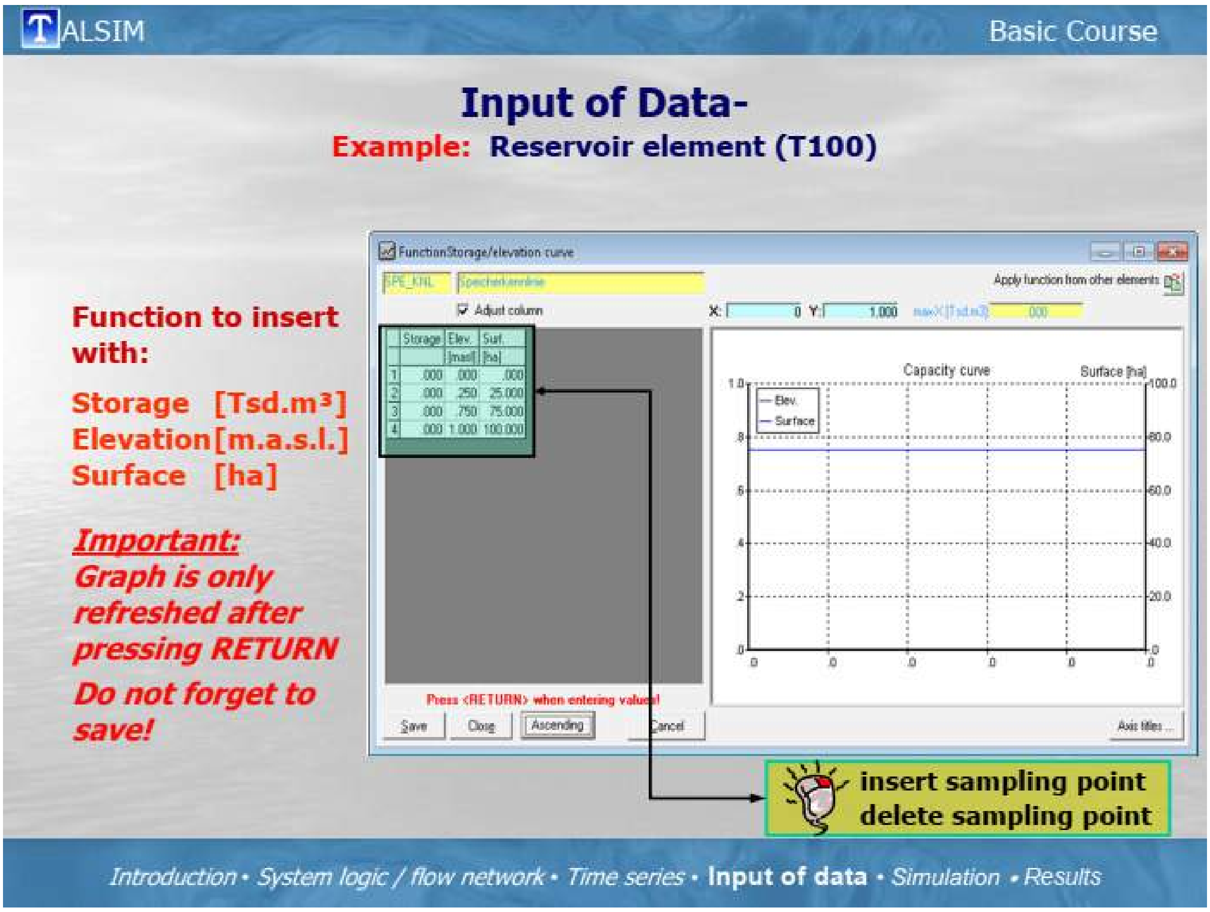
TALSIM Basic Course

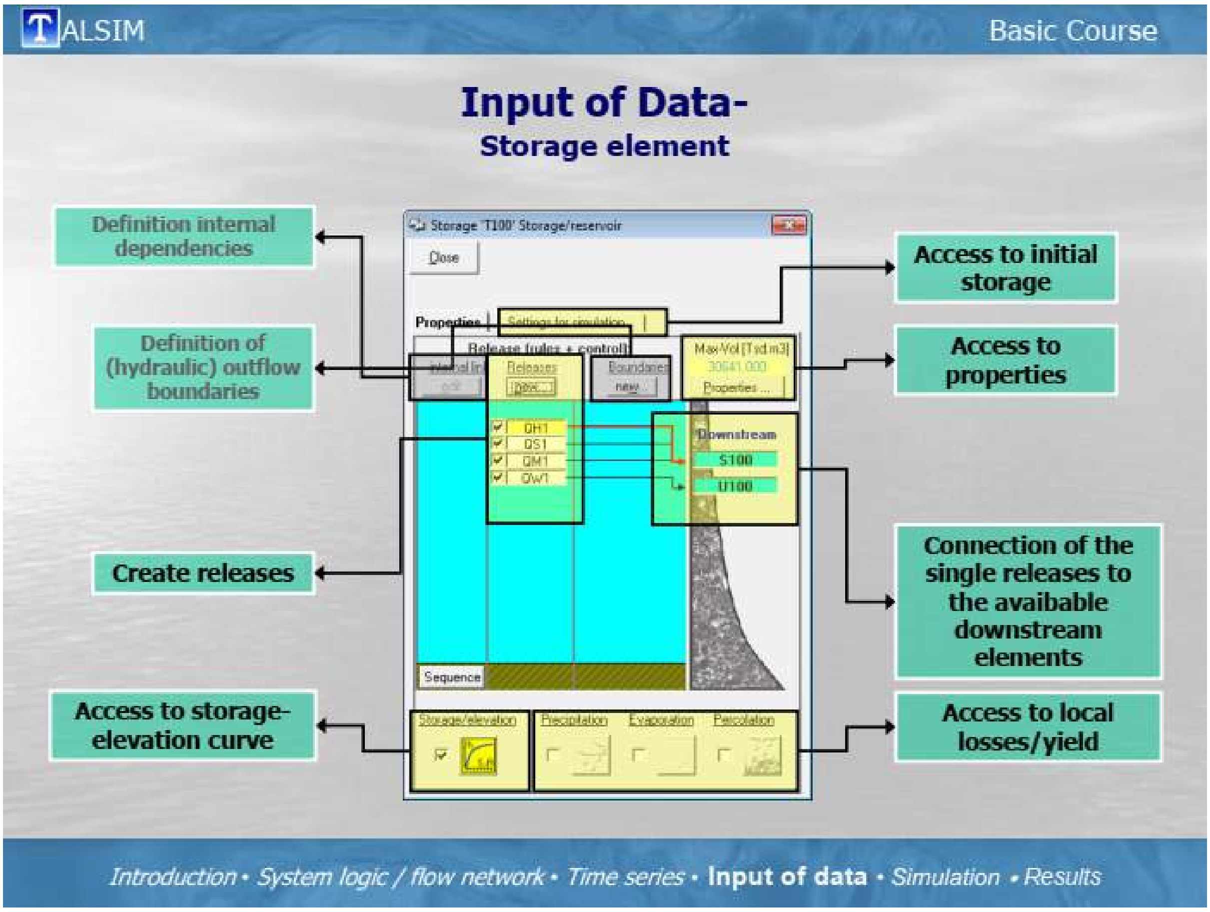
Input of Data-
Reservoir element

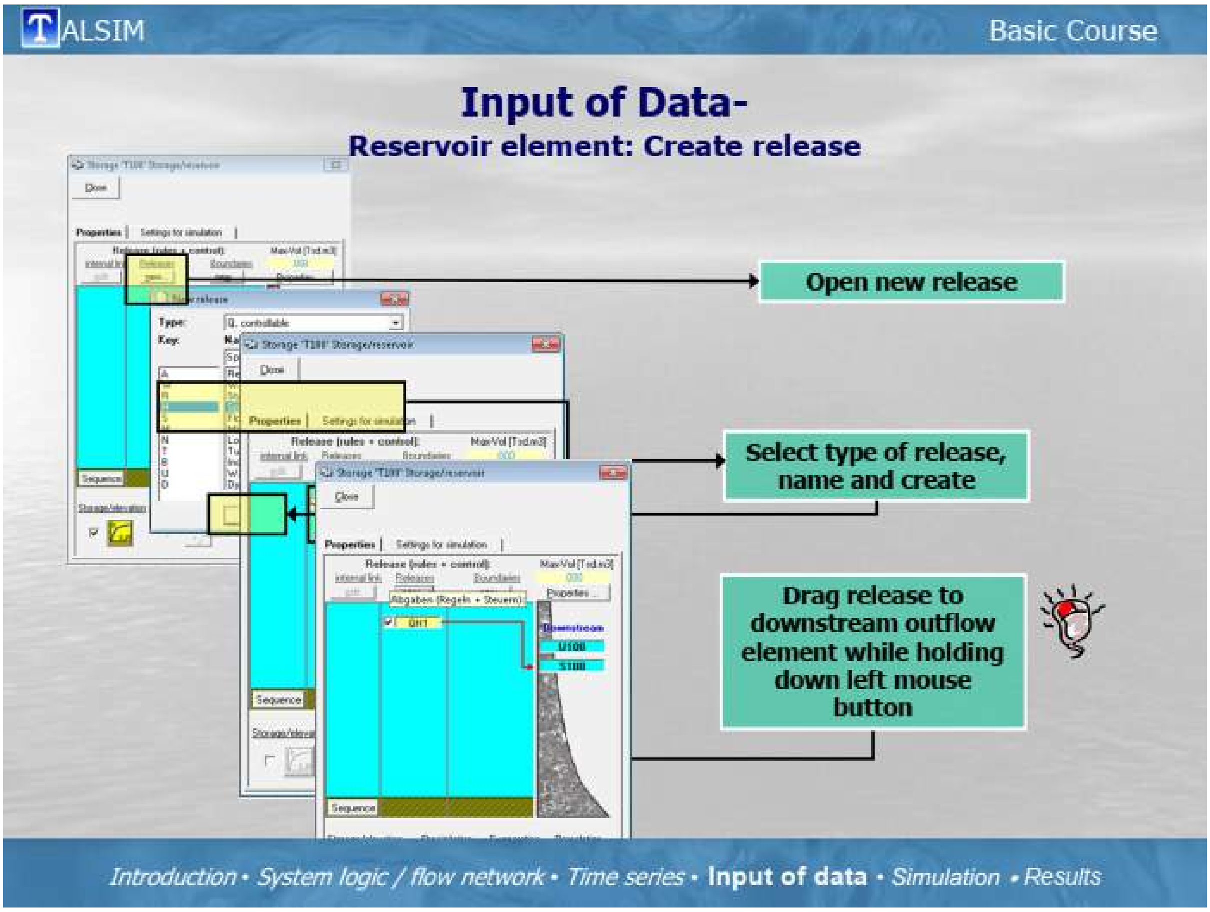
Input masks		
Geometry (1)	**Local losses/ yield** (2)	**Releases** (3)
a) Properties b) Storage-Elevation curve	a) Precipitation b) Evaporation c) Percolation	a) Different kinds and number of releases b) Internal dependencies c) Connection with system states
Options and Parameter		
a) h_{max}, V_{max} • h, V: high water discharge height and volume a) Volume characteristic curve ($V_{(h)}$), Surface characteristic curve ($A_{(h)}$)	Each in the form of a mean value and constant yearly/ weekly / daily patterns or a time series	a) Functions dependent on the volume (V) b) Reduction of releases by defined thresholds c) Connection to any previously defined system states

Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*


TALSIM
Basic Course
Input of Data-
Example: Reservoir element (T100)
Crest: 255 [m.a.s.l.]
Storage at crest: 30641 [Tsd.m³]
Elevation Spillways: 251.8 [masl]
Storage at Spillways: 25060 [Tsd.m³]
Elevation bottom: 208 [masl]
Attributes:Storage 'T100' Storage/reservoir
Max. storage (at crest)
Spillway
Bottom
Change of max. storage
Adjust functions
Keep functions untouched
OK
Cancel
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Example: Reservoir element (T100)
Function to insert with:
Storage [Tsd.m³]
Elevation [m.a.s.l.]
Surface [ha]
Important:
Graph is only refreshed after pressing RETURN
Do not forget to save!
Function:Storage/elevation curve
Apply function from other elements
Adjust column
Capacity curve
Surface [ha]
Elev.
Surface
Press <RETURN> when entering values!
Save
Close
Ascending
Cancel
Axis titles ...
insert sampling point
delete sampling point
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Input of Data-
Storage element
Definition internal dependencies
Definition of (hydraulic) outflow boundaries
Create releases
Access to storage-elevation curve
Access to initial storage
Access to properties
Connection of the single releases to the available downstream elements
Access to local losses/yield
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

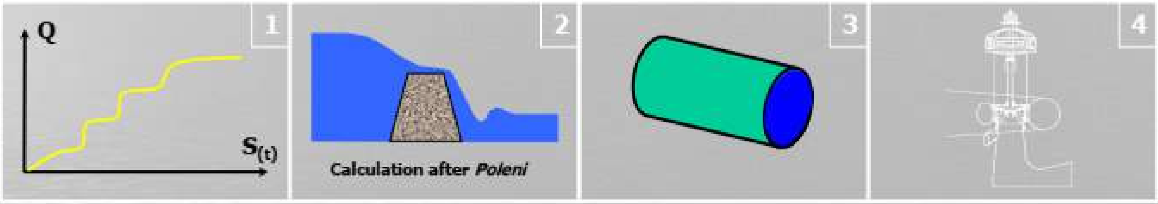

TALSIM
Basic Course
Input of Data-
Reservoir element: Create release
Open new release
Select type of release, name and create
Drag release to downstream outflow element while holding down left mouse button
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

TALSIM Basic Course

Input of Data-
Reservoir: Operation rules

Calculation options

As a function	Weir hydraulics	Pipeline	Turbine



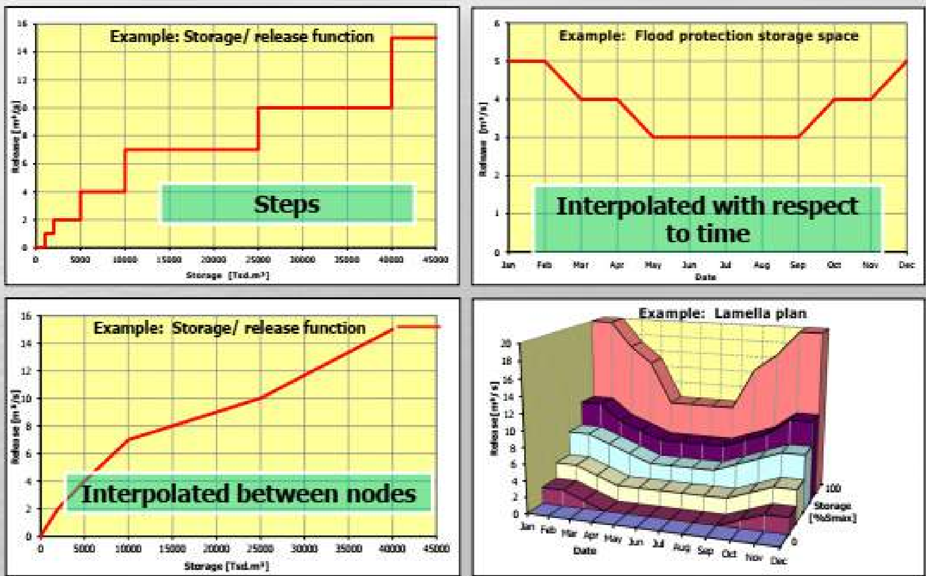
Properties

As a function	Weir hydraulics	Pipeline	Turbine
Function f(s) Time-dependent const./ variable annual change Lamella plan	Height of weir edges Overflow breadth Overflow coefficient Combination with system conditions	Pipe cross-section with: L, D, k Local losses Tailwater level	Power Coefficient of losses, Absorbtion capacity Q_{max} Efficiency curve Tailwater level

Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

TALSIM Basic Course

Input of Data-
Reservoir element: Examples of functions



Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

TALSIM Basic Course

Input of Data-
Example: Reservoir element (T100)

Designation	Identifier	Function	Sequence	Interpolation	
				Node	Time
Flood discharge:	QH1	Weir	S100	-	-
Flood protection zone:	QS1	Const. JJG	S100	-	Yes
Control output:	QR1	Character-istic Curve	S100	Yes	-
Water supply:	QW1		U100	Yes	-

Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

TALSIM Basic Course

Input of Data-
Example: Storage element (T100)

Flood discharge QH1

Tailwater level: -

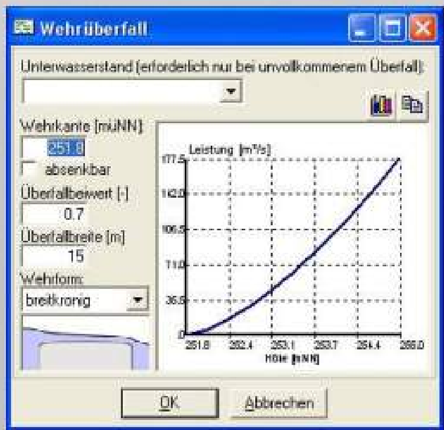
Weir Border: 251.8 [m.a.s.l.]
(compare to master data!)

Lowerable: no

Spillway coefficient: 0.7 [-]

Spillway width: 15 [m]

Spillway width: broad-crested



Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

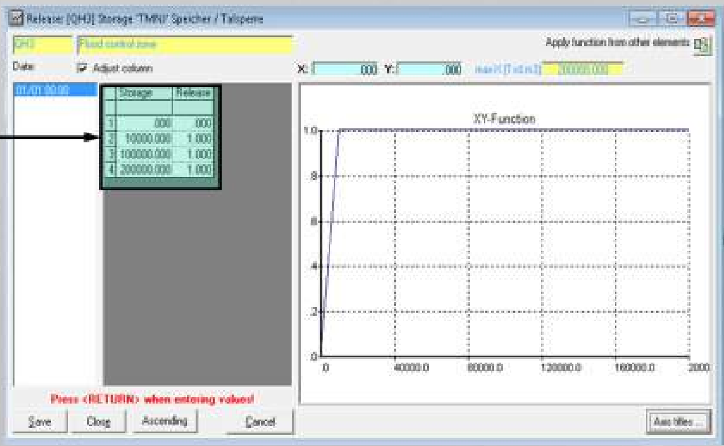
TALSIM Basic Course

Input of Data-

Example: Storage element (T100)

Flood protection zone QS1

Input values



Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

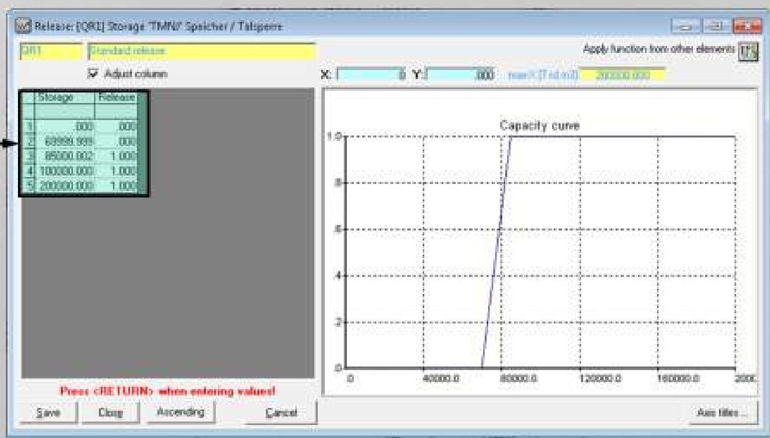
TALSIM Basic Course

Input of Data

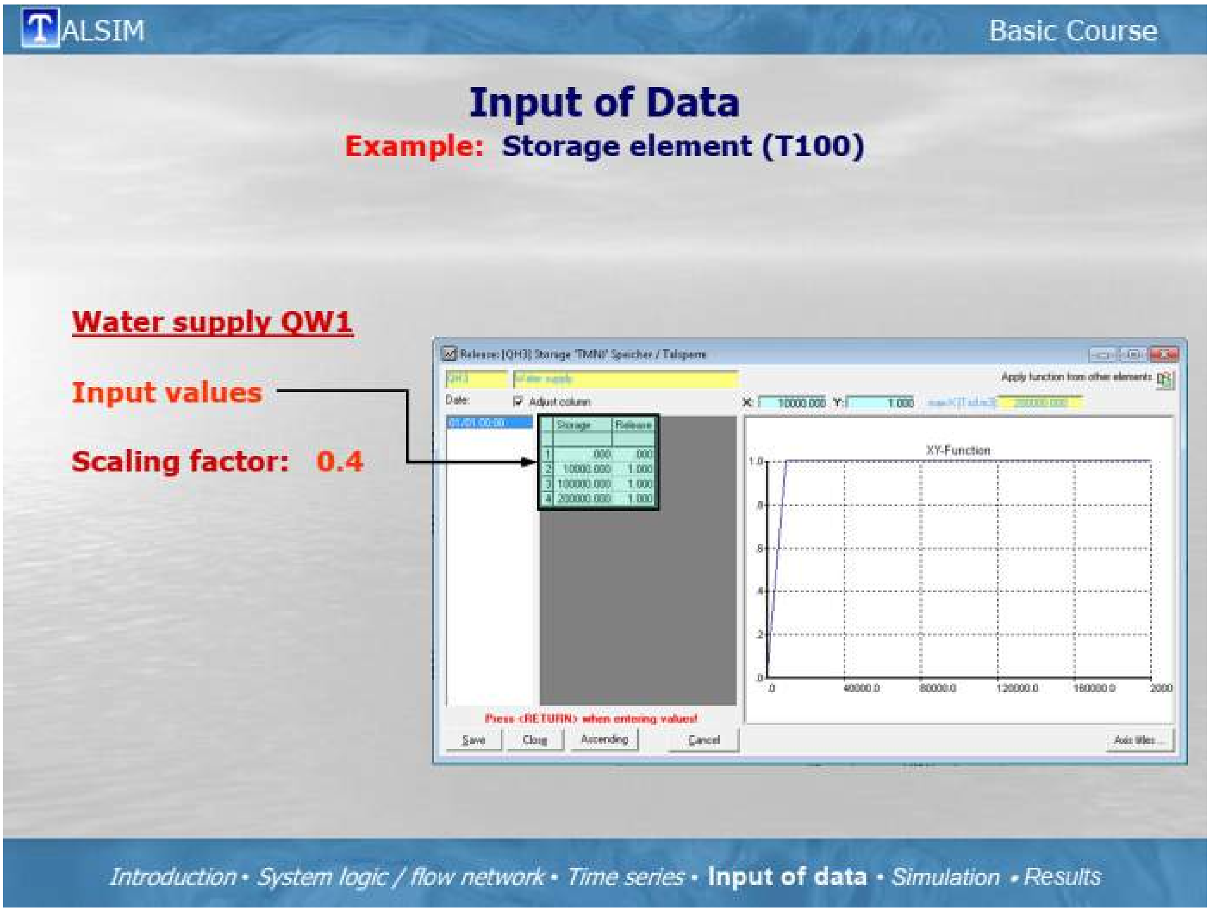
Example: Storage element (T100)

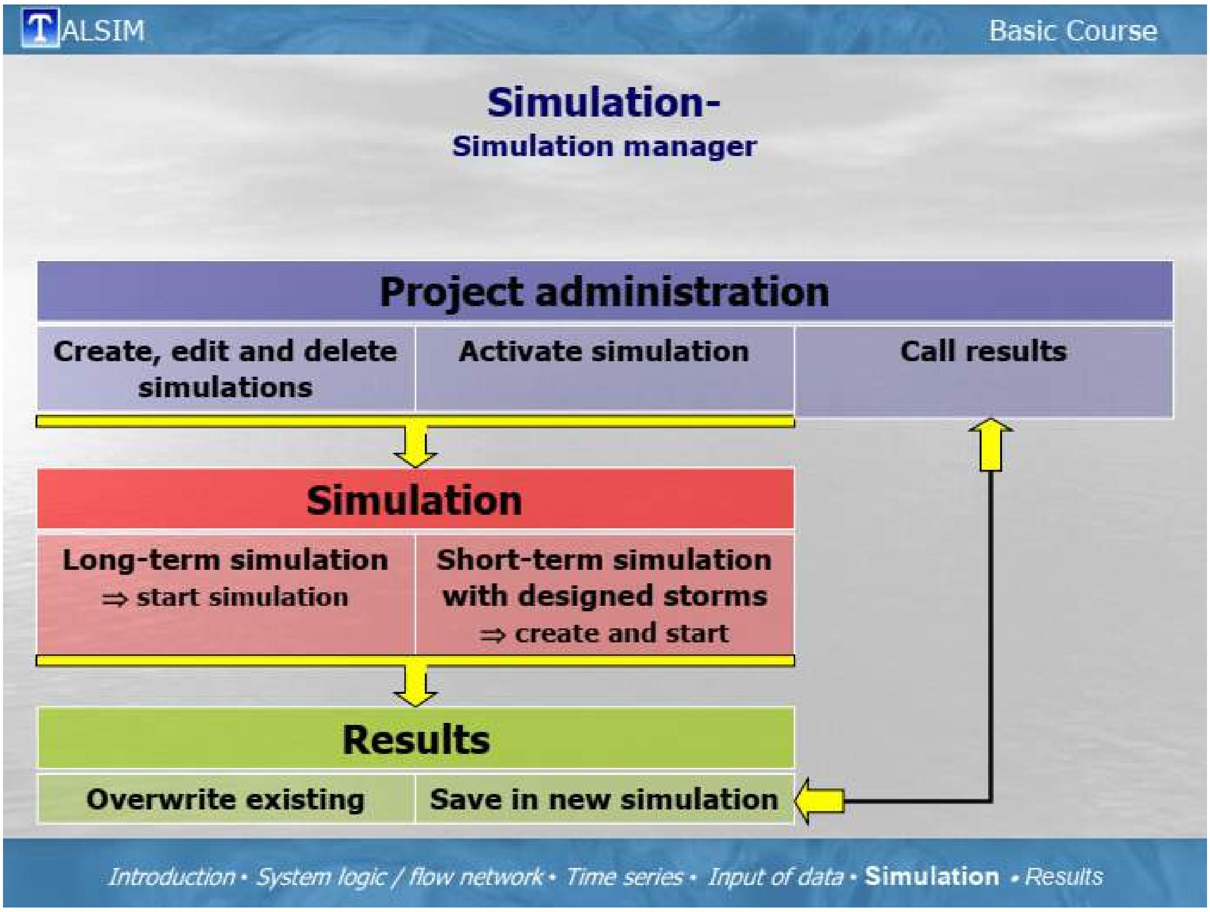
Control output QR1

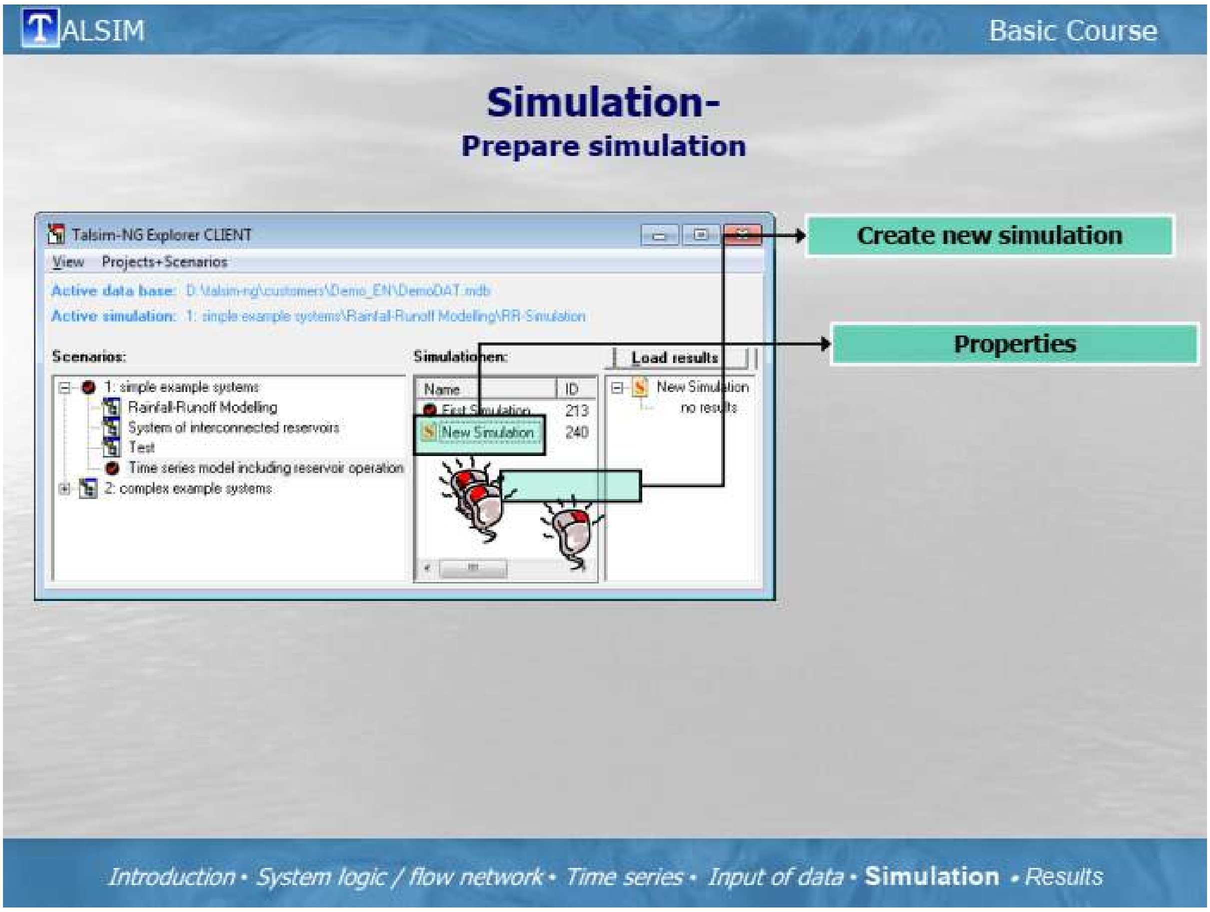
Input values

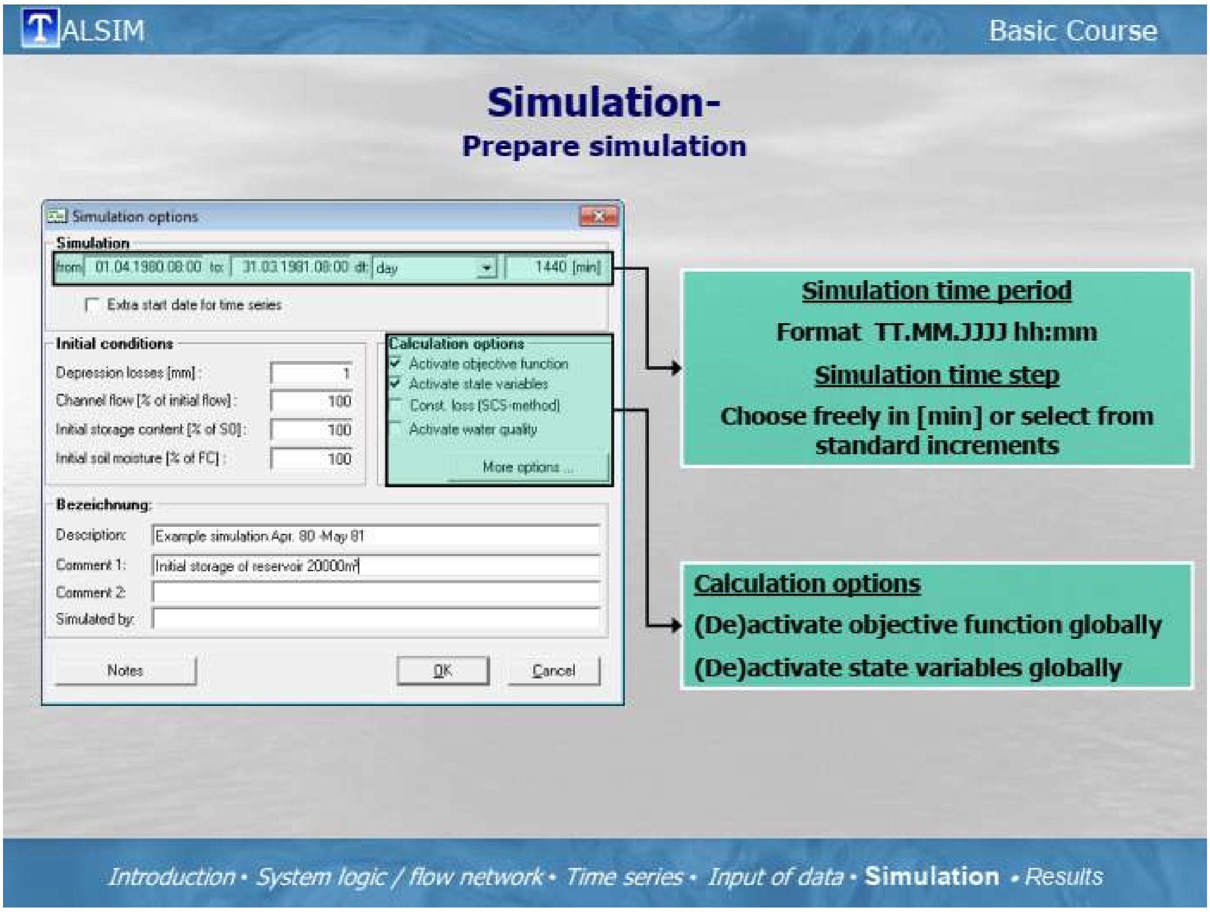


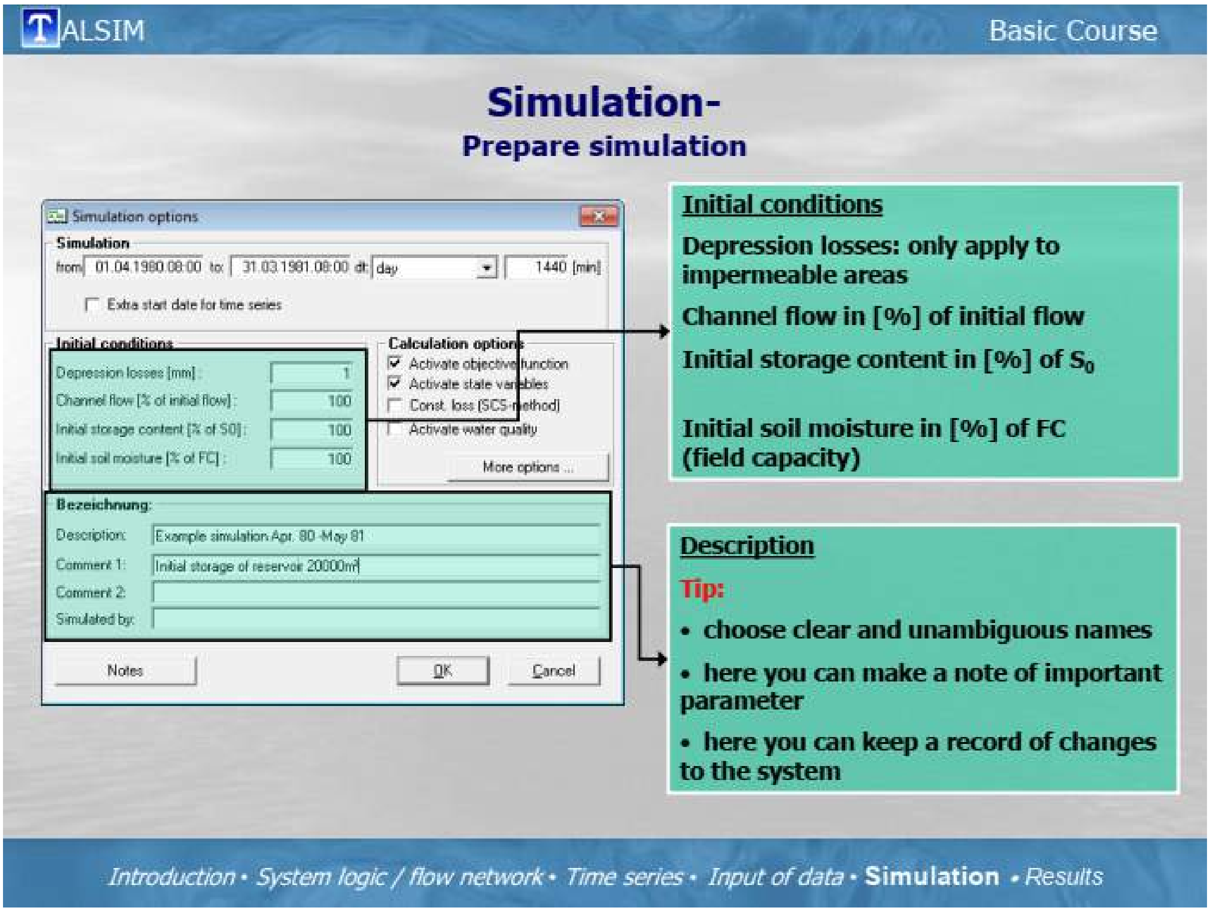
Introduction • System logic / flow network • Time series • **Input of data** *• Simulation • Results*

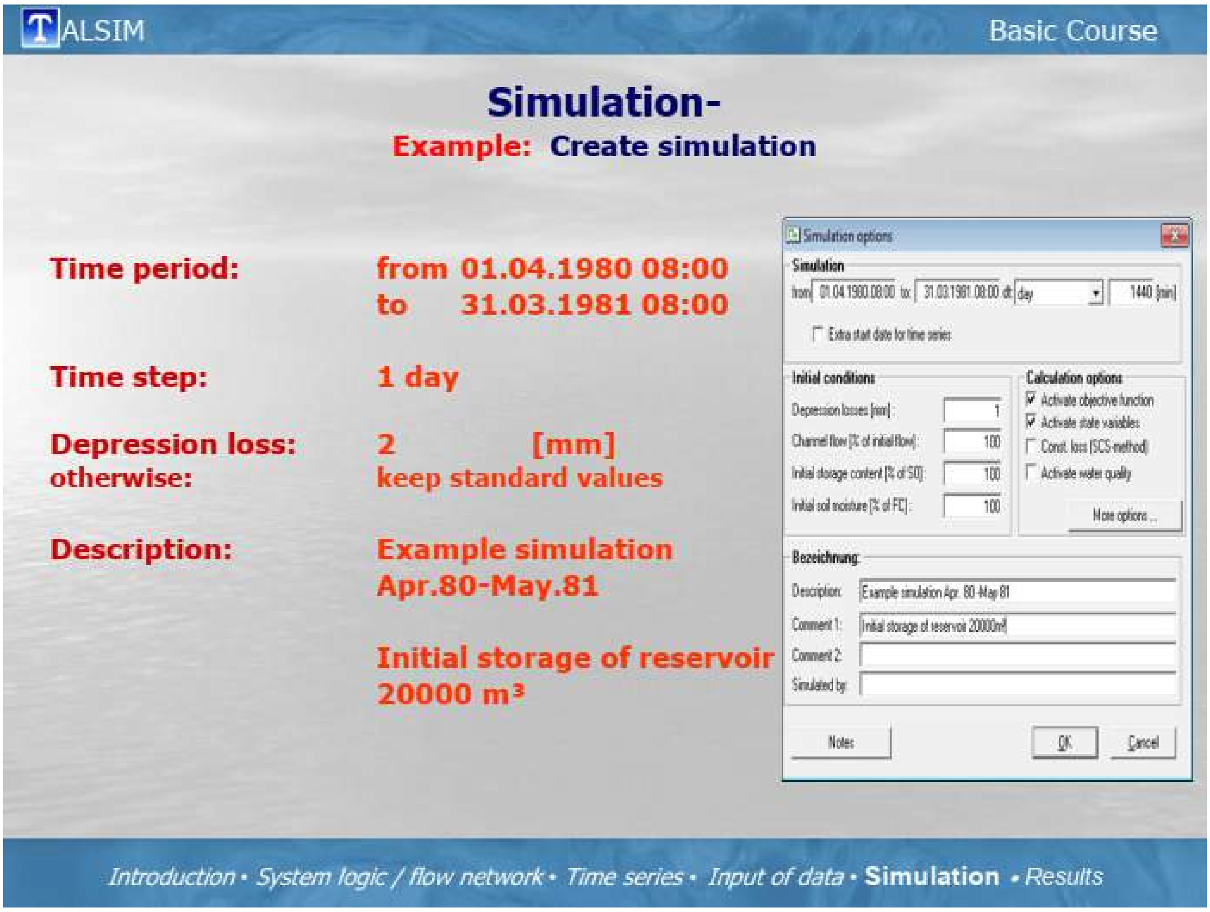

TALSIM
Basic Course
Input of Data
Example: Storage element (T100)
Water supply QW1
Input values
Scaling factor: 0.4
Apply function from other elements
Adjust column
Storage
Release
XY-Function
Press <RETURN> when entering values!
Save
Close
Ascending
Cancel
Axis titles...
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Simulation manager
Project administration
Create, edit and delete simulations
Activate simulation
Call results
Simulation
Long-term simulation
⇒ start simulation
Short-term simulation with designed storms
⇒ create and start
Results
Overwrite existing
Save in new simulation
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Prepare simulation
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Active data base: D:\talsim-ng\customers\Demo_EN\DemoDAT.mdb
Active simulation: 1: simple example systems\Rainfall-Runoff Modelling\RR-Simulation
Scenarios:
1: simple example systems
Rainfall-Runoff Modelling
System of interconnected reservoirs
Test
Time series model including reservoir operation
2: complex example systems
Simulationen:
Load results
Name
ID
First Simulation
213
New Simulation
240
New Simulation
no results
Create new simulation
Properties
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Prepare simulation
Simulation options
Simulation
from: 01.04.1980 08:00 to: 31.03.1981 08:00 dt: day 1440 [min]
Extra start date for time series
Initial conditions
Depression losses [mm]: 1
Channel flow [% of initial flow]: 100
Initial storage content [% of S0]: 100
Initial soil moisture [% of FC]: 100
Calculation options
Activate objective function
Activate state variables
Const. loss (SCS-method)
Activate water quality
More options ...
Bezeichnung:
Description: Example simulation Apr. 80 -May 81
Comment 1: Initial storage of reservoir 20000m³
Comment 2:
Simulated by:
Notes
OK
Cancel
Simulation time period
Format TT.MM.JJJJ hh:mm
Simulation time step
Choose freely in [min] or select from standard increments
Calculation options
(De)activate objective function globally
(De)activate state variables globally
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Prepare simulation
Simulation options
Simulation
from 01.04.1980 08:00 to: 31.03.1981 08:00 dt: day 1440 [min]
Extra start date for time series
Initial conditions
Depression losses [mm]: 1
Channel flow [% of initial flow]: 100
Initial storage content [% of S0]: 100
Initial soil moisture [% of FC]: 100
Calculation options
Activate objective function
Activate state variables
Const. loss (SCS-method)
Activate water quality
More options ...
Bezeichnung:
Description: Example simulation Apr. 80 -May 81
Comment 1: Initial storage of reservoir 20000m³
Comment 2:
Simulated by:
Notes
OK
Cancel
Initial conditions
Depression losses: only apply to impermeable areas
Channel flow in [%] of initial flow
Initial storage content in [%] of S0
Initial soil moisture in [%] of FC (field capacity)
Description
Tip:
• choose clear and unambiguous names
• here you can make a note of important parameter
• here you can keep a record of changes to the system
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Example: Create simulation
Time period:
from 01.04.1980 08:00
to 31.03.1981 08:00
Time step:
1 day
Depression loss:
otherwise:
2 [mm]
keep standard values
Description:
Example simulation Apr.80-May.81
Initial storage of reservoir 20000 m³
Simulation options
Simulation
from 01.04.1980 08:00 to: 31.03.1981 08:00 dt: day 1440 [min]
Extra start date for time series
Initial conditions
Depression losses [mm]: 1
Channel flow [% of initial flow]: 100
Initial storage content [% of S0]: 100
Initial soil moisture [% of FC]: 100
Calculation options
Activate objective function
Activate state variables
Const. loss (SCS-method)
Activate water quality
More options ...
Bezeichnung:
Description: Example simulation Apr. 80 -May 81
Comment 1: Initial storage of reservoir 20000m³
Comment 2:
Simulated by:
Notes
OK
Cancel
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

TALSIM Basic Course

Simulation-
Types of simulations

Simulation	
Long-term simulation	**Short-term simulation**
Stress by connected time series	Stress by designed rainfall and generated runoff
Long-term view Statistic evaluation of target variables	View of extreme events Effect of a flood event on defined recurrence period Examination of system under extreme conditions, safety check for reservoirs/dams

Introduction • System logic / flow network • Time series • Input of data • **Simulation** • Results

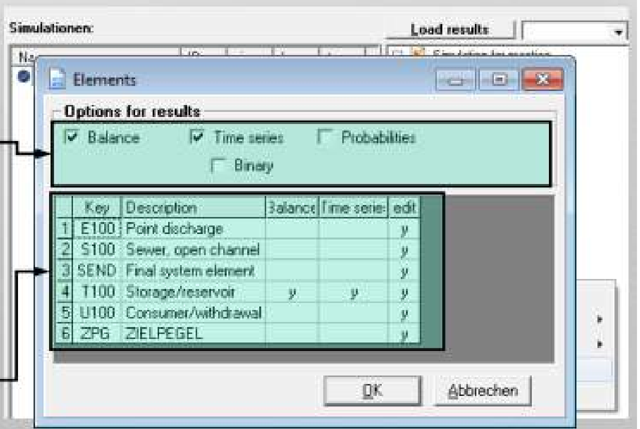
TALSIM Basic Course

Simulation-
Example: Output of results

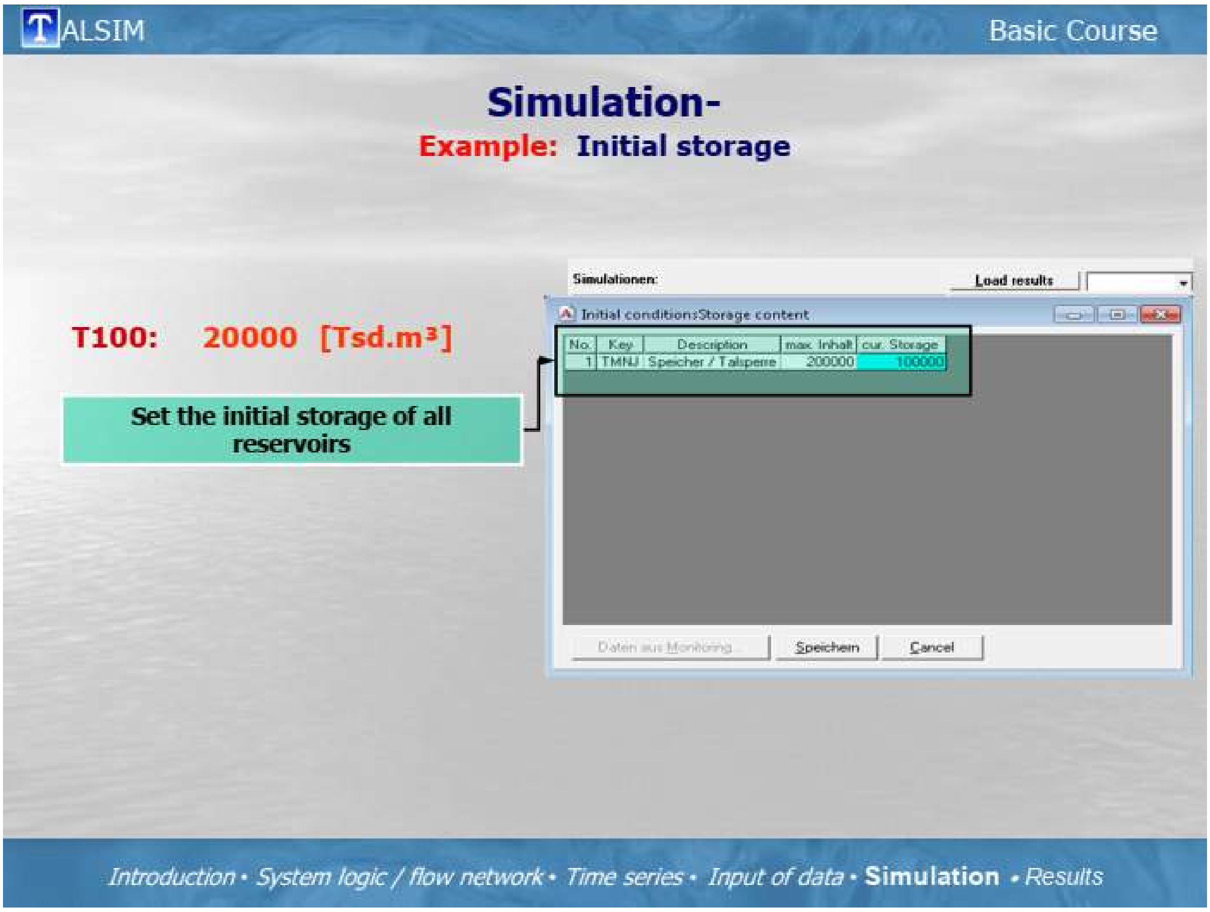
Options to select

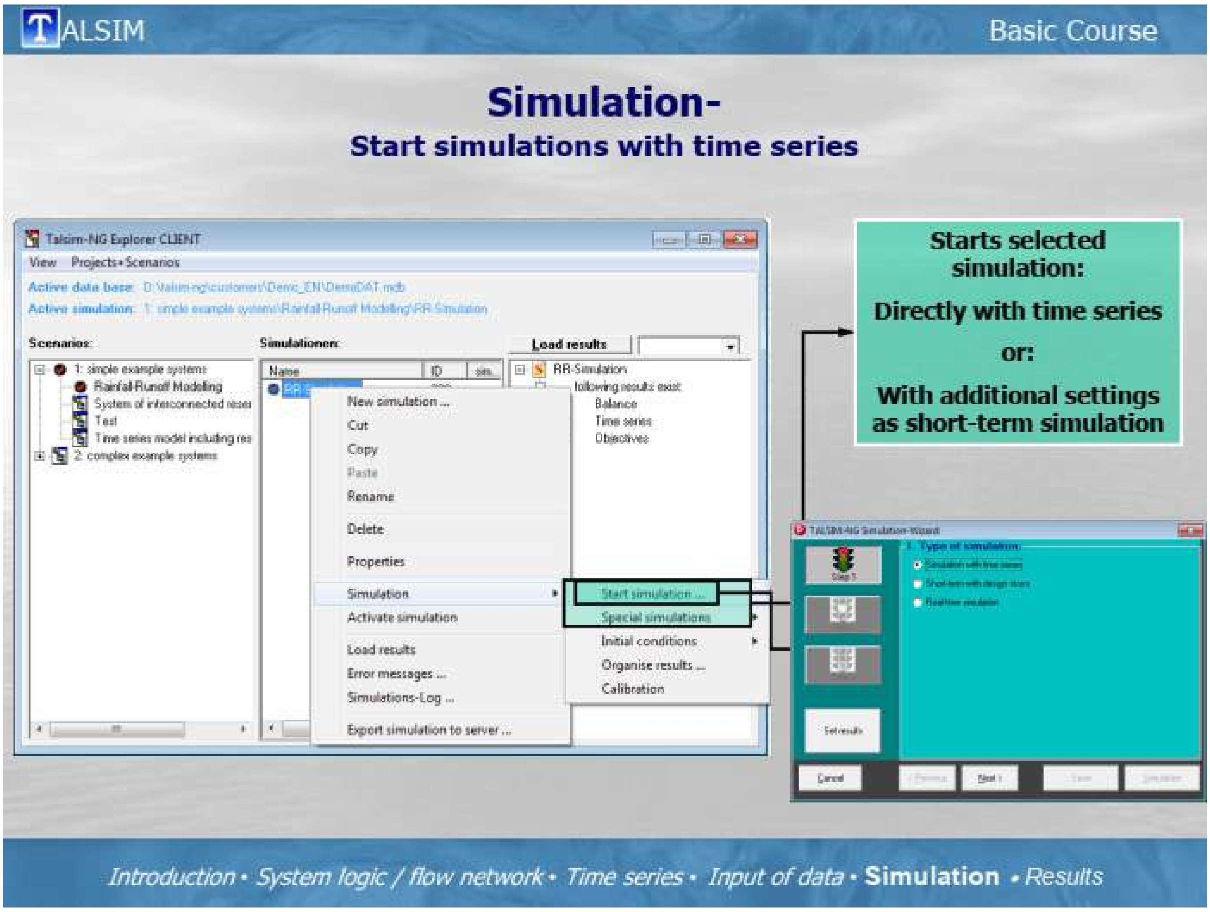
(De)activate output globally:
- Balances
- Time series
- Probability distributions

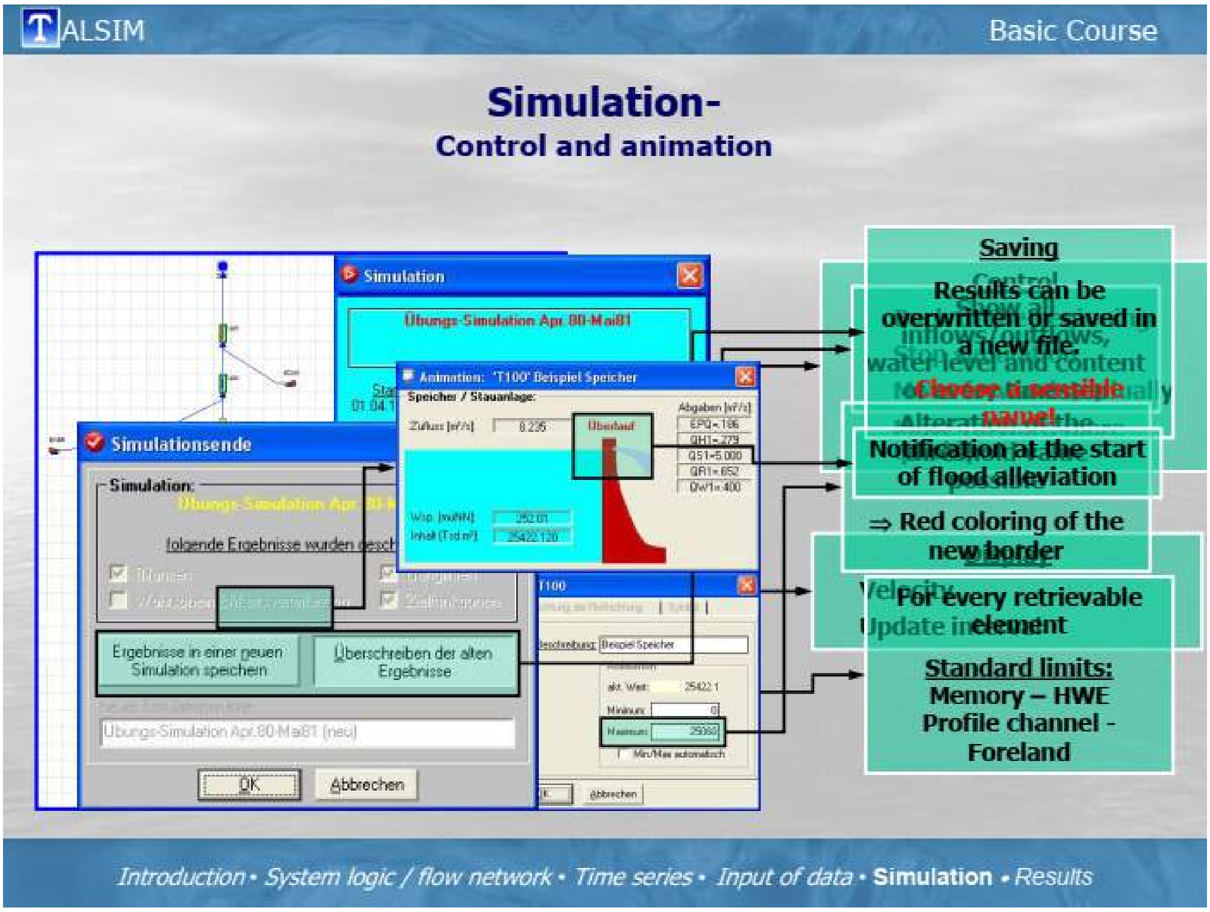
(De)activate output per element by double clicking
- Balances
- Time series

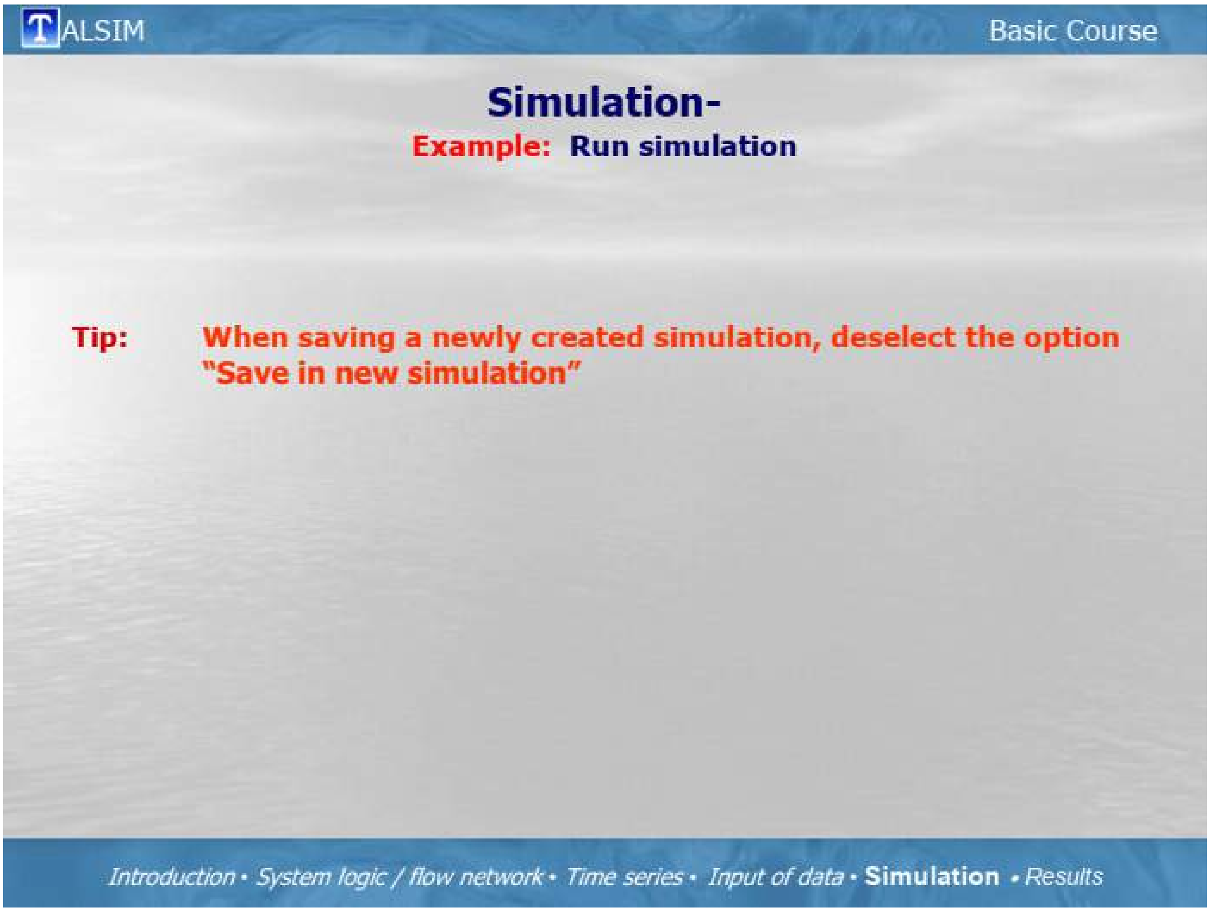


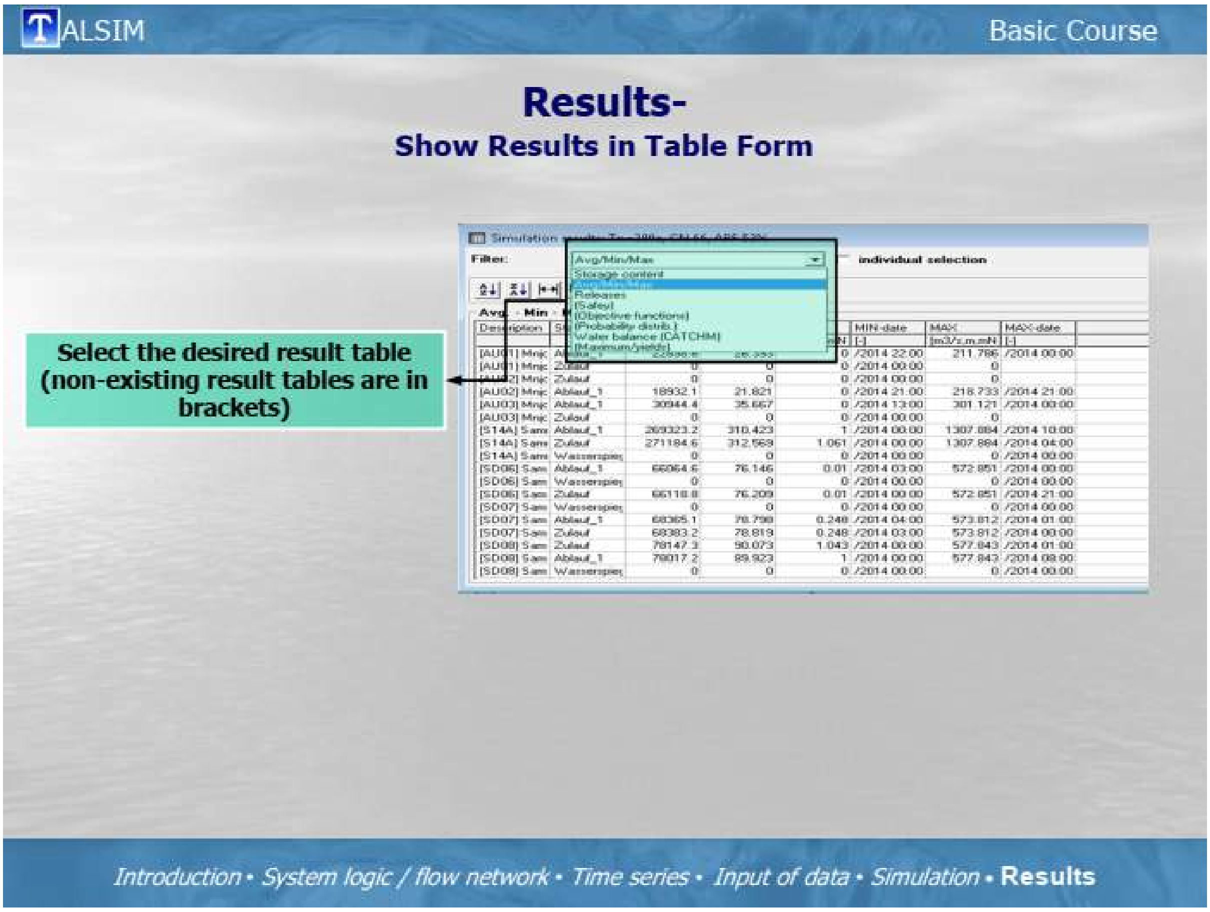
Introduction • System logic / flow network • Time series • Input of data • **Simulation** • Results

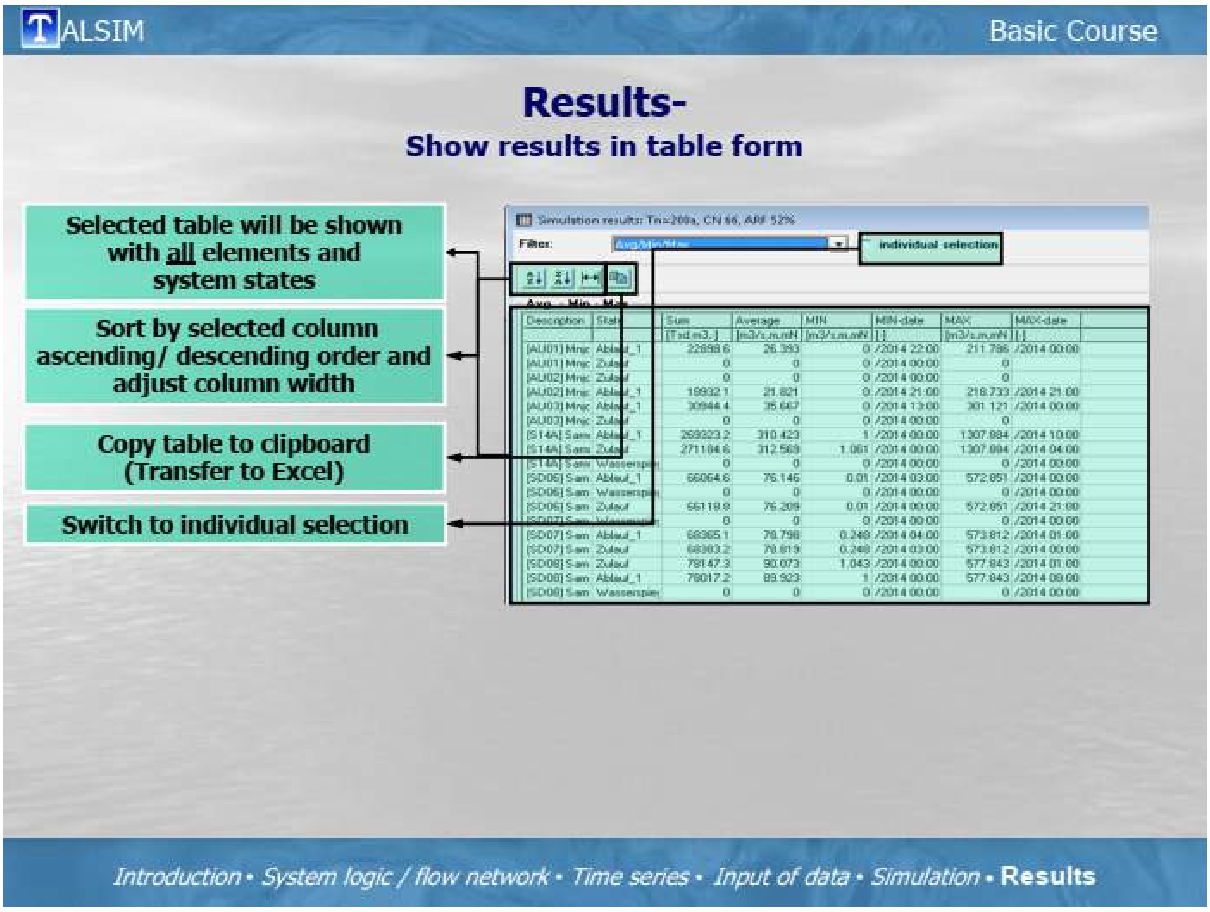

TALSIM
Basic Course
Simulation-
Example: Initial storage
T100: 20000 [Tsd.m³]
Set the initial storage of all reservoirs
Simulationen:
Load results
Initial conditions:Storage content
No. Key Description max. Inhalt cur. Storage
1 TMNJ Speicher / Talsperre 200000 100000
Daten aus Monitoring
Speichern
Cancel
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

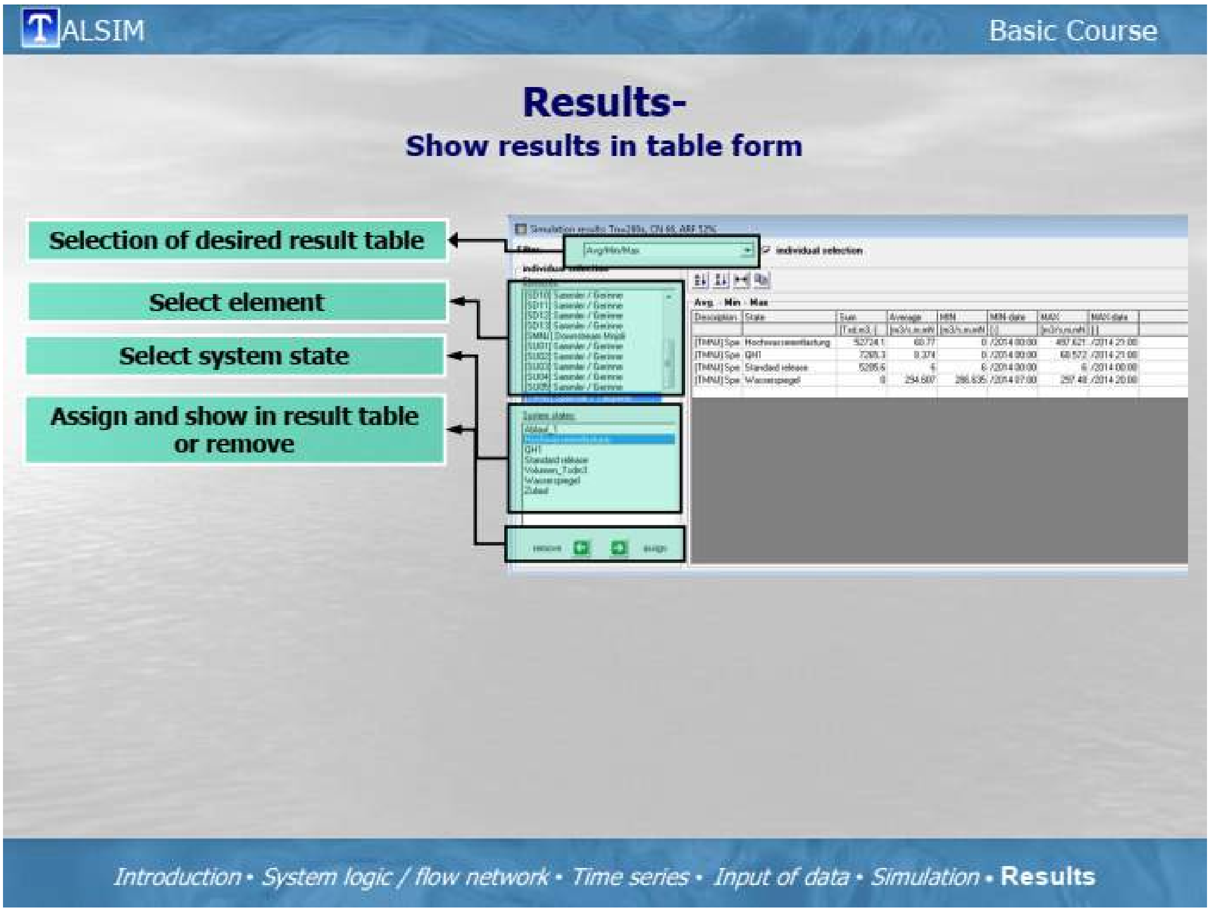

TALSIM
Basic Course
Simulation-
Start simulations with time series
Talsim-NG Explorer CLIENT
View Projects+Scenarios
Scenarios:
Simulationen:
Load results
1: simple example systems
Rainfall-Runoff Modelling
2: complex example systems
RR-Simulation
following results exist
Balance
Time series
Objectives
New simulation ...
Cut
Copy
Paste
Rename
Delete
Properties
Simulation
Activate simulation
Load results
Error messages ...
Simulations-Log ...
Export simulation to server ...
Start simulation ...
Special simulations
Initial conditions
Organise results ...
Calibration
Starts selected simulation:
Directly with time series
or:
With additional settings as short-term simulation
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

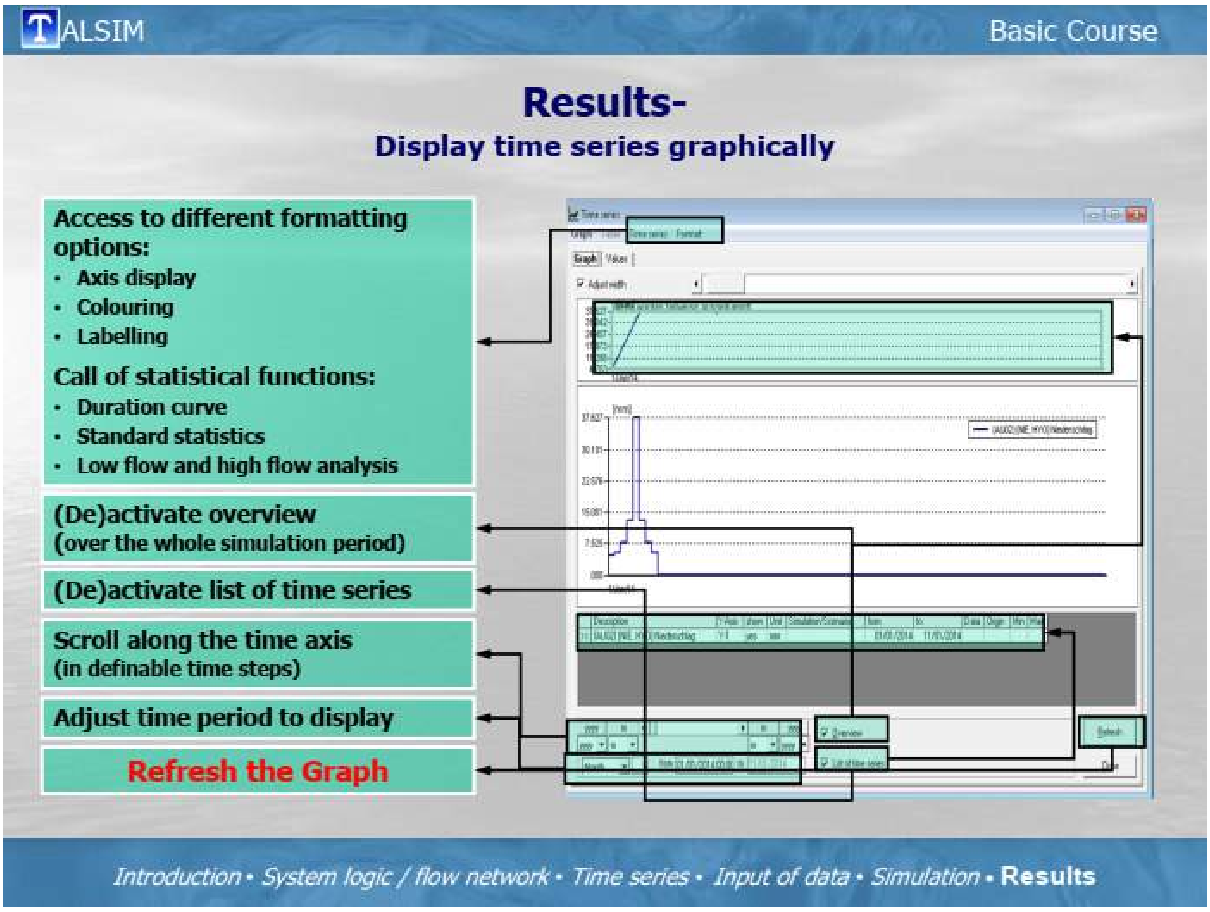

TALSIM
Basic Course
Simulation-
Control and animation
Saving
Results can be overwritten or saved in a new file.
Choose a sensible name!
Notification at the start of flood alleviation
⇒ Red coloring of the new border
For every retrievable element
Standard limits:
Memory – HWE
Profile channel - Foreland
Simulation
Simulationsende
Ergebnisse in einer neuen Simulation speichern
Überschreiben der alten Ergebnisse
OK
Abbrechen
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Simulation-
Example: Run simulation
Tip:
When saving a newly created simulation, deselect the option "Save in new simulation"
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Results-
Show Results in Table Form
Select the desired result table (non-existing result tables are in brackets)
individual selection
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Results-
Show results in table form
Selected table will be shown with all elements and system states
Sort by selected column ascending/ descending order and adjust column width
Copy table to clipboard (Transfer to Excel)
Switch to individual selection
individual selection
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Results-
Show results in table form
Selection of desired result table
Select element
Select system state
Assign and show in result table or remove
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results


TALSIM
Basic Course
Results-
Display time series graphically
Access to different formatting options:
• Axis display
• Colouring
• Labelling
Call of statistical functions:
• Duration curve
• Standard statistics
• Low flow and high flow analysis
(De)activate overview (over the whole simulation period)
(De)activate list of time series
Scroll along the time axis (in definable time steps)
Adjust time period to display
Refresh the Graph
Introduction • System logic / flow network • Time series • Input of data • Simulation • Results

TALSIM Basic Course

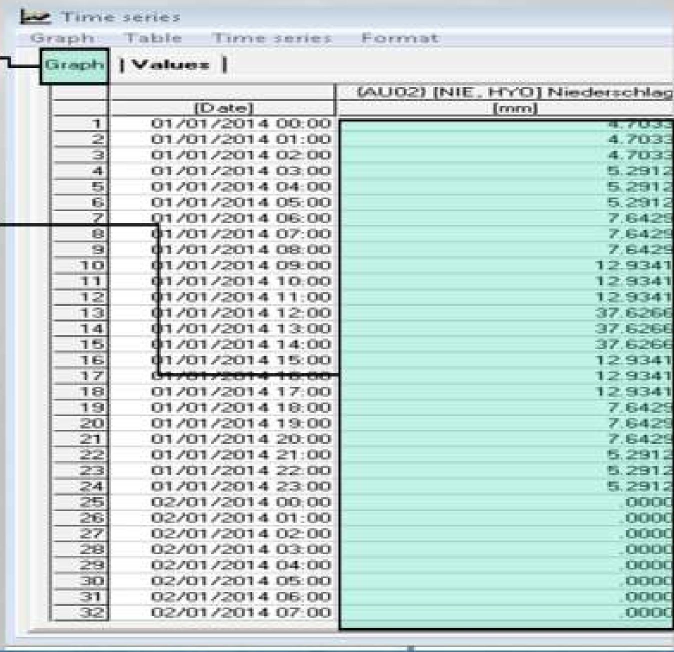
Results-
Display time series graphically

Switch to table of values:

Display for time period is set in Graphics tab

Exchange with Spreadsheet program:

Select Values and copy (Ctrl + C)



	[Date]	{AU02} [NIE , HYO] Niederschlag [mm]
1	01/01/2014 00:00	4.7033
2	01/01/2014 01:00	4.7033
3	01/01/2014 02:00	4.7033
4	01/01/2014 03:00	5.2912
5	01/01/2014 04:00	5.2912
6	01/01/2014 05:00	5.2912
7	01/01/2014 06:00	7.6429
8	01/01/2014 07:00	7.6429
9	01/01/2014 08:00	7.6429
10	01/01/2014 09:00	12.9341
11	01/01/2014 10:00	12.9341
12	01/01/2014 11:00	12.9341
13	01/01/2014 12:00	37.6266
14	01/01/2014 13:00	37.6266
15	01/01/2014 14:00	37.6266
16	01/01/2014 15:00	12.9341
17	[illegible]	12.9341
18	01/01/2014 17:00	12.9341
19	01/01/2014 18:00	7.6429
20	01/01/2014 19:00	7.6429
21	01/01/2014 20:00	7.6429
22	01/01/2014 21:00	5.2912
23	01/01/2014 22:00	5.2912
24	01/01/2014 23:00	5.2912
25	02/01/2014 00:00	.0000
26	02/01/2014 01:00	.0000
27	02/01/2014 02:00	.0000
28	02/01/2014 03:00	.0000
29	02/01/2014 04:00	.0000
30	02/01/2014 05:00	.0000
31	02/01/2014 06:00	.0000
32	02/01/2014 07:00	.0000

Introduction • System logic / flow network • Time series • Input of data • Simulation • **Results**

TALSIM Basic Course

Results-
Example: Check selected results

Maximum and minimum storage = ?

Volume released by the reservoir = ?

Display time series graphically:

- **Inflow to the reservoir**
- **Flood relief delivery**
- **Flood protection zone delivery**
- **Storage**

Introduction • System logic / flow network • Time series • Input of data • Simulation • **Results**

TALSIM Basic Course

End of day 1

TALSIM Basic Course

TALSIM – Basic Course

Content – Day 1

1. Introduction to the program
2. Basic concepts of reservoir operations
3. System setup in TALSIM
4. Long-term simulation and presentation of results

Content – Day 2

1. **RR-Modelling with TALSIM**
2. **System states and short-term storm simulations**
3. **Interface: Import/Export**
4. **Summary and additional questions**

TALSIM Basic Course

Rainfall Runoff Modelling in TALSIM

Theory and Practice

- Data basis and system resolution
- Selection of computation mode
- Catchment parameter
- Data basis for the computation with runoff coefficient (ϕ) and SCS-method
- Data basis for the Soil moisture model

Basics • *Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model*

TALSIM Basic Course

Basics for the System Setup-

Evaluation of the data basis

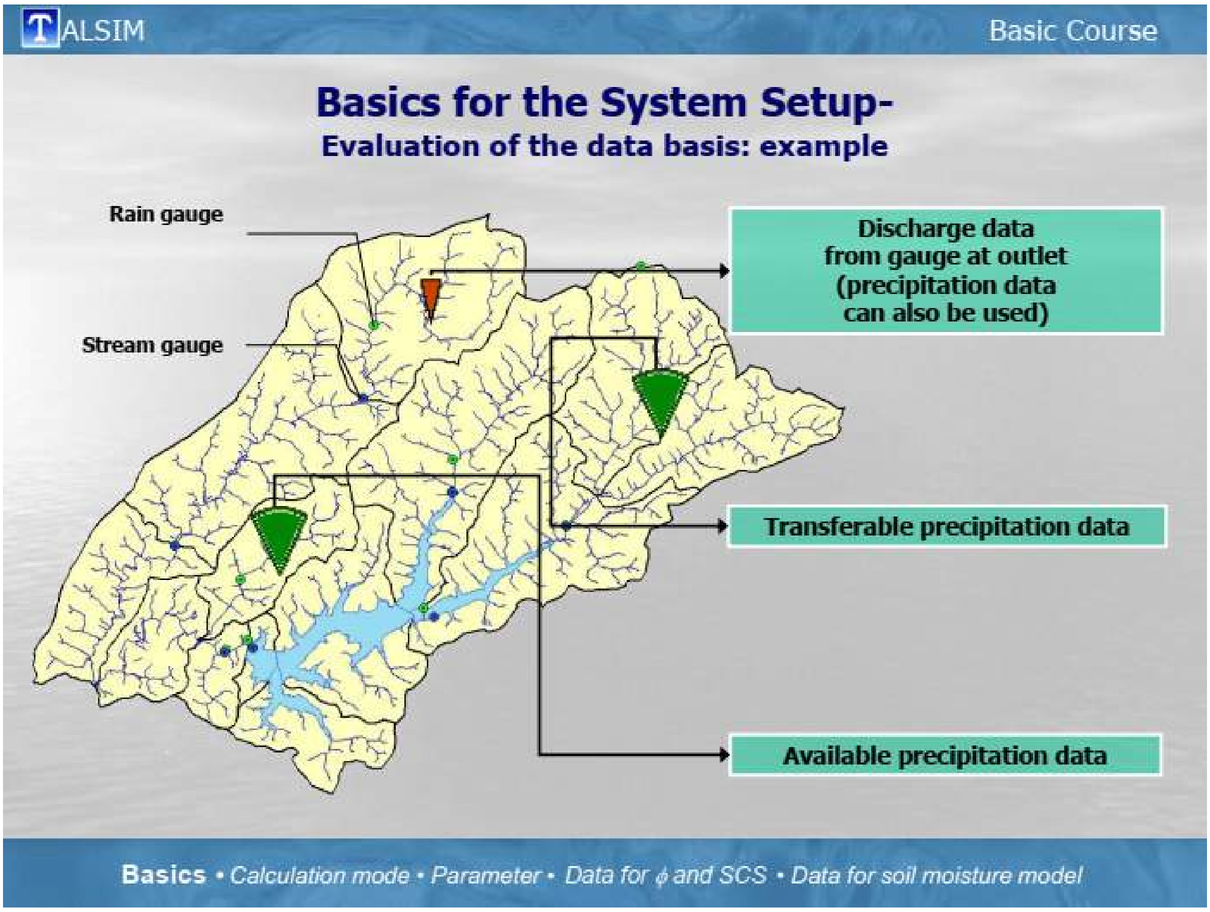
⇨ **Which data is available?**

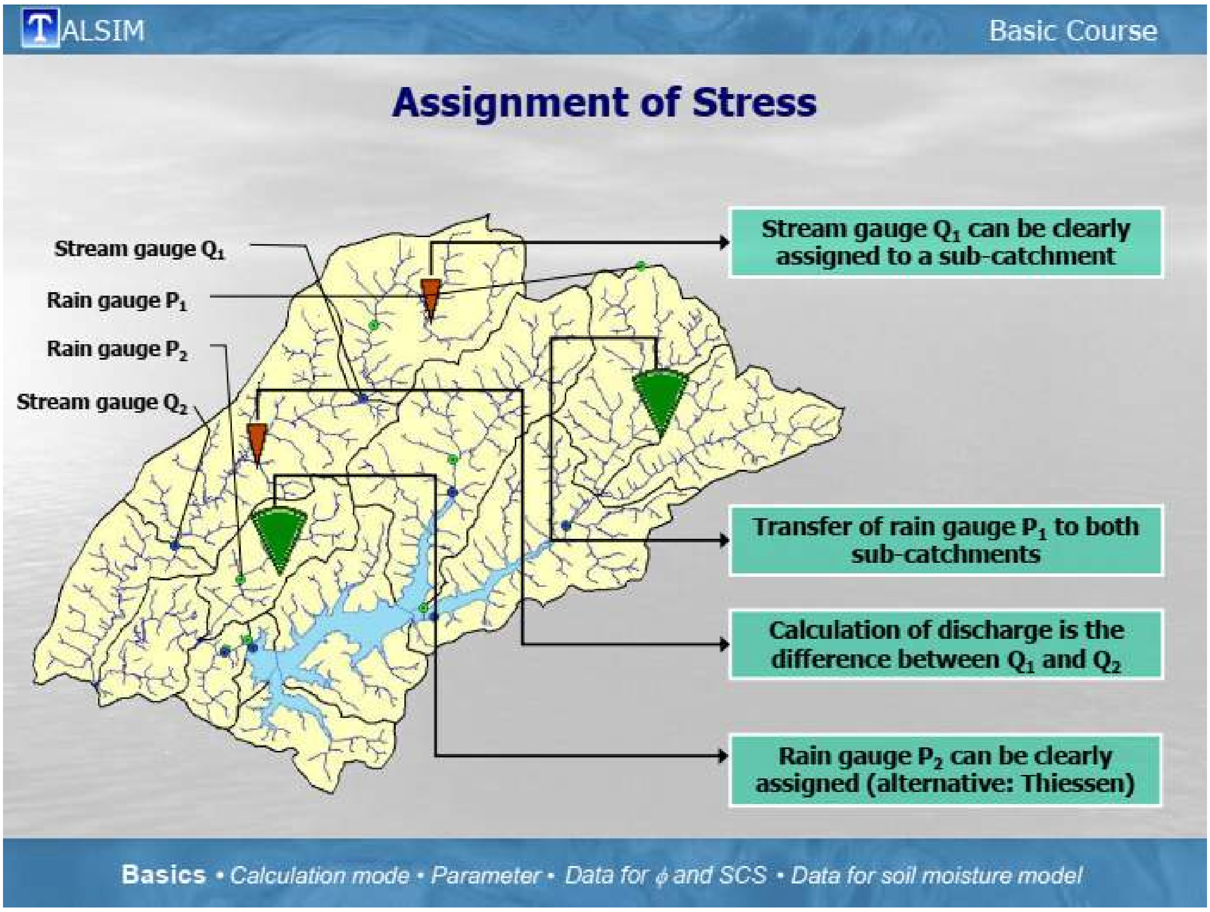
- Discharge at gauges
- Time series of precipitation

⇨ **Data basis decides on the type of model:**

only discharge	⇨ pure time series model ⇒ Discharge elements
only precipitation	⇨ pure rainfall runoff model ⇒ Sub-catchments
both	⇨ mixed model ⇒ Discharge elements and Sub-catchments

Basics • *Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model*

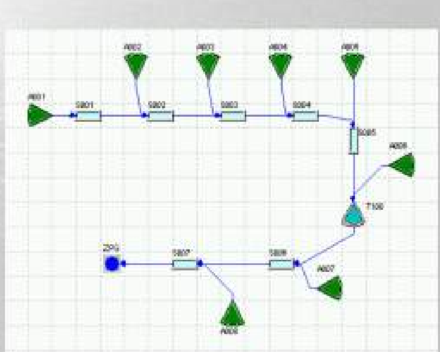

TALSIM
Basic Course
Basics for the System Setup-
Evaluation of the data basis: example
Rain gauge
Stream gauge
Discharge data from gauge at outlet (precipitation data can also be used)
Transferable precipitation data
Available precipitation data
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Assignment of Stress
Stream gauge Q1
Rain gauge P1
Rain gauge P2
Stream gauge Q2
Stream gauge Q1 can be clearly assigned to a sub-catchment
Transfer of rain gauge P1 to both sub-catchments
Calculation of discharge is the difference between Q1 and Q2
Rain gauge P2 can be clearly assigned (alternative: Thiessen)
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

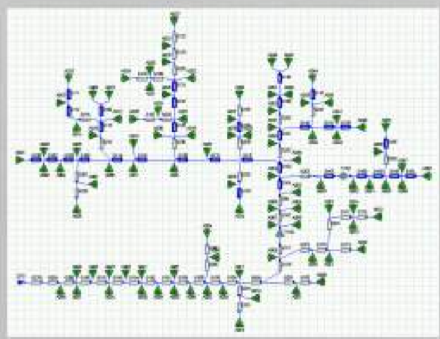
TALSIM Basic Course

System Resolution

- **Scope of tasks and data basis determine resolution of the system**
- **Simple rules for runoff generation (runoff coefficient, SCS) are generally combined with a coarse representation of the system**
- **The higher the degree of detail present, the more important it is to represent the streams accurately**



?

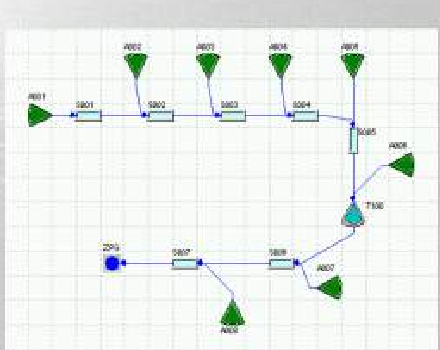


Basics • *Calculation mode* • *Parameter* • *Data for ϕ and SCS* • *Data for soil moisture model*

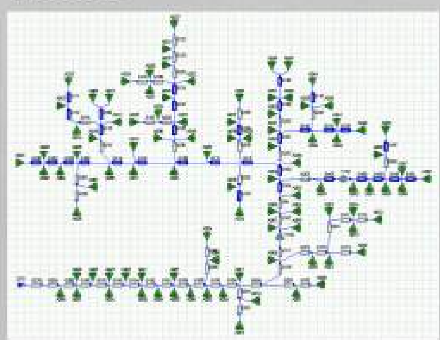
TALSIM Basic Course

System Resolution

Runoff concentration :	**Runoff concentration:**
Hydrograph of the surface runoff of a sub-catchment is transformed	**Refers mainly to surface runoff**
Routing in the channel:	**Routing in the channel:**
Representation is limited	**Detailed representation is possible**



?



Basics • *Calculation mode* • *Parameter* • *Data for ϕ and SCS* • *Data for soil moisture model*

TALSIM Basic Course

System Resolution

Low resolution:

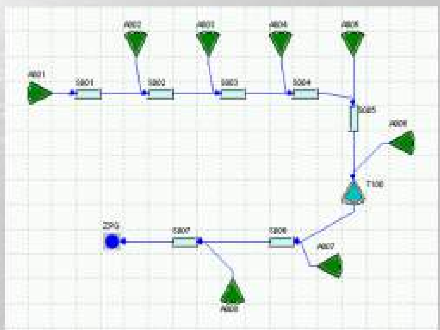
direct representation of **routing in the channel** is limited

- part of the routing is implicitly modelled by the **runoff concentration** in the sub-catchments

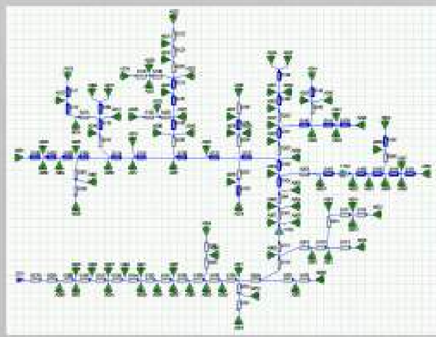
High resolution:

direct and detailed representation of **routing in the channel** is possible

- **runoff concentration** in the sub-catchments mainly represents the surface water flow until reaching the channel



?

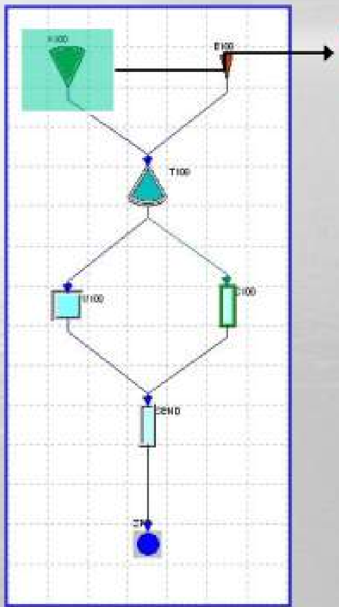


Basics • *Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model*

TALSIM Basic Course

Extend System by a Sub-catchment Element

Example system:



Extend the system by a sub-catchment
⇨ A100

Basics • *Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model*

TALSIM Basic Course

Calculation Modes-
Sub-catchment element

Calculation mode for runoff generation		
Runoff coefficient	**SCS-method**	**Soil moisture model**
1 Computation is simply done by the definition of a constant runoff coefficient (ϕ)	2 Computation by the method of the *Soil-Conservation-Service* Consideration of soil, land use and wetting ⇨ runoff coefficient varies with time	3 Complex computation of the water balance of a soil Simultaneous solution of all the soil processes per time step ⇨ Interflow, base flow
Parameter		
• Runoff coefficient f [-]	• CN-value [-] • Rain of previous 21 days [mm]	• Soil horizons, types • Land uses • Hydrologic response units (HRU) • Retention for Q_{Base} and $Q_{Interflow}$

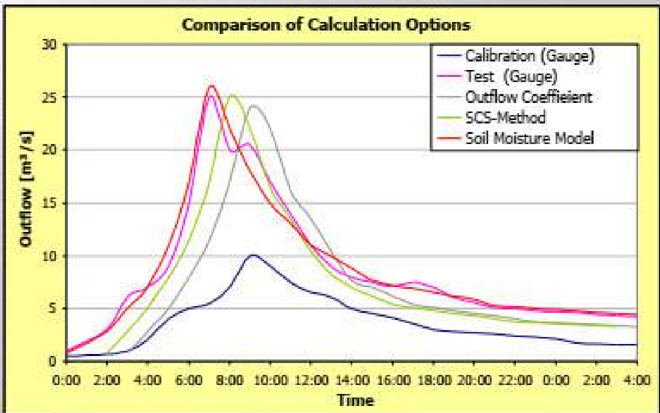
Basics • **Calculation mode** • *Parameter* • *Data for ϕ and SCS* • *Data for soil moisture model*

TALSIM Basic Course

Calculation Modes-
Applicability

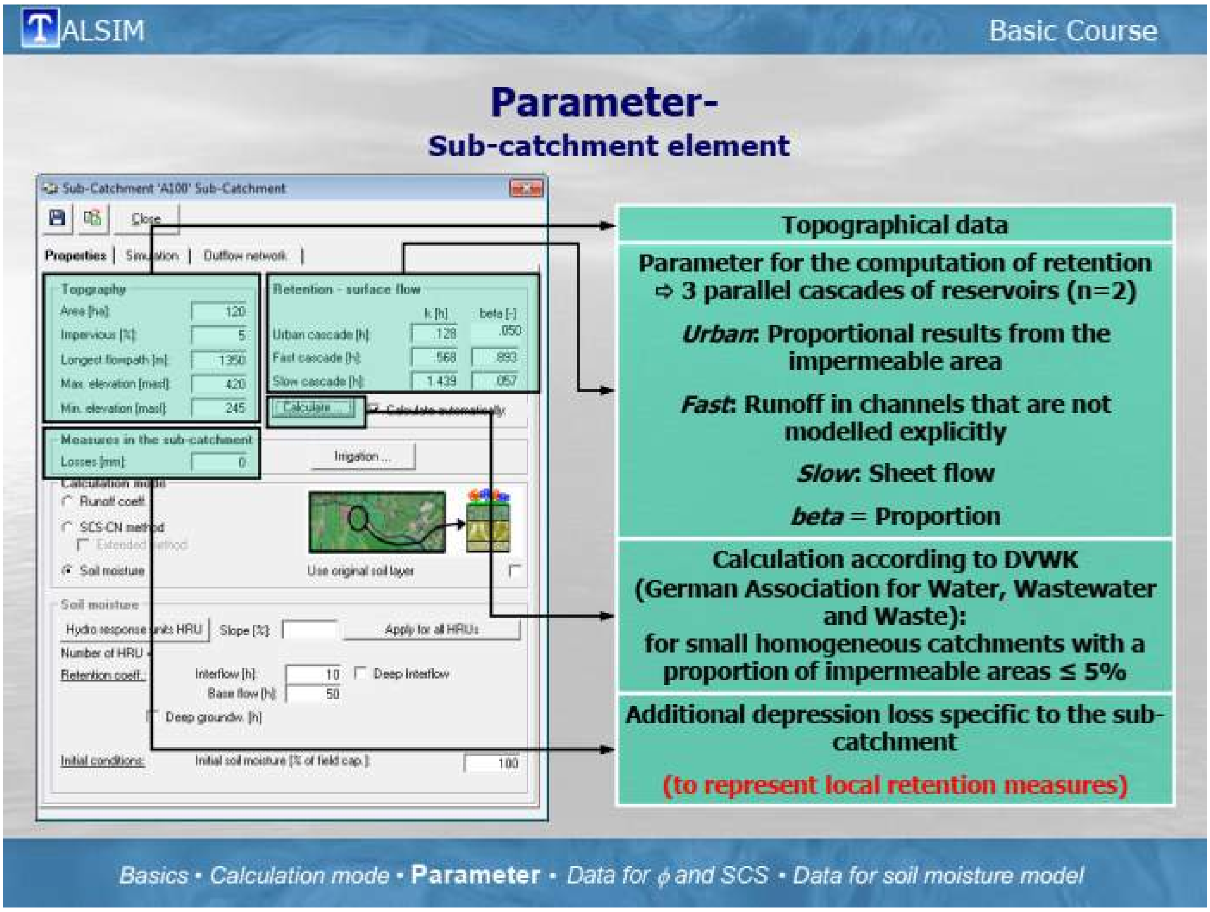
⇨ The more detailed the data base, the more the use of complex methods should be considered (SCS, soil moisture model)

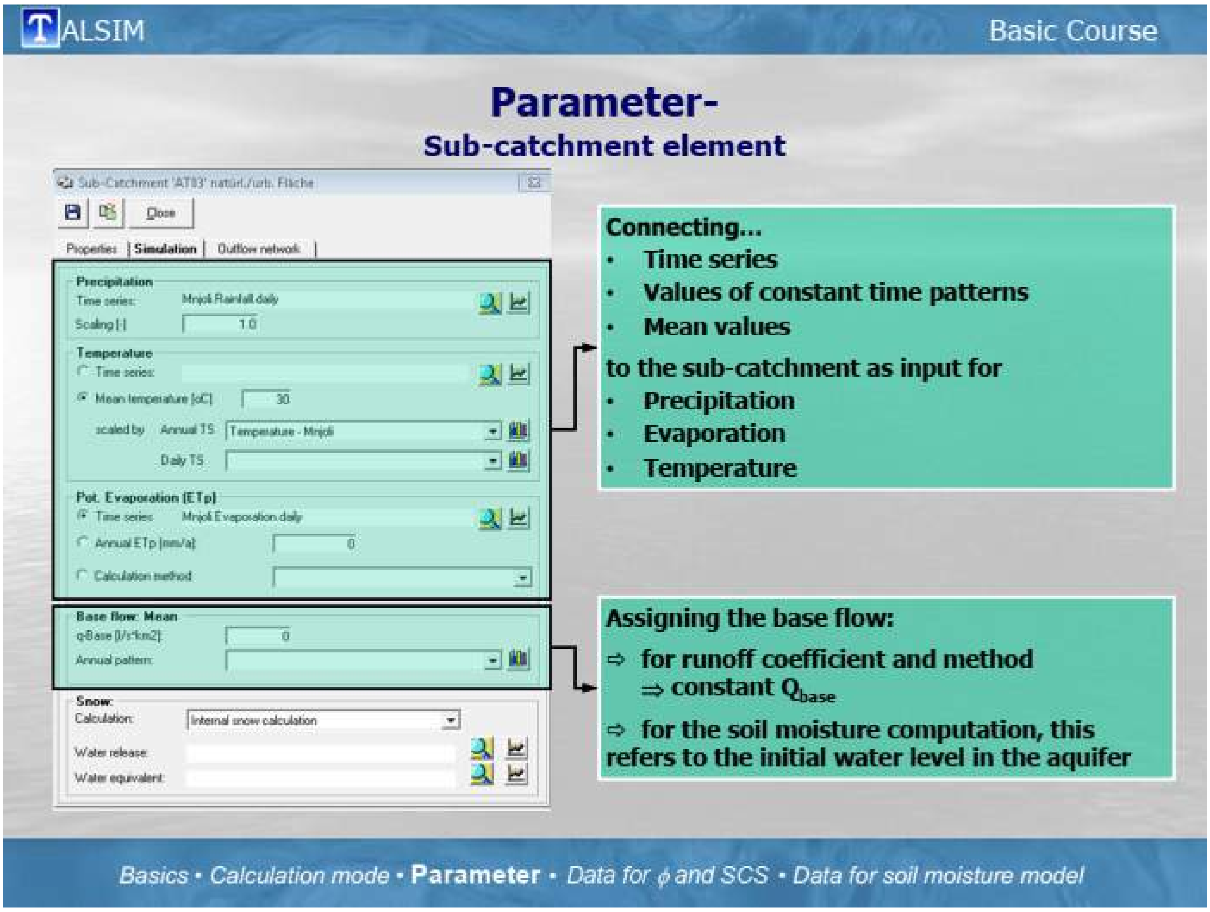
⇨ The simpler the method for runoff generation, the stronger the influence of the calibration event(s) on future computations

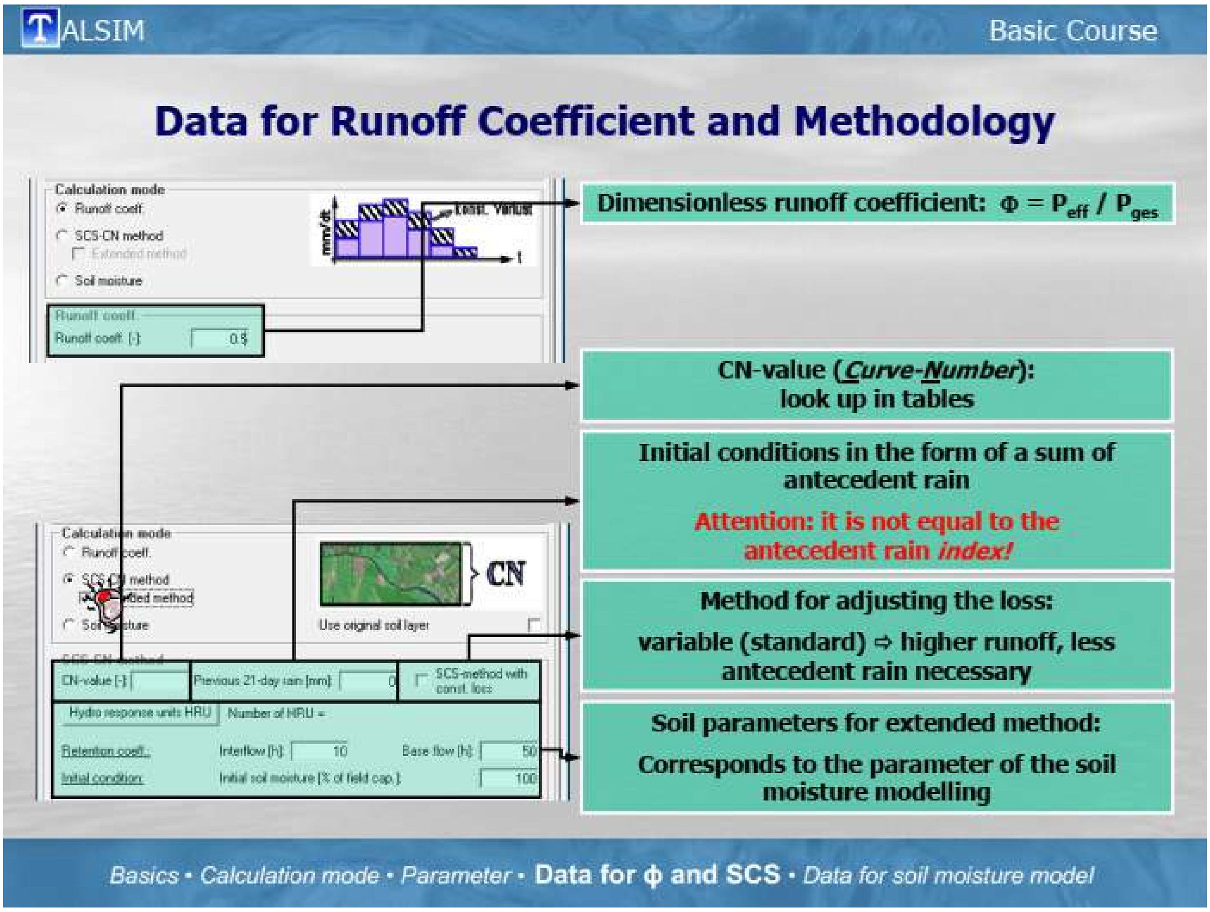


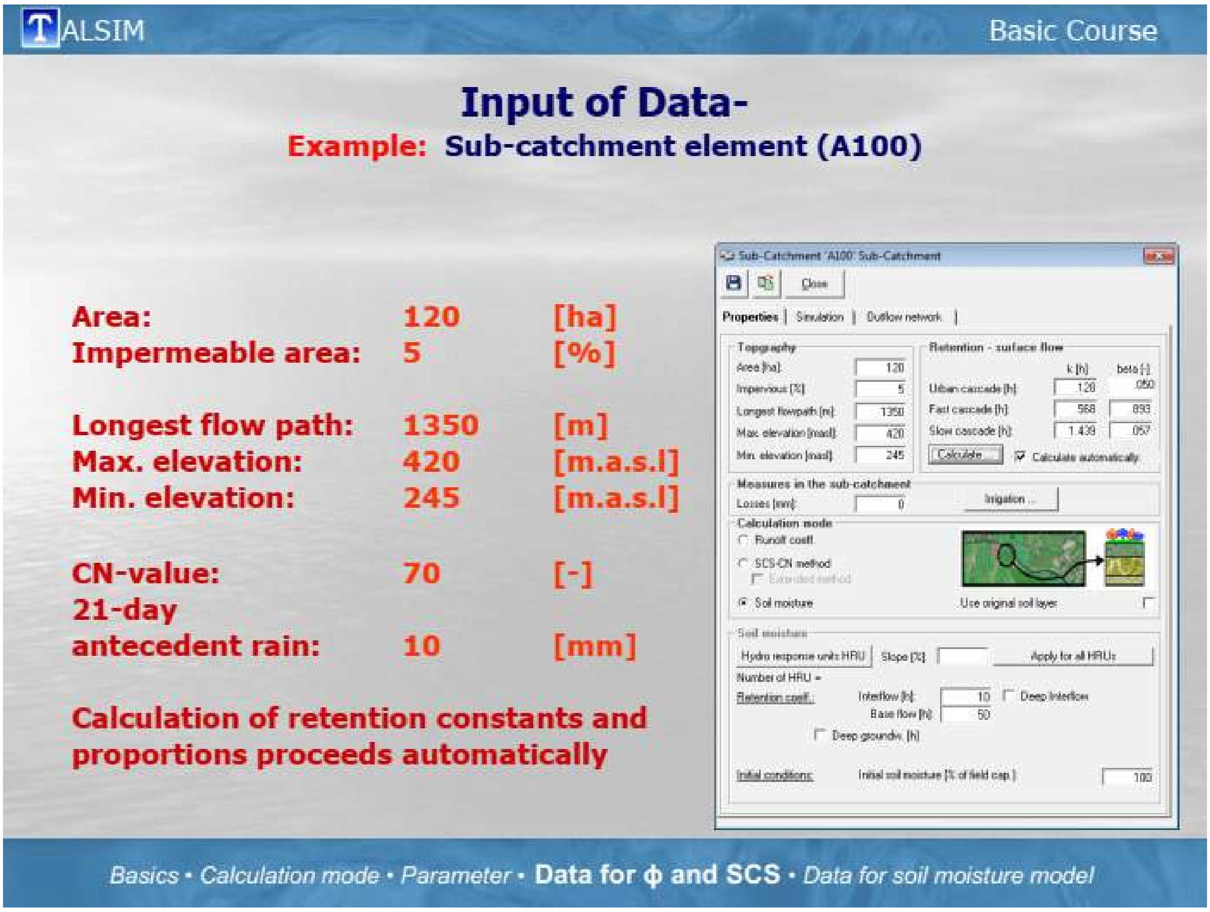
There is a risk that the results remain „stuck" at the calibration event (both in magnitude and timing)

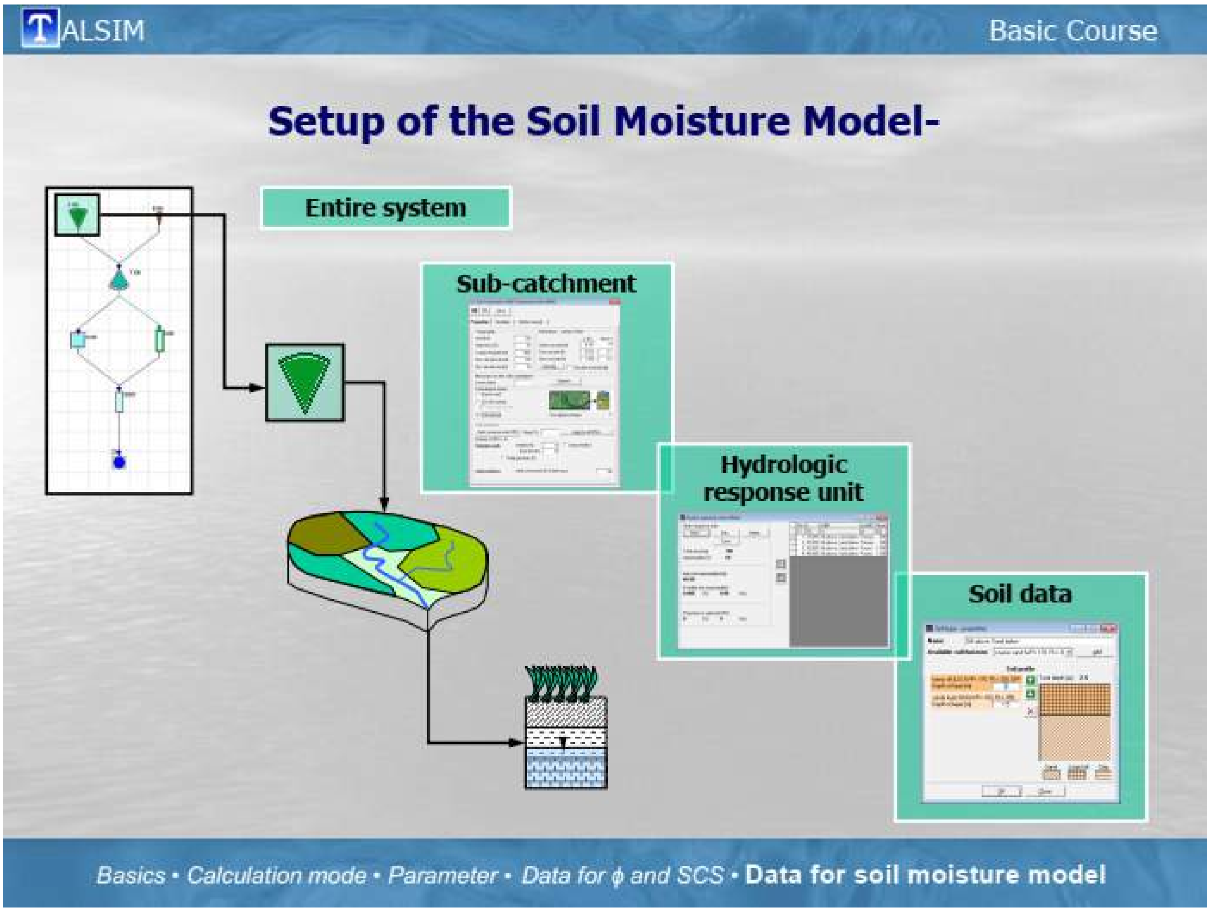
Basics • **Calculation mode** • *Parameter* • *Data for ϕ and SCS* • *Data for soil moisture model*

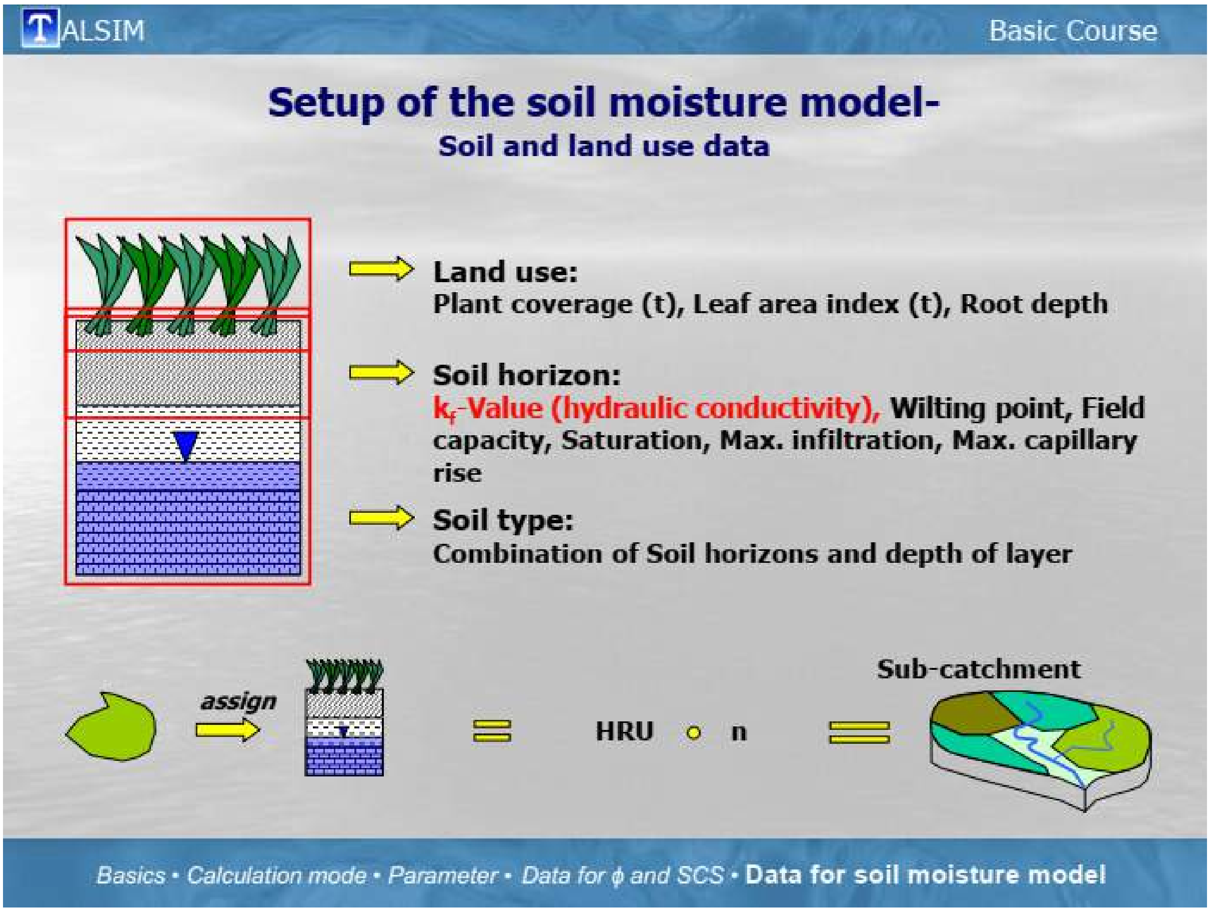

TALSIM
Basic Course
Parameter-
Sub-catchment element
Topographical data
Parameter for the computation of retention
⇨ 3 parallel cascades of reservoirs (n=2)
Urban: Proportional results from the impermeable area
Fast: Runoff in channels that are not modelled explicitly
Slow: Sheet flow
beta = Proportion
Calculation according to DVWK
(German Association for Water, Wastewater and Waste):
for small homogeneous catchments with a proportion of impermeable areas ≤ 5%
Additional depression loss specific to the sub-catchment
(to represent local retention measures)
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

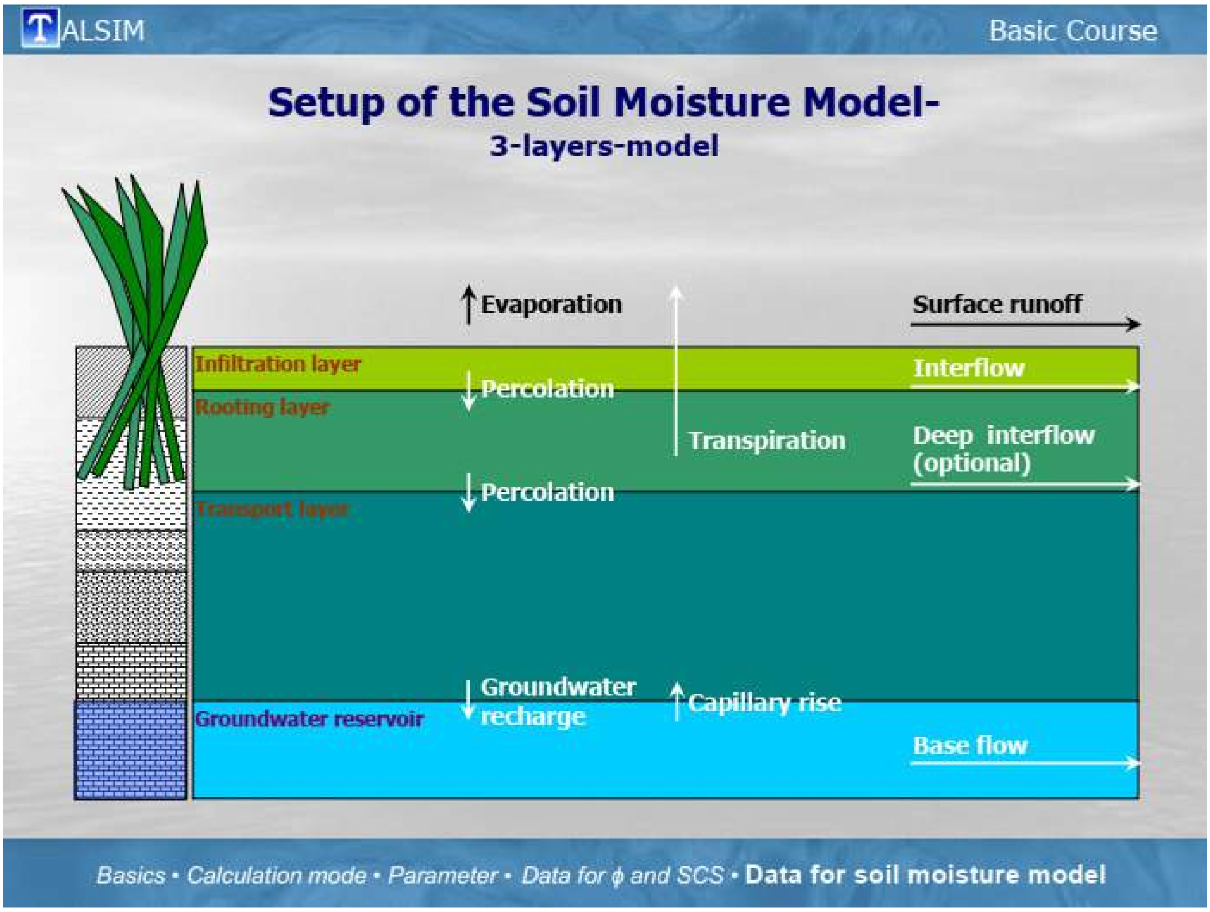

TALSIM
Basic Course
Parameter-
Sub-catchment element
Connecting...
Time series
Values of constant time patterns
Mean values
to the sub-catchment as input for
Precipitation
Evaporation
Temperature
Assigning the base flow:
⇨ for runoff coefficient and method
⇒ constant Qbase
⇨ for the soil moisture computation, this refers to the initial water level in the aquifer
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

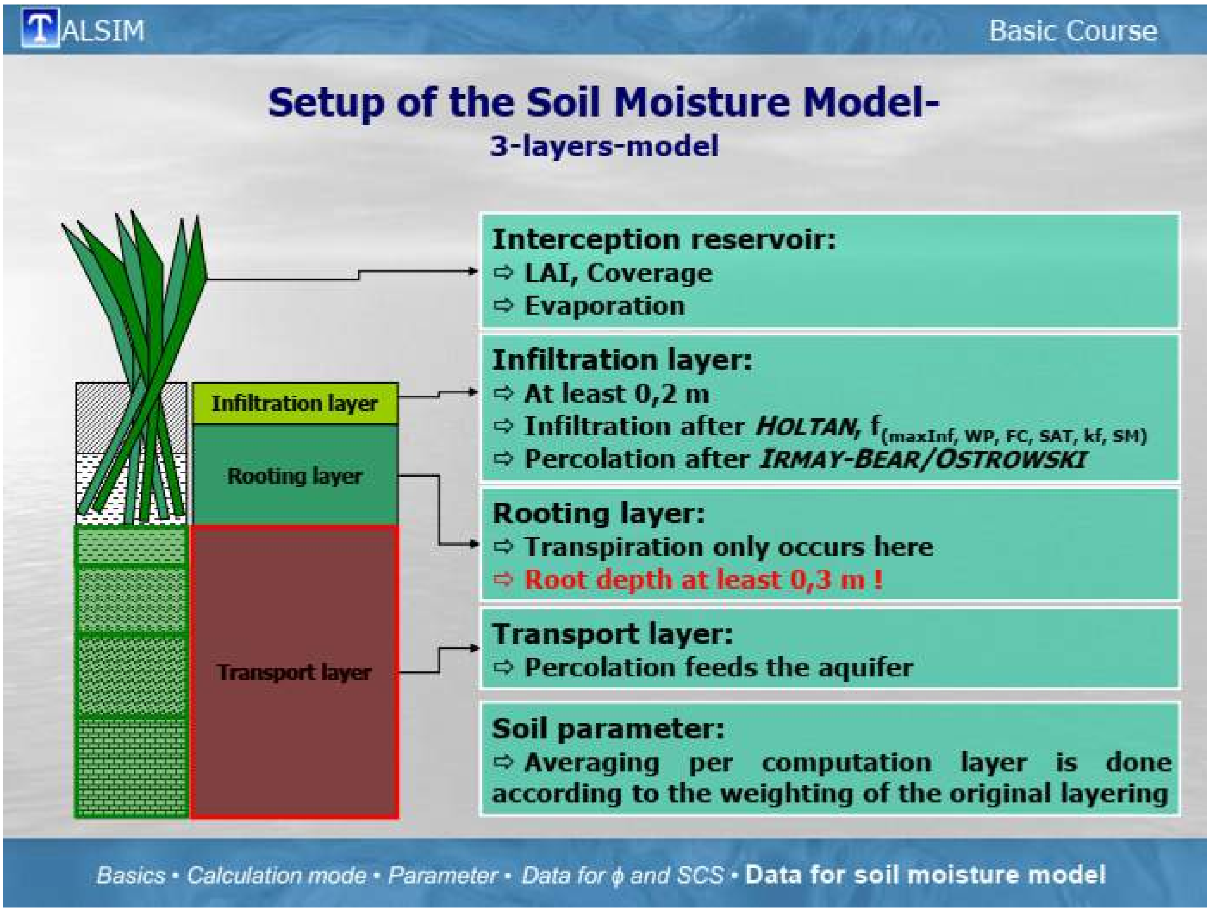

TALSIM
Basic Course
Data for Runoff Coefficient and Methodology
Dimensionless runoff coefficient: Φ = Peff / Pges
CN-value (Curve-Number): look up in tables
Initial conditions in the form of a sum of antecedent rain
Attention: it is not equal to the antecedent rain index!
Method for adjusting the loss: variable (standard) ⇒ higher runoff, less antecedent rain necessary
Soil parameters for extended method: Corresponds to the parameter of the soil moisture modelling
CN
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

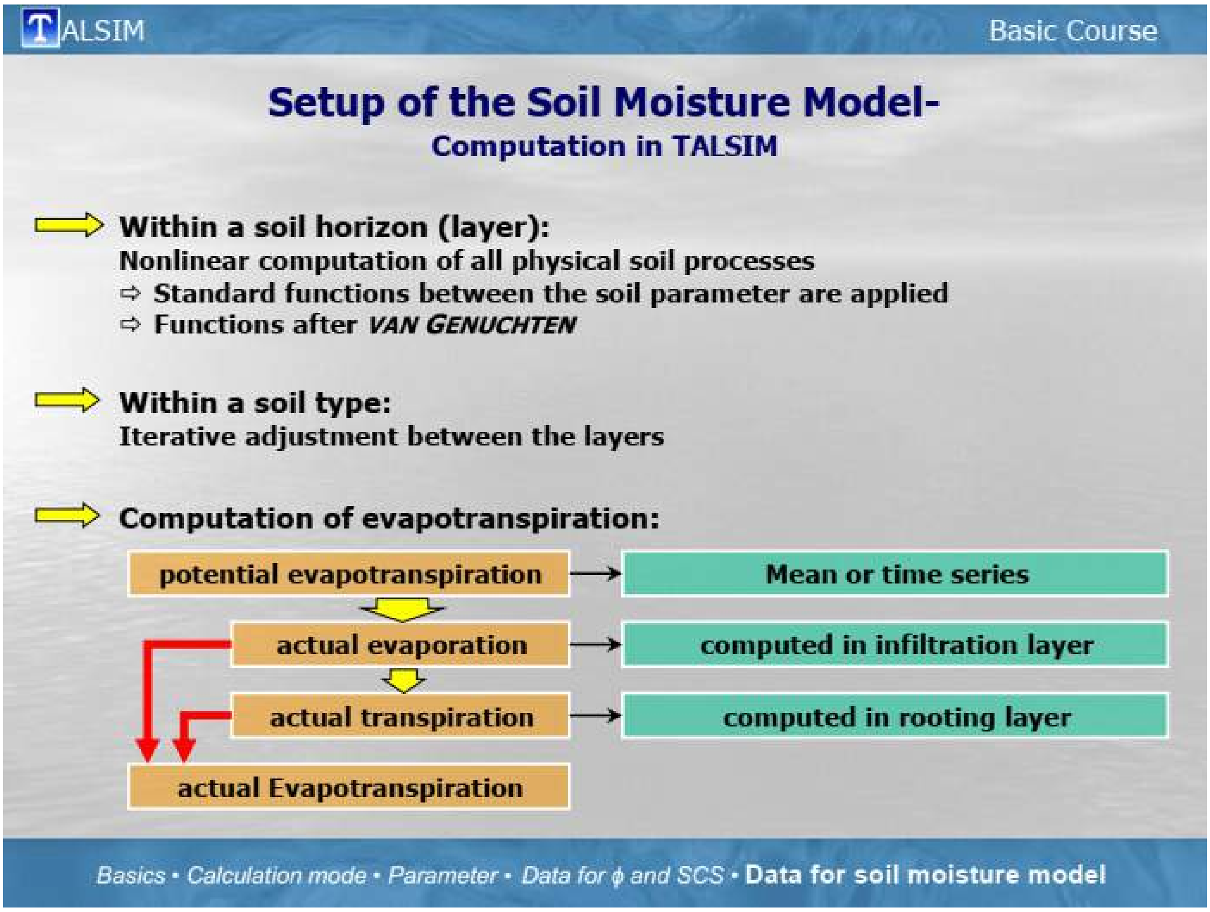

TALSIM
Basic Course
Input of Data-
Example: Sub-catchment element (A100)
Area: 120 [ha]
Impermeable area: 5 [%]
Longest flow path: 1350 [m]
Max. elevation: 420 [m.a.s.l]
Min. elevation: 245 [m.a.s.l]
CN-value: 70 [-]
21-day antecedent rain: 10 [mm]
Calculation of retention constants and proportions proceeds automatically
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

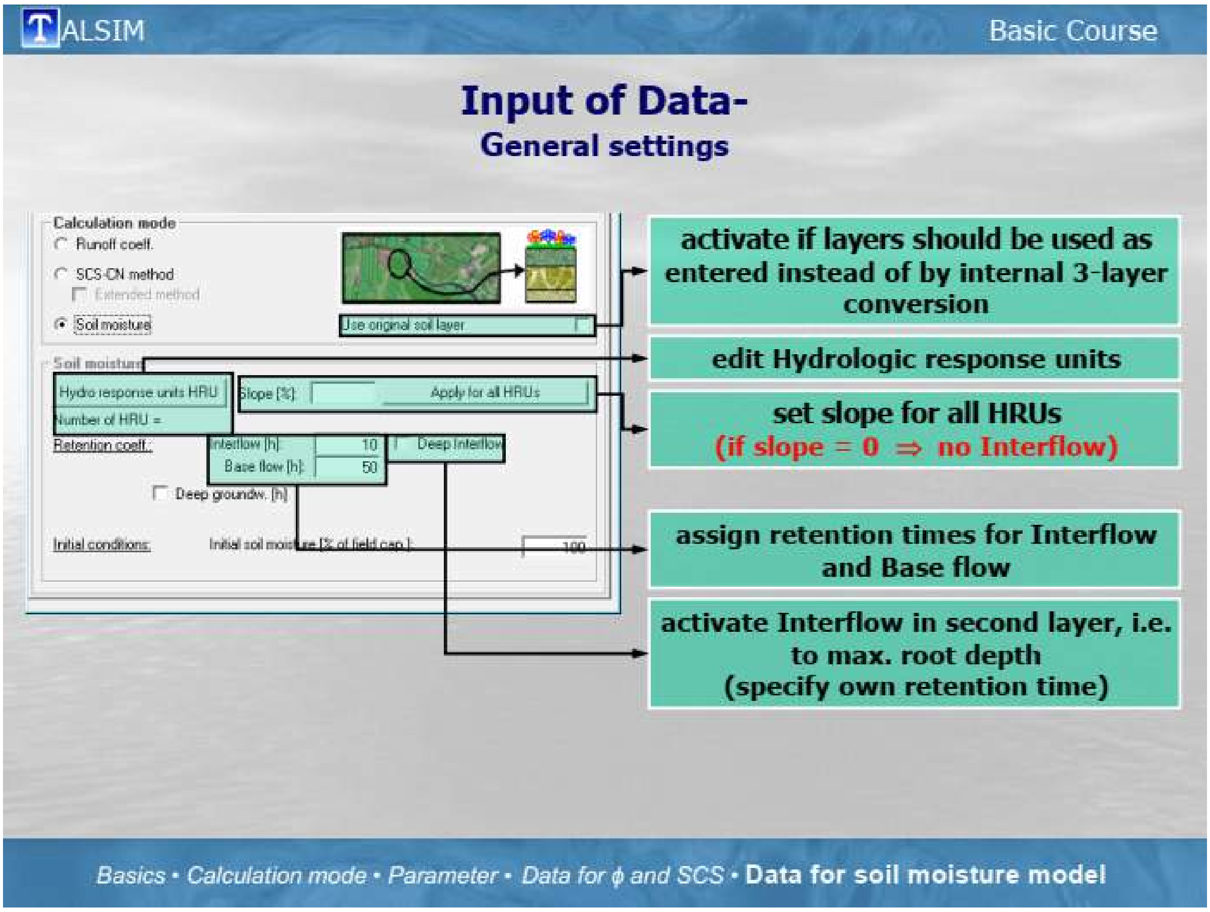

TALSIM
Basic Course
Setup of the Soil Moisture Model-
Entire system
Sub-catchment
Hydrologic response unit
Soil data
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

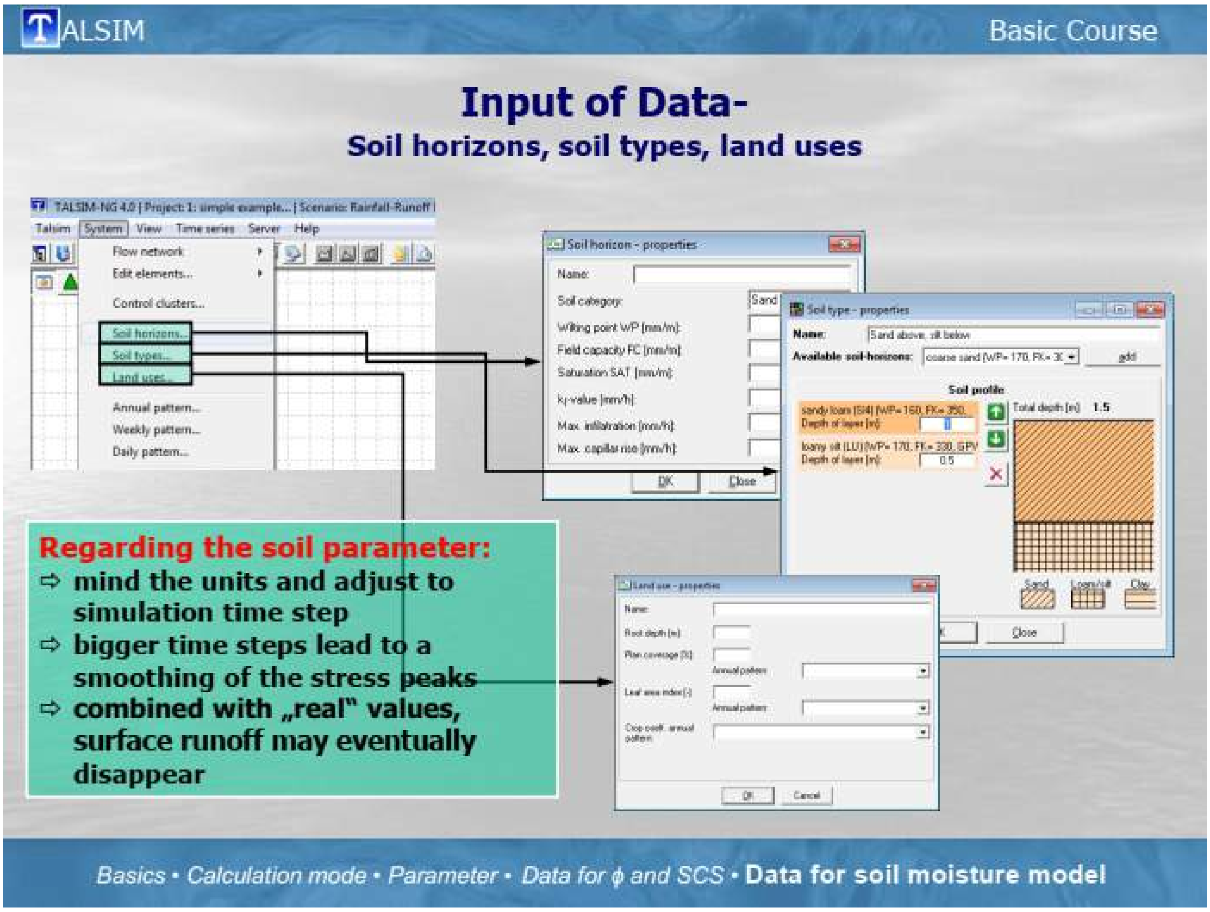

TALSIM
Basic Course
Setup of the soil moisture model-
Soil and land use data
Land use:
Plant coverage (t), Leaf area index (t), Root depth
Soil horizon:
k_f-Value (hydraulic conductivity), Wilting point, Field capacity, Saturation, Max. infiltration, Max. capillary rise
Soil type:
Combination of Soil horizons and depth of layer
assign
HRU ∘ n
Sub-catchment
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

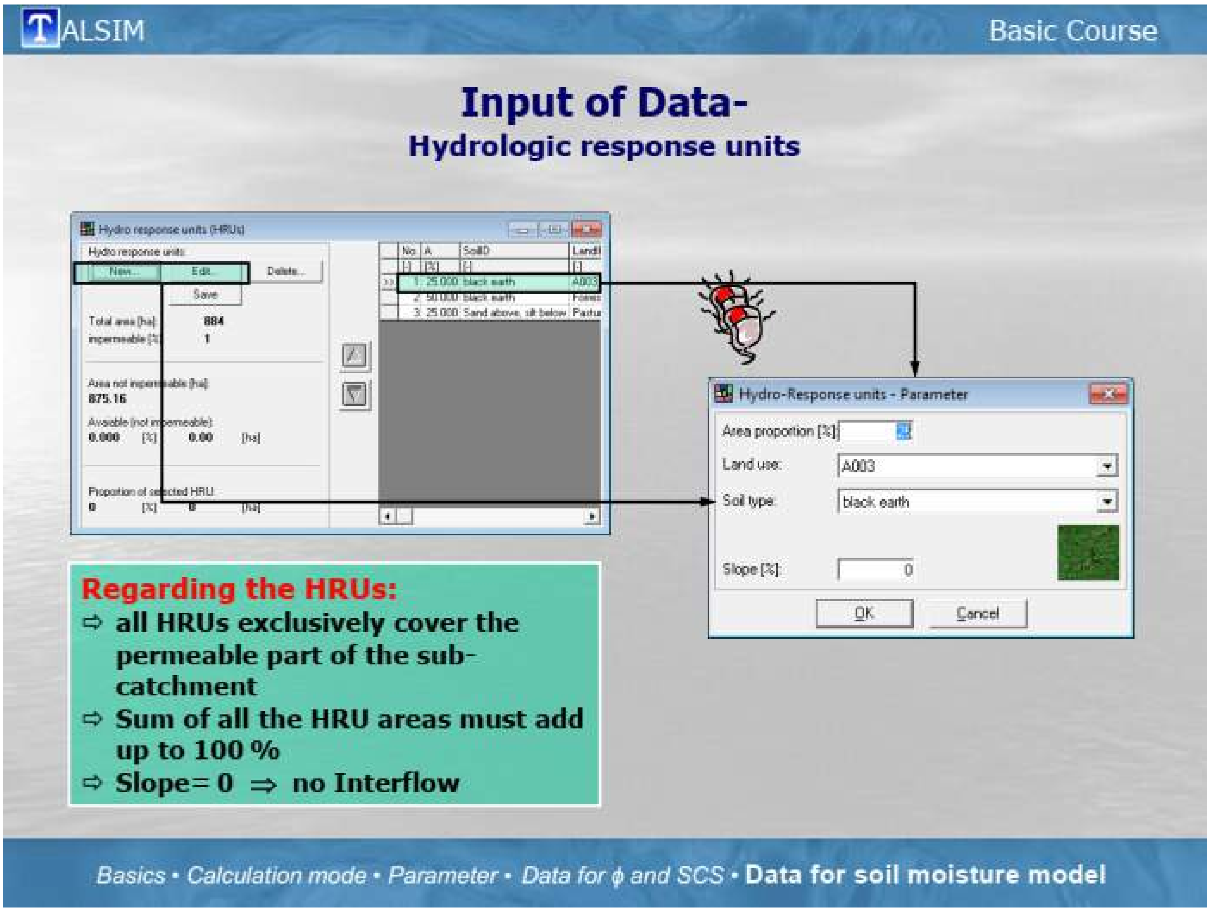

TALSIM
Basic Course
Setup of the Soil Moisture Model-
3-layers-model
Evaporation
Surface runoff
Infiltration layer
Percolation
Interflow
Rooting layer
Transpiration
Deep interflow (optional)
Percolation
Transport layer
Groundwater recharge
Capillary rise
Groundwater reservoir
Base flow
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Setup of the Soil Moisture Model-
3-layers-model
Interception reservoir:
⇨ LAI, Coverage
⇨ Evaporation
Infiltration layer:
⇨ At least 0,2 m
⇨ Infiltration after HOLTAN, f(maxInf, WP, FC, SAT, kf, SM)
⇨ Percolation after IRMAY-BEAR/OSTROWSKI
Rooting layer:
⇨ Transpiration only occurs here
⇨ Root depth at least 0,3 m !
Transport layer:
⇨ Percolation feeds the aquifer
Soil parameter:
⇨ Averaging per computation layer is done according to the weighting of the original layering
Infiltration layer
Rooting layer
Transport layer
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Setup of the Soil Moisture Model-
Computation in TALSIM
Within a soil horizon (layer):
Nonlinear computation of all physical soil processes
⇨ Standard functions between the soil parameter are applied
⇨ Functions after VAN GENUCHTEN
Within a soil type:
Iterative adjustment between the layers
Computation of evapotranspiration:
potential evapotranspiration
Mean or time series
actual evaporation
computed in infiltration layer
actual transpiration
computed in rooting layer
actual Evapotranspiration
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Input of Data-
General settings
Calculation mode
Runoff coeff.
SCS-CN method
Extended method
Soil moisture
Use original soil layer
Soil moisture
Hydro response units HRU
Number of HRU =
Slope [%]:
Apply for all HRUs
Retention coeff.:
Interflow [h]: 10
Base flow [h]: 50
Deep Interflow
Deep groundw. [h]
Initial conditions:
Initial soil moisture [% of field cap.]: 100
activate if layers should be used as entered instead of by internal 3-layer conversion
edit Hydrologic response units
set slope for all HRUs
(if slope = 0 ⇒ no Interflow)
assign retention times for Interflow and Base flow
activate Interflow in second layer, i.e. to max. root depth
(specify own retention time)
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Input of Data-
Soil horizons, soil types, land uses
TALSIM-NG 4.0 | Project: 1: simple example... | Scenario: Rainfall-Runoff
Talsim System View Time series Server Help
Flow network
Edit elements...
Control clusters...
Soil horizons...
Soil types...
Land uses...
Annual pattern...
Weekly pattern...
Daily pattern...
Soil horizon - properties
Name:
Soil category:
Wilting point WP [mm/m]:
Field capacity FC [mm/m]:
Saturation SAT [mm/m]:
Max. infiltration [mm/h]:
Max. capillar rise [mm/h]:
OK
Close
Soil type - properties
Name: Sand above, silt below
Available soil-horizons:
add
Soil profile
Total depth [m]: 1.5
Sand
Loam/silt
Clay
Close
Land use - properties
Name:
Root depth [m]:
Plan coverage [%]:
Annual pattern:
Leaf area index [-]:
Crop coeff. annual pattern:
OK
Cancel
Regarding the soil parameter:
⇨ mind the units and adjust to simulation time step
⇨ bigger time steps lead to a smoothing of the stress peaks
⇨ combined with „real" values, surface runoff may eventually disappear
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model


TALSIM
Basic Course
Input of Data-
Hydrologic response units
Hydro response units (HRUs)
Hydro response units:
New...
Edit...
Delete...
Save
Total area [ha]: 884
impermeable [%]: 1
Area not impermeable [ha]: 875.16
Available (not impermeable): 0.000 [%] 0.00 [ha]
Proportion of selected HRU: 0 [%] 0 [ha]
No. A SoilD LandU
1 25.000 black earth A003
2 50.000 black earth
3 25.000 Sand above, silt below
Hydro-Response units - Parameter
Area proportion [%]:
Land use: A003
Soil type: black earth
Slope [%]: 0
OK
Cancel
Regarding the HRUs:
⇨ all HRUs exclusively cover the permeable part of the sub-catchment
⇨ Sum of all the HRU areas must add up to 100 %
⇨ Slope= 0 ⇒ no Interflow
Basics • Calculation mode • Parameter • Data for ϕ and SCS • Data for soil moisture model

TALSIM Basic Course

Input of Data-

Example: Sub-catchment Element (A100)

Soil horizons							
Name	***Category***	***WP***	***FK***	***SAT***	***k_f***	***max.Inf***	***max.Cap***
-	-	[mm/m]	[mm/m]	[mm/m]	[mm/h]	[mm/h]	[mm/h]
loamy silt (LU)	silt	170	330	380	1.75	3	0
sandy loam (Sl4)	sand	160	350	400	15	20	0

Soil types		
Name	***Soil horizon***	***Depth of layer [m]***
sand above, silt below	sandy loam (Sl4)	1.0
	loamy silt (LU)	0.5
silt above, sand below	loamy silt (LU)	1
	sandy loam (Sl4)	1.5

Land uses			
Name	***Root depth***	***Plant coverage***	***Leaf area index (LAI)***
-	[m]	[%]	[-]
Meadows & pasture	0.5	90	2
Forest	2	80	8

Basics • Calculation mode • Parameter • Data for ϕ and SCS • **Data for soil moisture model**

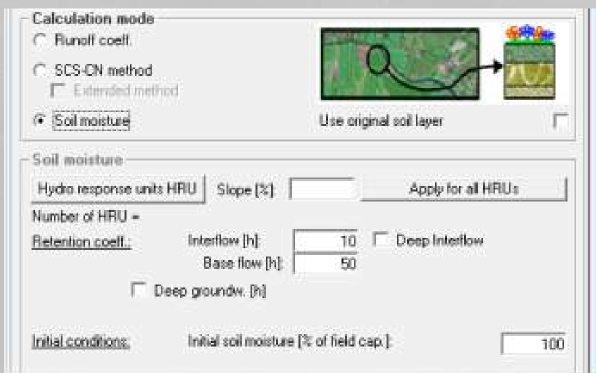
TALSIM Basic Course

Input of Data-

Example: Sub-catchment element (A100)

Calculation mode: **Soil moisture model**

k-Interflow: **10 [h]**
k-Base flow: **50 [h]**
Initial soil moisture: **100 [% of FK]**



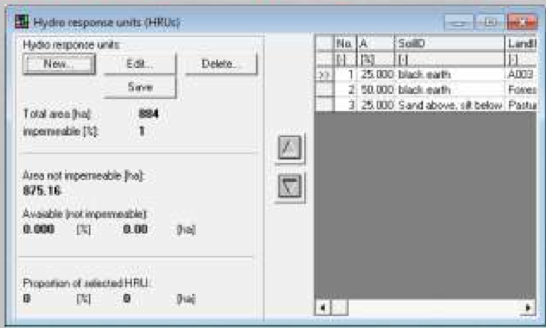
Basics • Calculation mode • Parameter • Data for ϕ and SCS • **Data for soil moisture model**

TALSIM Basic Course

Input of Data-

Example: Sub-catchment element (A100)

Hydrologic Response units				
Area	***Land use***	***Soil type***	***Symbol***	***Slope***
[%]	-	-	-	[%]
50	Meadow/ pasture	Sand above, silt below	Field	0.1
30	Forest	Sand above, silt below	Forest	0.8
20	Meadow/ pasture	Silt above, sand below	Meadow	0.5



Basics • Calculation mode • Parameter • Data for ϕ and SCS • **Data for soil moisture model**

TALSIM Basic Course

System States-

Theory and Practice

- **Definition**
- **Create and connect**
- **Example of an implementation**
- **Continuation ⇨ State clusters**

Definition *• Create and Edit • Connect • Example • State clusters*

TALSIM Basic Course

System States-
What is a system state?

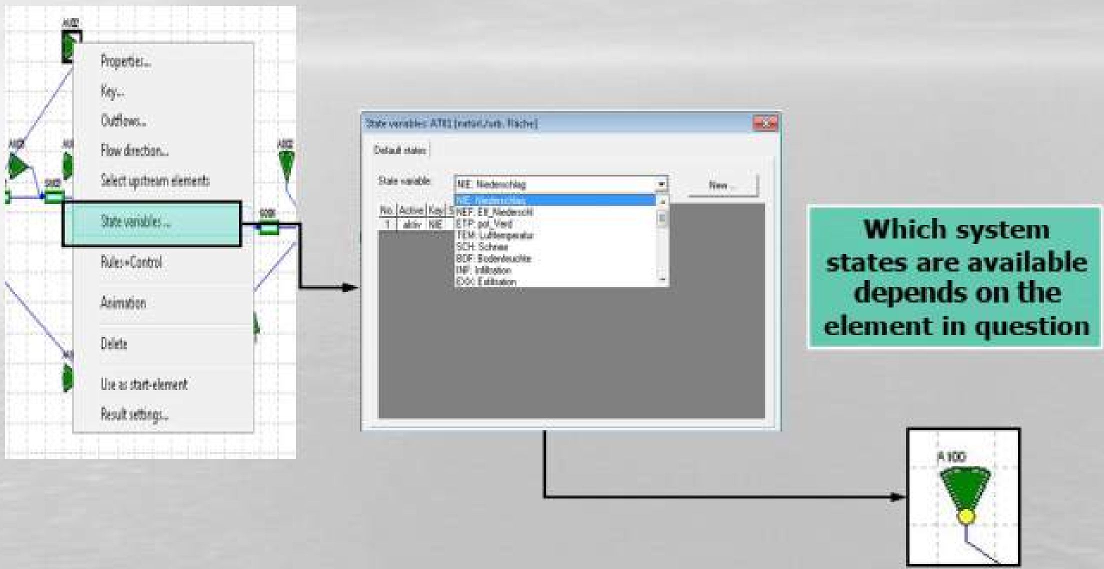
- **System state - quantity that is computed during the simulation**
  - ⇨ **dependent on an element: e.g. runoff, effect. precipitation, interflow, etc.**
  - ⇨ **the actual value can be used or it can be processed by a function**

- **Purpose:**
  - ⇨ **directly influences rules regarding reservoir operations**
  - ⇨ **any clustering/ extension to complex structures of rules is possible with the help of state clusters**

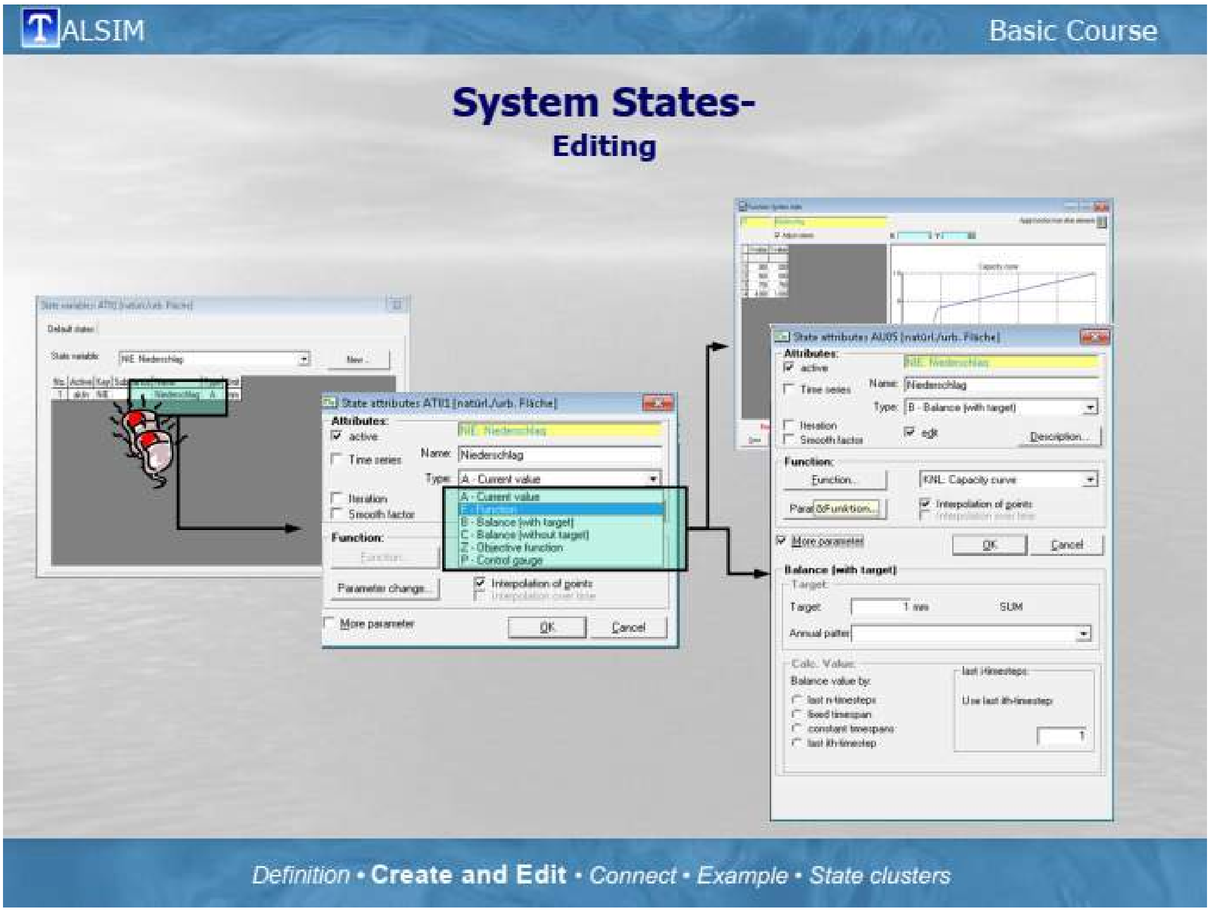
Definition • *Create and Edit* • *Connect* • *Example* • *State clusters*

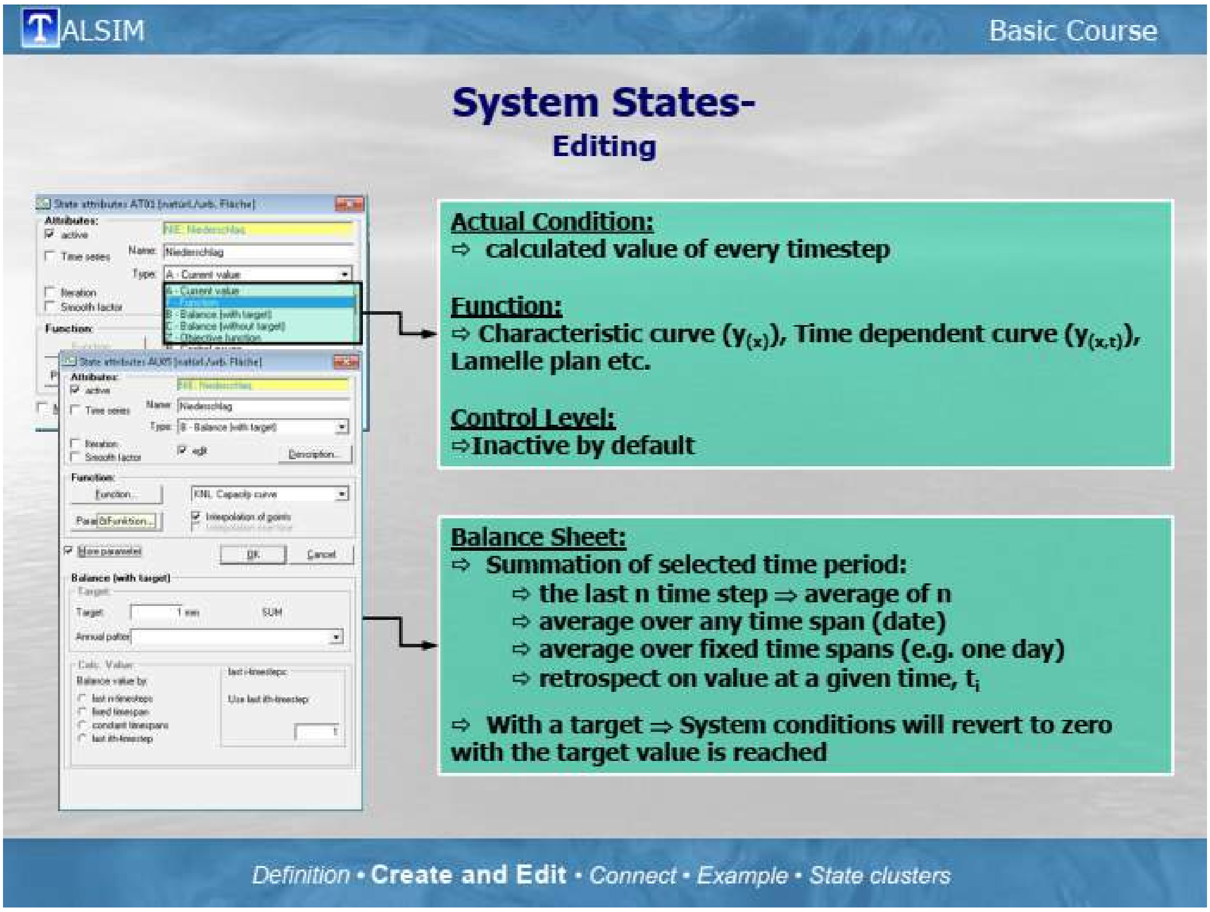
TALSIM Basic Course

System States-
Creation



Definition • **Create and Edit** • *Connect* • *Example* • *State clusters*

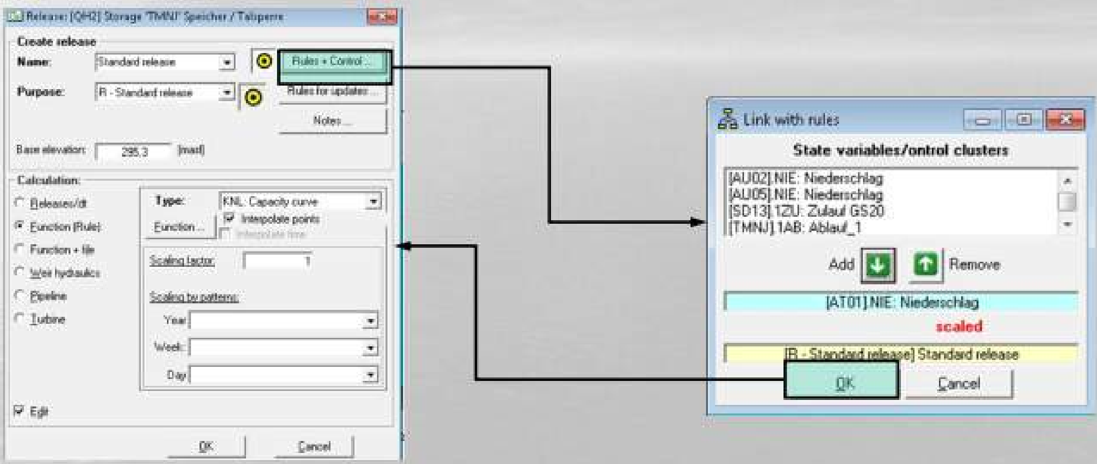

TALSIM
Basic Course
System States-
Editing
State attributes AT01 [natürl./urb. Fläche]
Attributes:
active
Time series
Name: Niederschlag
Type: A - Current value
A - Current value
F - Function
B - Balance (with target)
C - Balance (without target)
Z - Objective function
P - Control gauge
Iteration
Smooth factor
Function:
Parameter change...
Interpolation of points
More parameter
OK
Cancel
State attributes AU05 [natürl./urb. Fläche]
Type: B - Balance (with target)
KNL Capacity curve
Balance (with target)
Target
SUM
Annual patter
Calc. Value
Balance value by:
last n-timesteps
fixed timespan
constant timespans
last ith-timestep
Use last ith-timestep
Definition • Create and Edit • Connect • Example • State clusters


TALSIM
Basic Course
System States-
Editing
Actual Condition:
⇨ calculated value of every timestep
Function:
⇨ Characteristic curve (y(x)), Time dependent curve (y(x,t)), Lamelle plan etc.
Control Level:
⇨Inactive by default
Balance Sheet:
⇨ Summation of selected time period:
⇨ the last n time step ⇒ average of n
⇨ average over any time span (date)
⇨ average over fixed time spans (e.g. one day)
⇨ retrospect on value at a given time, ti
⇨ With a target ⇒ System conditions will revert to zero with the target value is reached
Definition • Create and Edit • Connect • Example • State clusters

TALSIM Basic Course

System States-

Connection to reservoir releases



Result: Release = reservoir factor • system state

Definition • Create and Edit • **Connect** *• Example • State clusters*

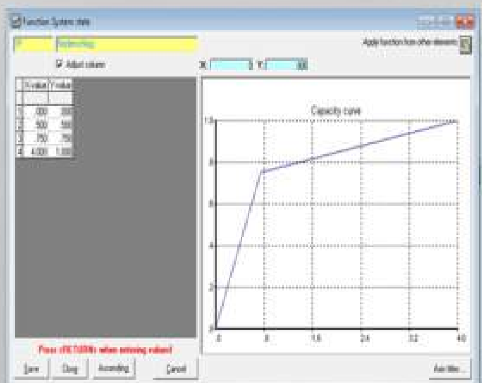
TALSIM Basic Course

System states

Example: Sub-catchment (A100) and reservoir (T100)

Create a system state (Outlow_1) of the element A100:

Name: Discharge from A100
Purpose: Function
Function: Characteristic Curve
Value: See Chart



Connect this system state to the release QW1!

Definition • Create and Edit • Connect • **Example** *• State clusters*

TALSIM Basic Course

State Clusters-
Short definition

Meaning:
In state clusters, the system states and other clusters are connected with the help of mathematical operations (addition, multiplication, minimum, maximum etc.)

Purpose:
Creation of complex structures of rules

Topic of the Advanced course

Definition • Create and Edit • Connect • Example • **State clusters**

TALSIM Basic Course

Short-term Simulation with Designed Storms-
Theory and Practice

- Introduction and setup
- Edit settings
- Design storm and generated floods
- Example of an implementation
- Simulation and Results

TALSIM Basic Course

Short-term Simulation with Designed Storms-
Introduction

Simulations in TALSIM	
Long-term simulation	**Short-term simulation**
Stress by connected time series	Stress by designed rainfall and generated runoff
Long-term view Statistical evaluation of target variables	View of extreme events Effect of a flood event over a defined recurrence period Examination of system under extreme conditions, safety check for reservoir/dams

no combination

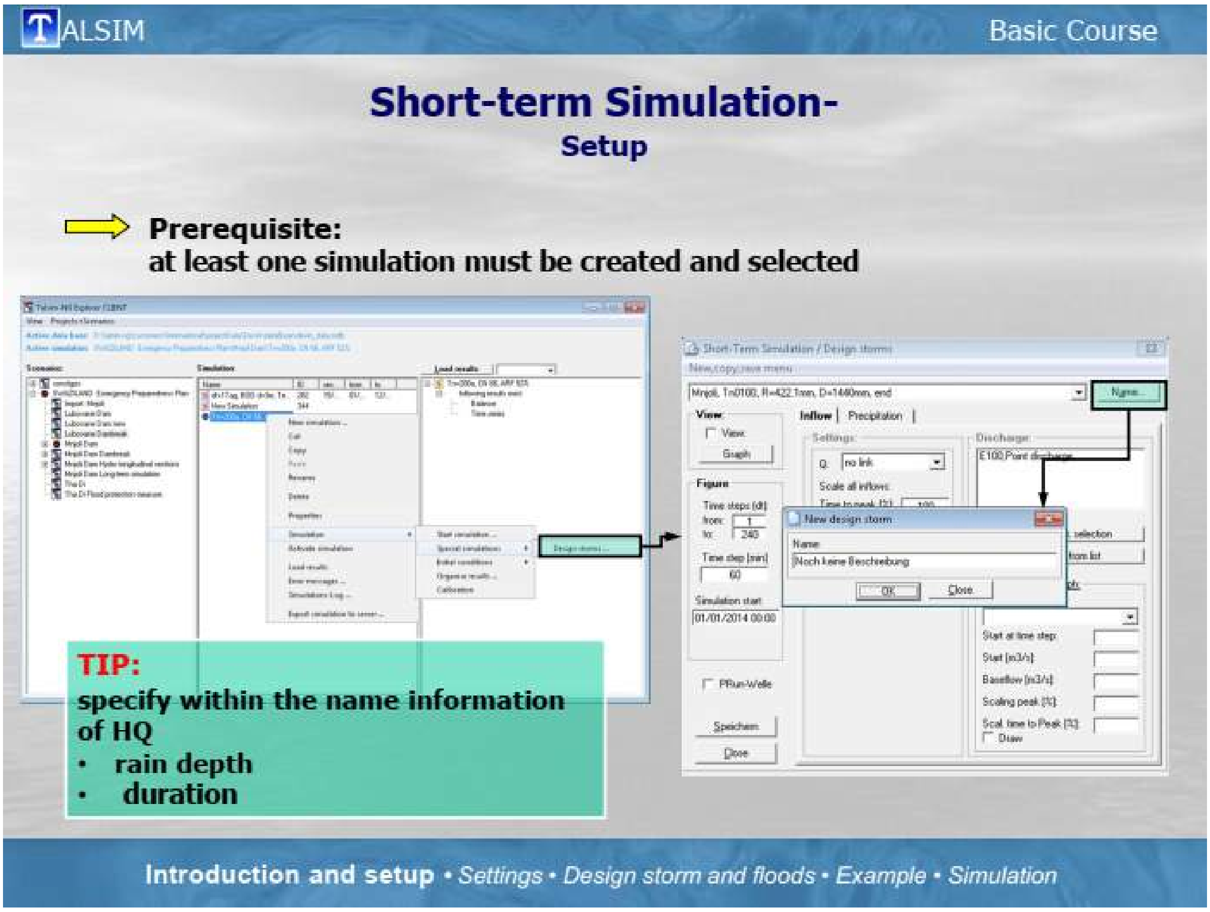
Introduction and setup • *Settings* • *Design storm and floods* • *Example* • *Simulation*

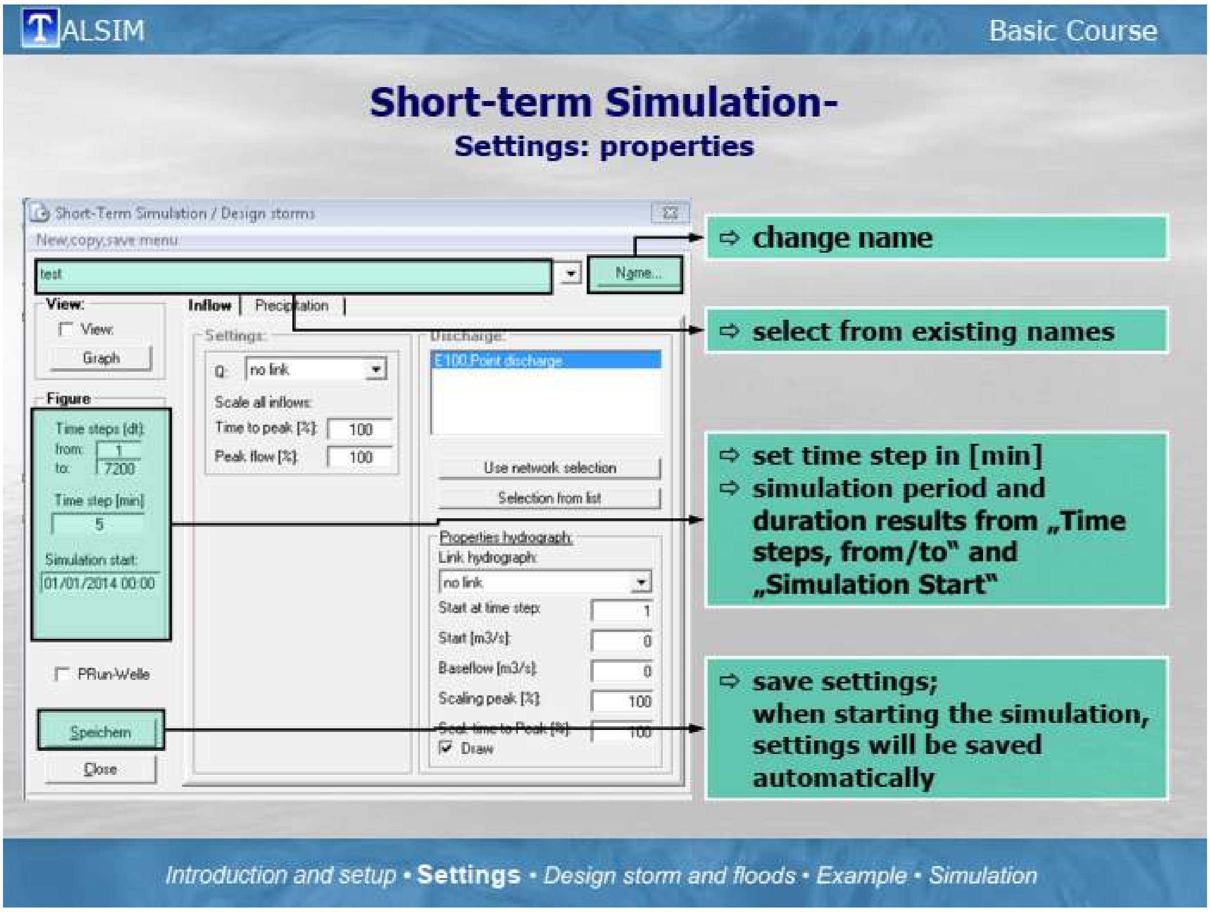
TALSIM Basic Course

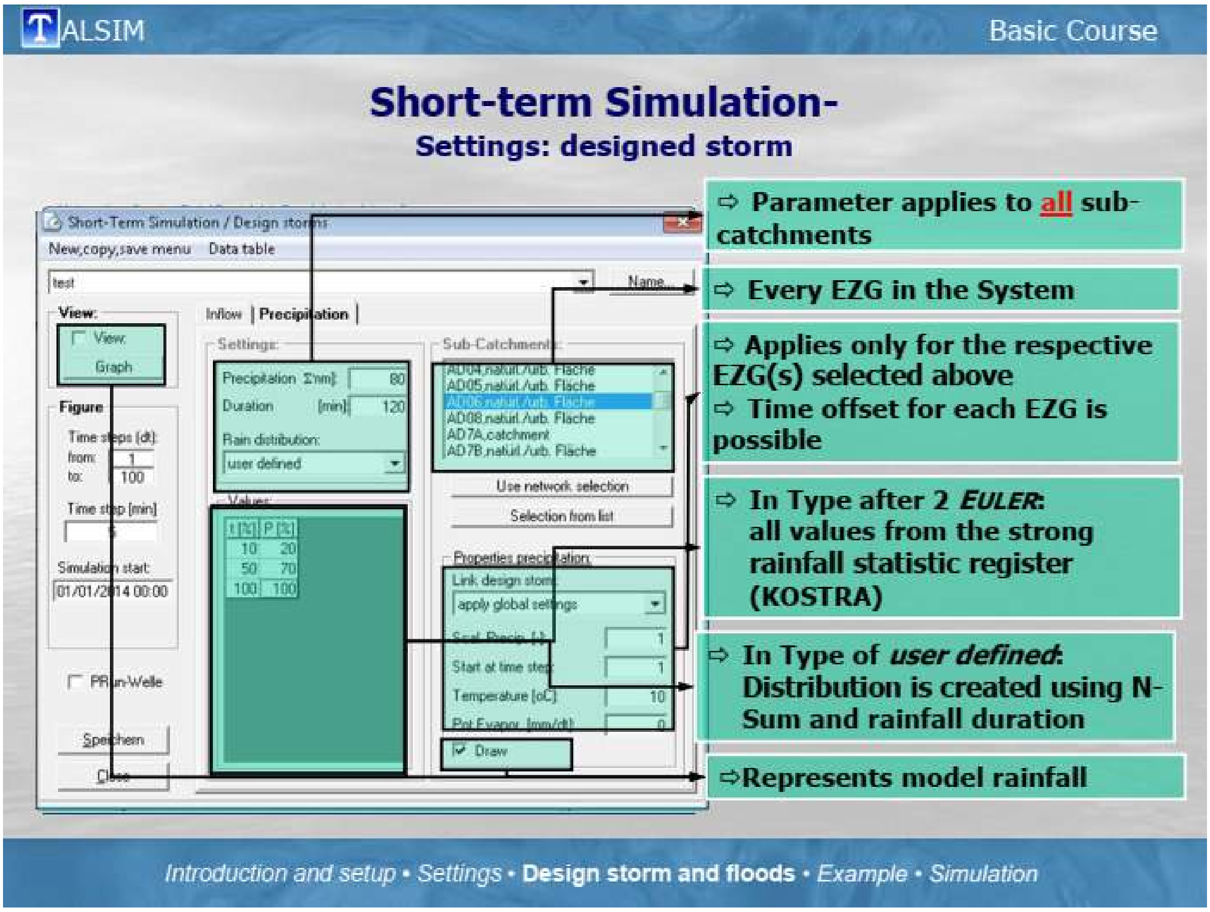
Short-term Simulation-
Introduction

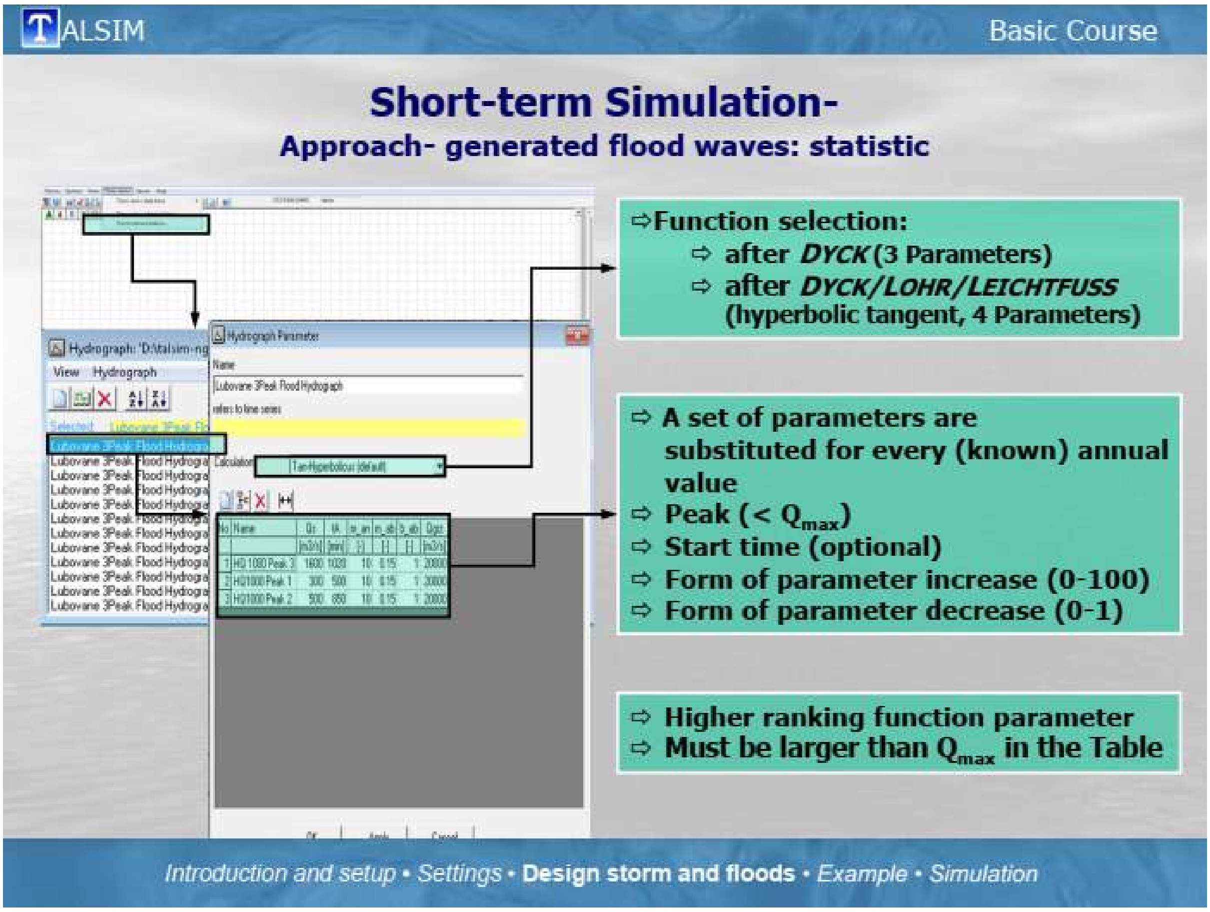
Short-term simulation	
Sub-catchment	**Discharge element**
1 Stress by the definition of a designed storm Statistics of heavy rainfall events are necessary (e.g. DWD, KOSTRA for Germany)	2 Stress by a generated flood Extensive preliminary statistical investigation of measured flood events necessary
Properties	
• Rain depth [mm] • Rain duration [min] • Evolution of intensity (Block, Pescher, Euler-2, DVWK)	• Statistics of flood events (peak, response time, form, parameter of the rising and falling limb, calculation mode) • Scaling factors for the peak and response time

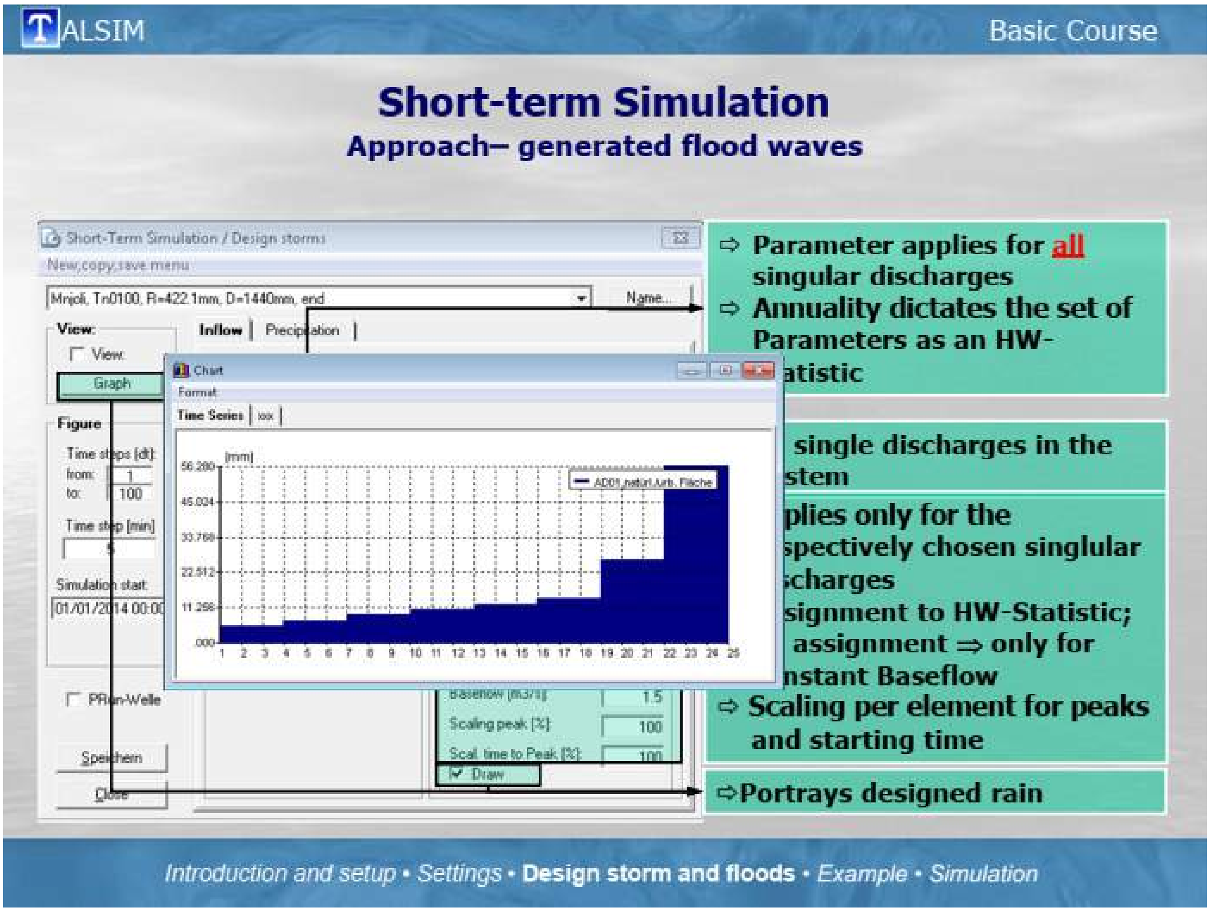
Introduction and setup • *Settings* • *Design storm and floods* • *Example* • *Simulation*

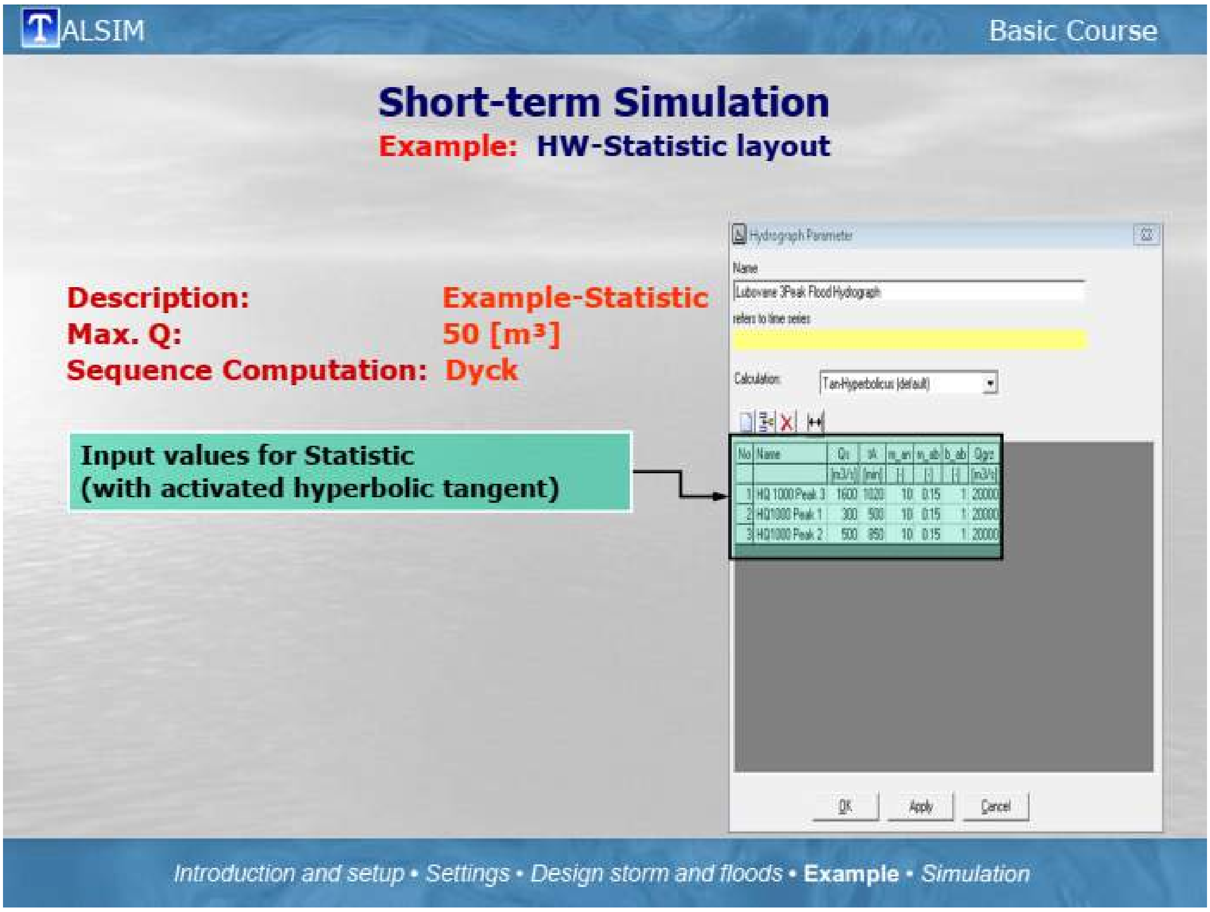

TALSIM
Basic Course
Short-term Simulation-
Setup
Prerequisite:
at least one simulation must be created and selected
Short-Term Simulation / Design storms
New design storm
Name:
Noch keine Beschreibung
OK
Close
TIP:
specify within the name information of HQ
• rain depth
• duration
Introduction and setup • Settings • Design storm and floods • Example • Simulation

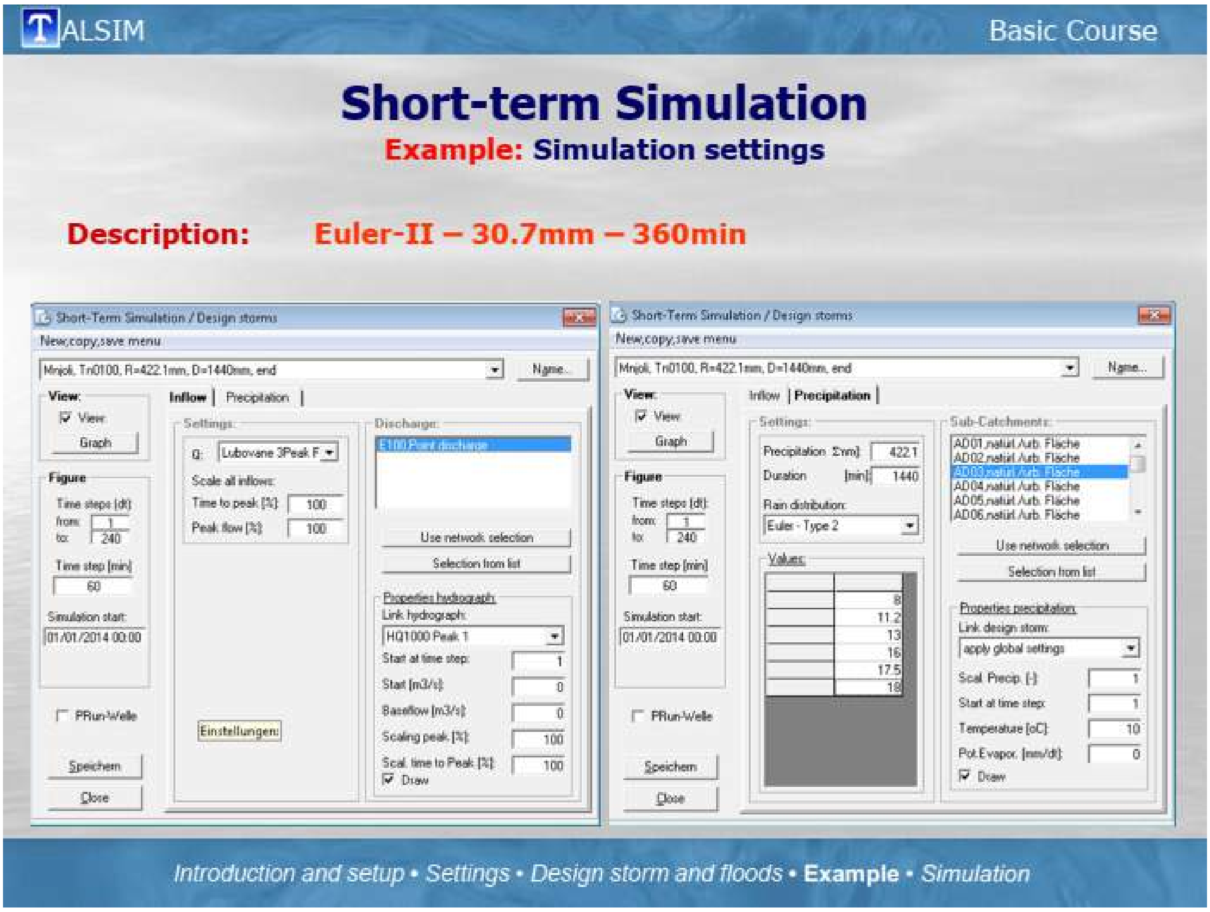

TALSIM
Basic Course
Short-term Simulation-
Settings: properties
Short-Term Simulation / Design storms
New,copy,save menu
test
Name...
View:
View
Graph
Inflow
Precipitation
Settings:
Q: no link
Scale all inflows:
Time to peak [%]: 100
Peak flow [%]: 100
Discharge:
E100 Point discharge
Use network selection
Selection from list
Figure
Time steps [dt]:
from: 1
to: 7200
Time step [min]
5
Simulation start:
01/01/2014 00:00
Properties hydrograph:
Link hydrograph:
no link
Start at time step: 1
Start [m3/s]: 0
Baseflow [m3/s]: 0
Scaling peak [%]: 100
Scal. time to Peak [%]: 100
Draw
PRun-Welle
Speichern
Close
change name
select from existing names
set time step in [min]
simulation period and duration results from „Time steps, from/to" and „Simulation Start"
save settings; when starting the simulation, settings will be saved automatically
Introduction and setup • Settings • Design storm and floods • Example • Simulation

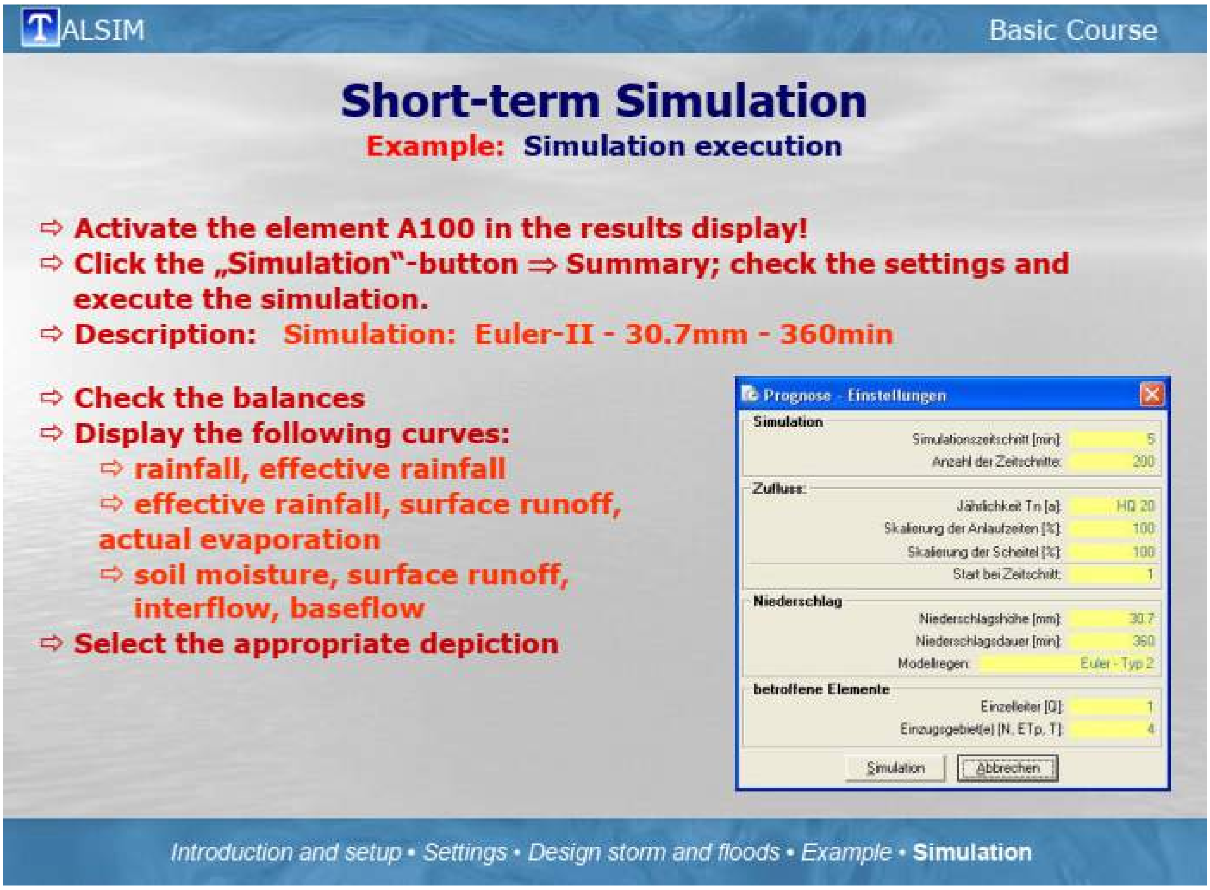

TALSIM
Basic Course
Short-term Simulation-
Settings: designed storm
Short-Term Simulation / Design storms
New,copy,save menu
Data table
Inflow
Precipitation
Settings:
Sub-Catchments:
Precipitation Σ[mm]
80
Duration [min]
120
Rain distribution:
user defined
Use network selection
Selection from list
Properties precipitation:
Link design storm
apply global settings
Start at time step
Temperature [oC]
Draw
⇨ Parameter applies to all sub-catchments
⇨ Every EZG in the System
⇨ Applies only for the respective EZG(s) selected above
⇨ Time offset for each EZG is possible
⇨ In Type after 2 EULER: all values from the strong rainfall statistic register (KOSTRA)
⇨ In Type of user defined: Distribution is created using N-Sum and rainfall duration
⇨Represents model rainfall
Introduction and setup • Settings • Design storm and floods • Example • Simulation

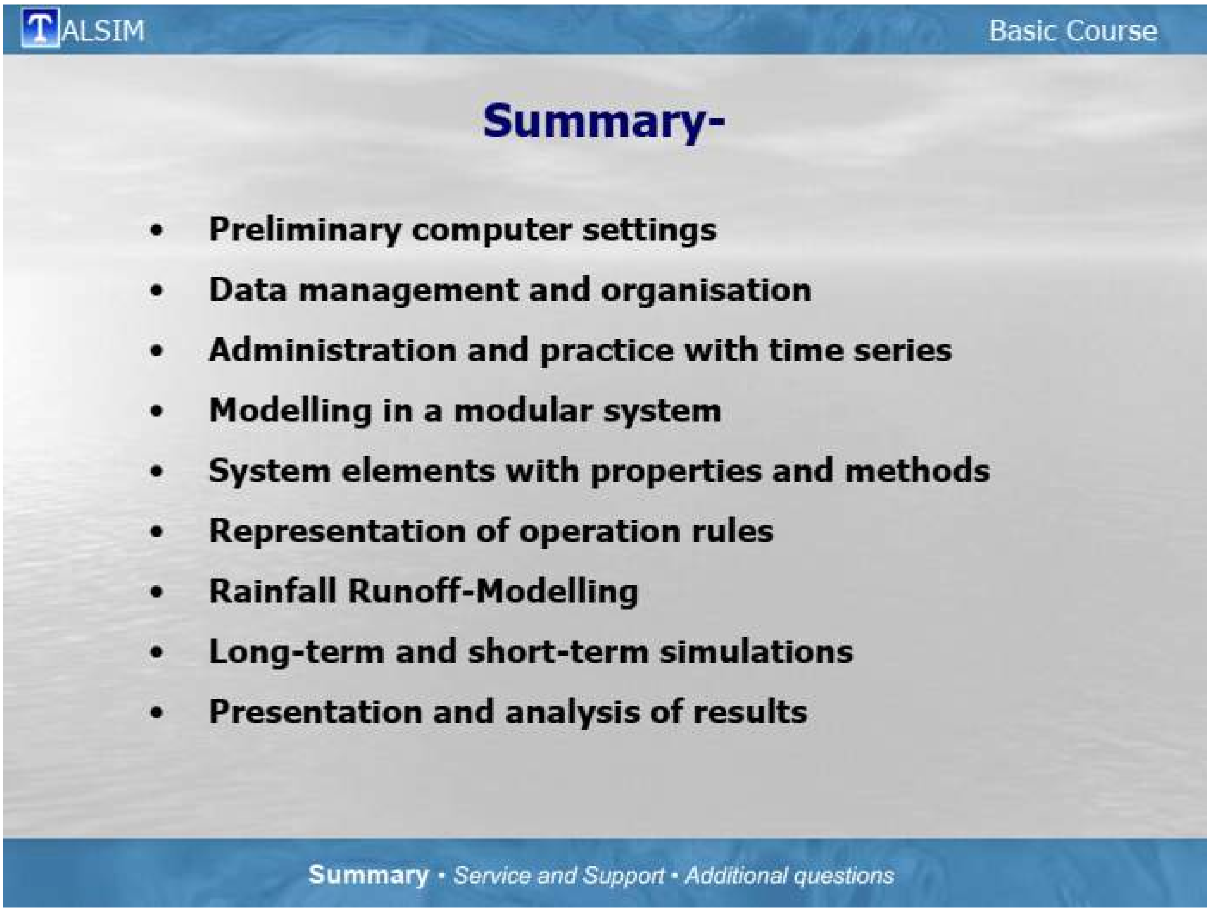

TALSIM
Basic Course
Short-term Simulation-
Approach- generated flood waves: statistic
Hydrograph Parameter
⇨Function selection:
⇨ after DYCK (3 Parameters)
⇨ after DYCK/LOHR/LEICHTFUSS (hyperbolic tangent, 4 Parameters)
⇨ A set of parameters are substituted for every (known) annual value
⇨ Peak (< Qmax)
⇨ Start time (optional)
⇨ Form of parameter increase (0-100)
⇨ Form of parameter decrease (0-1)
⇨ Higher ranking function parameter
⇨ Must be larger than Qmax in the Table
Introduction and setup • Settings • Design storm and floods • Example • Simulation

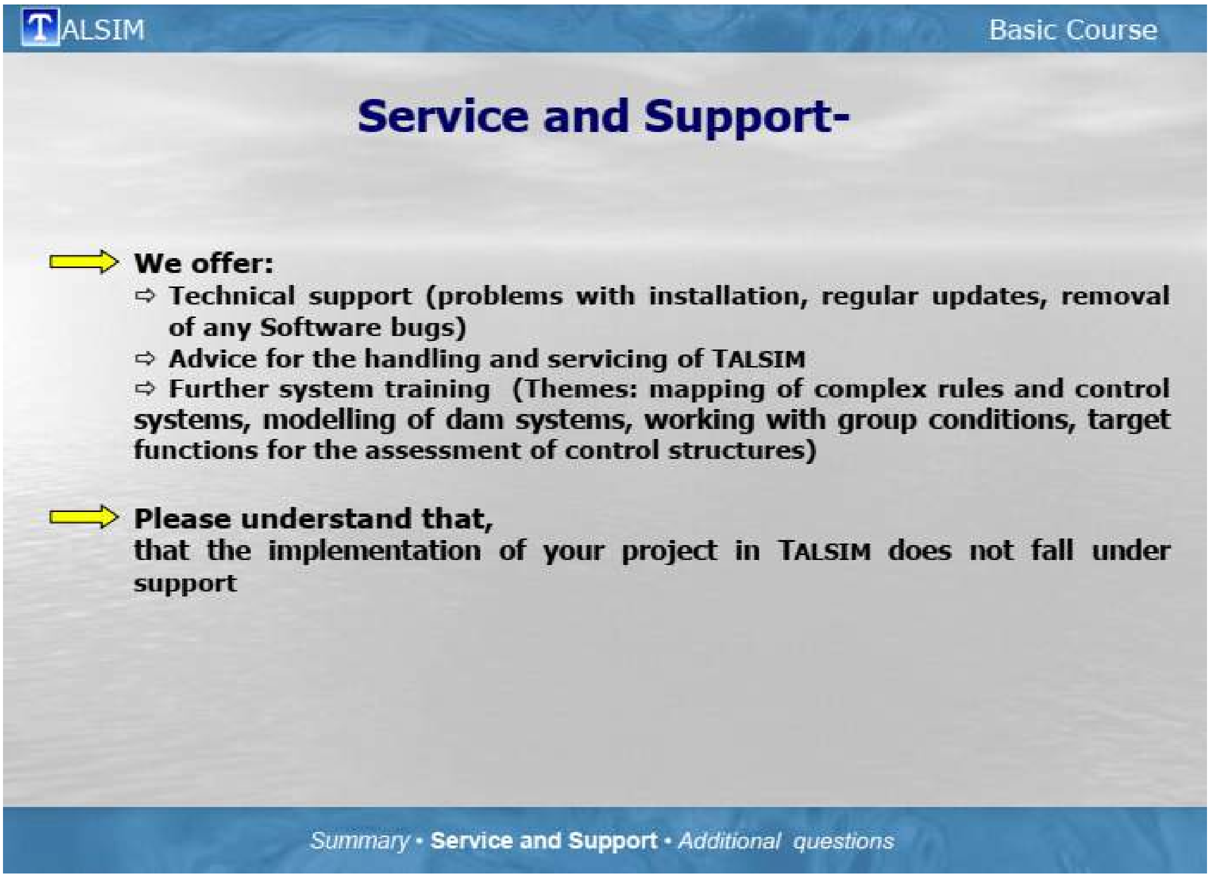

TALSIM
Basic Course
Short-term Simulation
Approach– generated flood waves
Short-Term Simulation / Design storms
New,copy,save menu
Mnjoli, Tn0100, R=422.1mm, D=1440mm, end
Name...
View:
Inflow
Precipitation
Graph
Figure
Time steps [dt]:
from:
to:
100
Time step [min]
Simulation start:
Chart
Format
Time Series
[mm]
PRun-Welle
Speichern
Close
Scaling peak [%]:
100
Scal. time to Peak [%]:
Draw
⇨ Parameter applies for all singular discharges
⇨ Annuality dictates the set of Parameters as an HW-
Statistic
single discharges in the
stem
plies only for the
spectively chosen singlular
scharges
signment to HW-Statistic;
assignment ⇒ only for
nstant Baseflow
⇨ Scaling per element for peaks and starting time
⇨Portrays designed rain
Introduction and setup • Settings • Design storm and floods • Example • Simulation

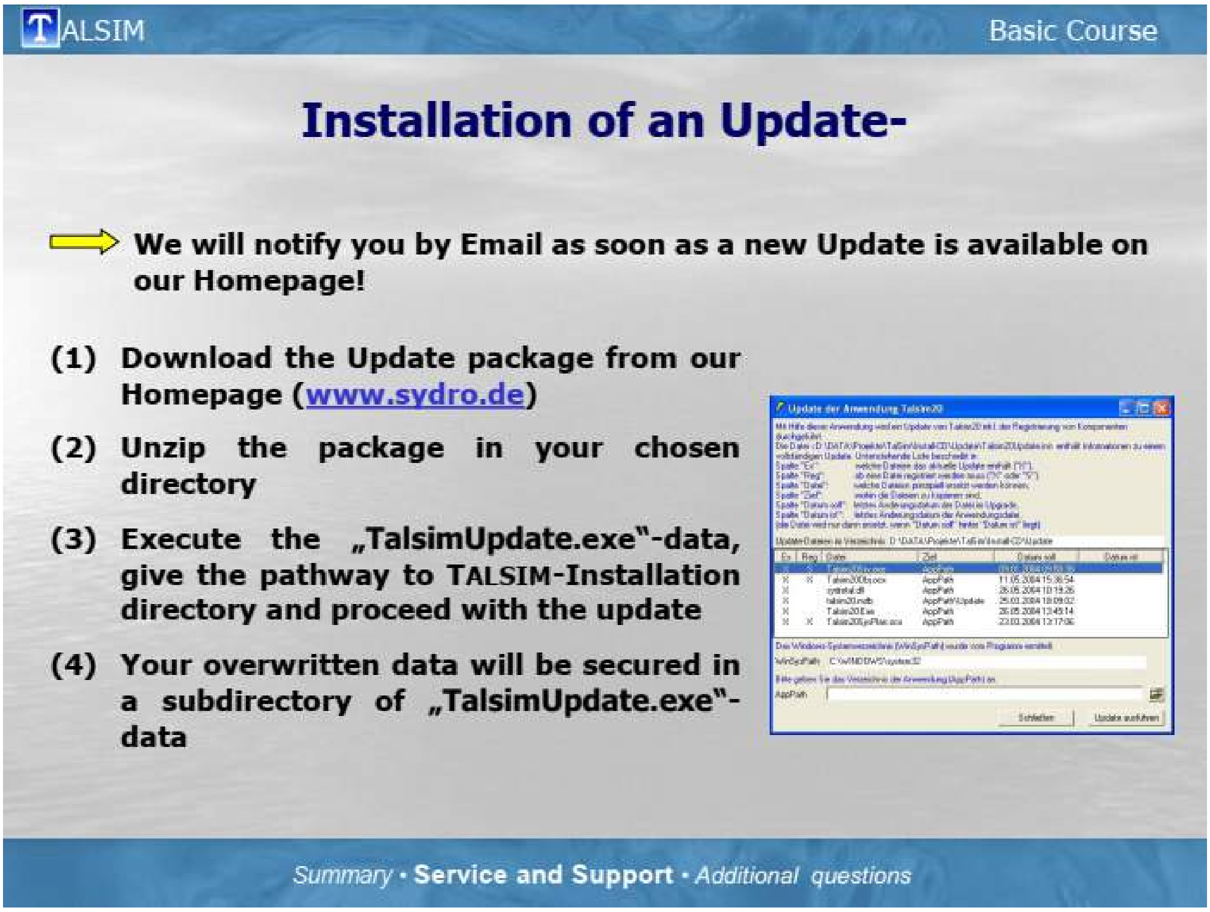

TALSIM
Basic Course
Short-term Simulation
Example: HW-Statistic layout
Description: Example-Statistic
Max. Q: 50 [m³]
Sequence Computation: Dyck
Input values for Statistic
(with activated hyperbolic tangent)
Hydrograph Parameter
Name
Calculation:
OK
Apply
Cancel
Introduction and setup • Settings • Design storm and floods • Example • Simulation

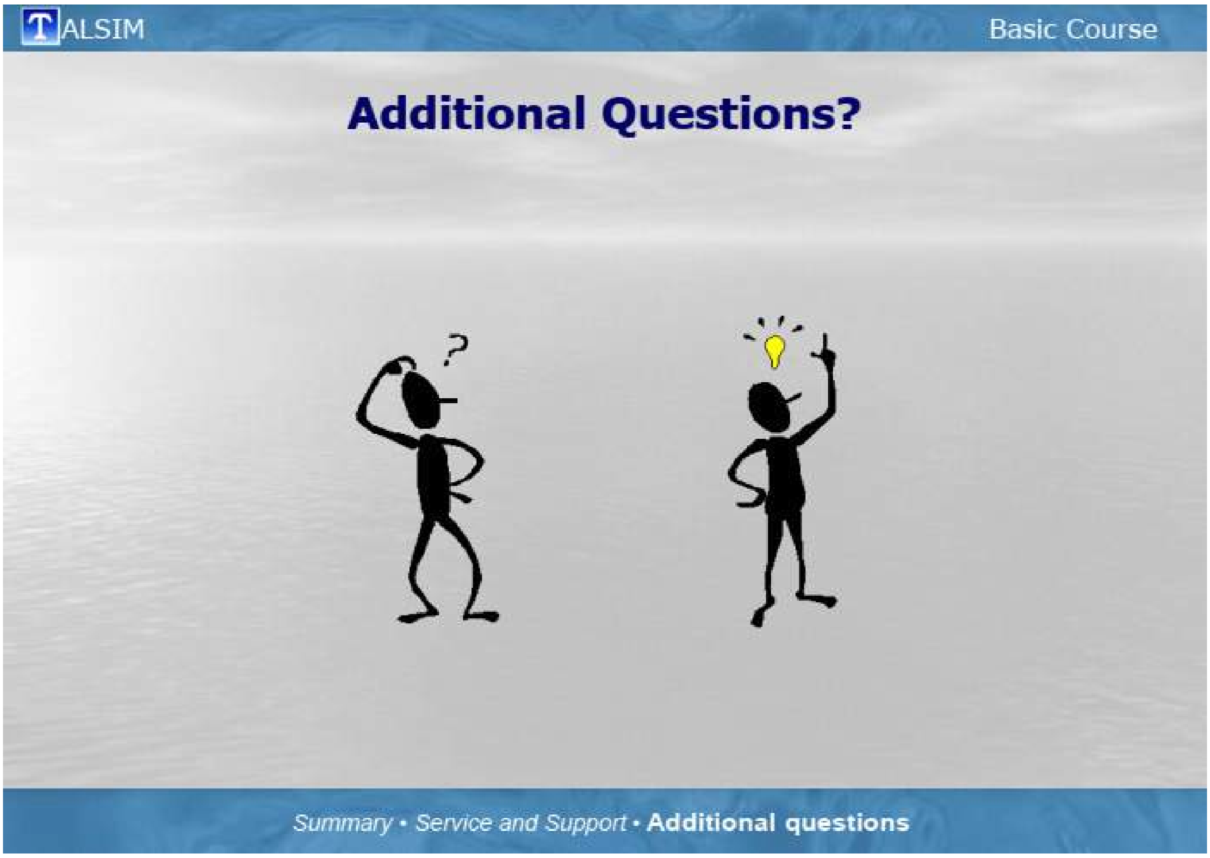

TALSIM
Basic Course
Short-term Simulation
Example: Simulation settings
Description: Euler-II – 30.7mm – 360min
Short-Term Simulation / Design storms
New,copy,save menu
Inflow
Precipitation
Use network selection
Selection from list
Properties hydrograph
Properties precipitation
Euler - Type 2
Speichern
Close
Introduction and setup • Settings • Design storm and floods • Example • Simulation


TALSIM
Basic Course
Short-term Simulation
Example: Simulation execution
⇨ Activate the element A100 in the results display!
⇨ Click the „Simulation"-button ⇒ Summary; check the settings and execute the simulation.
⇨ Description: Simulation: Euler-II - 30.7mm - 360min
⇨ Check the balances
⇨ Display the following curves:
⇨ rainfall, effective rainfall
⇨ effective rainfall, surface runoff, actual evaporation
⇨ soil moisture, surface runoff, interflow, baseflow
⇨ Select the appropriate depiction
Prognose - Einstellungen
Simulation
Simulationszeitschritt [min]: 5
Anzahl der Zeitschritte: 200
Zufluss:
Jährlichkeit Tn [a]: HQ 20
Skalierung der Anlaufzeiten [%]: 100
Skalierung der Scheitel [%]: 100
Start bei Zeitschritt: 1
Niederschlag
Niederschlagshöhe [mm]: 30.7
Niederschlagsdauer [min]: 360
Modellregen: Euler - Typ 2
betroffene Elemente
Einzelleiter [Q]: 1
Einzugsgebiet(e) [N, ETp, T]: 4
Simulation
Abbrechen
Introduction and setup • Settings • Design storm and floods • Example • Simulation


TALSIM
Basic Course
Summary-
• Preliminary computer settings
• Data management and organisation
• Administration and practice with time series
• Modelling in a modular system
• System elements with properties and methods
• Representation of operation rules
• Rainfall Runoff-Modelling
• Long-term and short-term simulations
• Presentation and analysis of results
Summary • Service and Support • Additional questions


TALSIM
Basic Course
Service and Support-
We offer:
⇨ Technical support (problems with installation, regular updates, removal of any Software bugs)
⇨ Advice for the handling and servicing of TALSIM
⇨ Further system training (Themes: mapping of complex rules and control systems, modelling of dam systems, working with group conditions, target functions for the assessment of control structures)
Please understand that,
that the implementation of your project in TALSIM does not fall under support
Summary • Service and Support • Additional questions


TALSIM
Basic Course
Installation of an Update-
We will notify you by Email as soon as a new Update is available on our Homepage!
(1) Download the Update package from our Homepage (www.sydro.de)
(2) Unzip the package in your chosen directory
(3) Execute the „TalsimUpdate.exe"-data, give the pathway to TALSIM-Installation directory and proceed with the update
(4) Your overwritten data will be secured in a subdirectory of „TalsimUpdate.exe"-data
Summary • Service and Support • Additional questions


TALSIM
Basic Course
Additional Questions?
Summary • Service and Support • Additional questions

Correspondence:
P.O.Box 6101
184 Fa Ngoum Road Unit 18
Ban Sithane Neua
Sikhottabong District
Vientiane 01000
Lao PDR

Tel: +856 21 263 263
Fax: +856 21 263 264
www.mrcmekong.org