



Training Manual for MIKE HYDRO Basin

STEP-BY-STEP TRAINING GUIDE







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MIKE HYDRO Basin Bargi: Setting up and analysing a water resource model of Bargi Dam in Madhya Pradesh Step-by-step training guide

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1 Introduction

1.1 The objective and tasks of the exercise

The present document is a step-by-step exercise for setting up a Water Resources analysis model for the Bargi dam basin in Madhya Pradesh using MIKE HYDRO Basin.

The overall objective of the exercise is to provide descriptions on how to setup and define a MIKE HYDRO Basin model in general as well as to describe the definition and usage of specific water resource modelling features within MIKE HYDRO.

The exercise includes the different steps included in defining the entire model framework for a MIKE HYDRO model used for resources analysis. The tasks included in this exercise are Catchment and River delineation, Rainfall-Runoff modelling including use of the Auto-calibration tool for Rainfall Runoff, definition of the Bargi Reservoir using a rule-curve approach and a connected spillway. Additionally, a number of different types of water users are located within the analysed Basin and these are defined in the model as well.

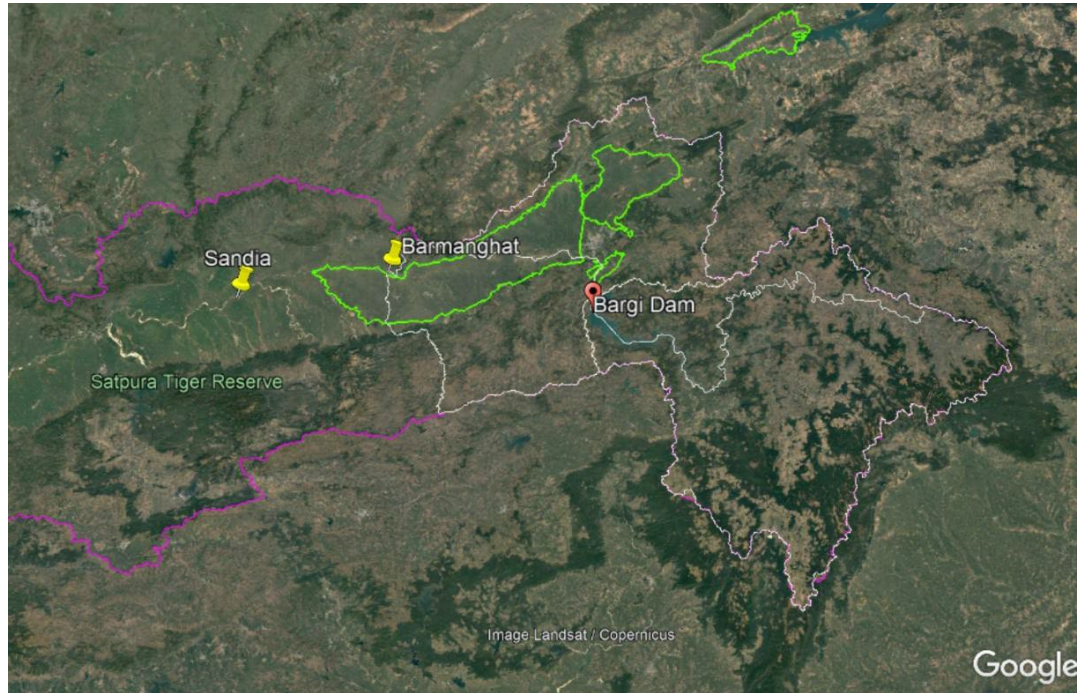
Each section includes a description on how to define the basic properties for the different features applied. Additionally, most sections include an additional task section which includes additional options for working with the specific feature involved in the Bargi basin exercise. The main purpose of the additional tasks is therefore, to become familiar with some of the more specific features included in MIKE HYDRO Basin.

1.2 Background information about the model area and its water resources issues

The catchment area upstream of the dam is presented on the map below. The catchment covers an area of approximately 17297 km², where the climate is influenced by the Arabian Sea. The year is divided into two primary seasons: The climate of the area is classified as sub-tropical, semi-arid. Average annual rainfall is 1350 mm about 80% of which is received during the monsoon period (July to September).

During its construction, the dam has been sized for an annual inflow of 35 million m³. Until now only an average inflow of 19.5 million m³ has been observed, which explains the frequent resource problem of the small amount of available water within the reservoir.

Furthermore, climate change observed over the last 10 years leads to a significant change in inflows reaching the dam – increasing the uncertainty involved for reservoir management. Annual inflows to the basin have been measured and shown a variation over the years ranging from 7 million m³ to 26 million m³ over the last decade.



Map of the river basin and Bargi dam

1.3 Model data for step-by-step exercise

A number of files containing specific data for the Bargi dam basin are provided with this exercise. Data files include a Digital Elevation Model, time series files as well as shape files.

All files are in the Bargi exercise data folder.



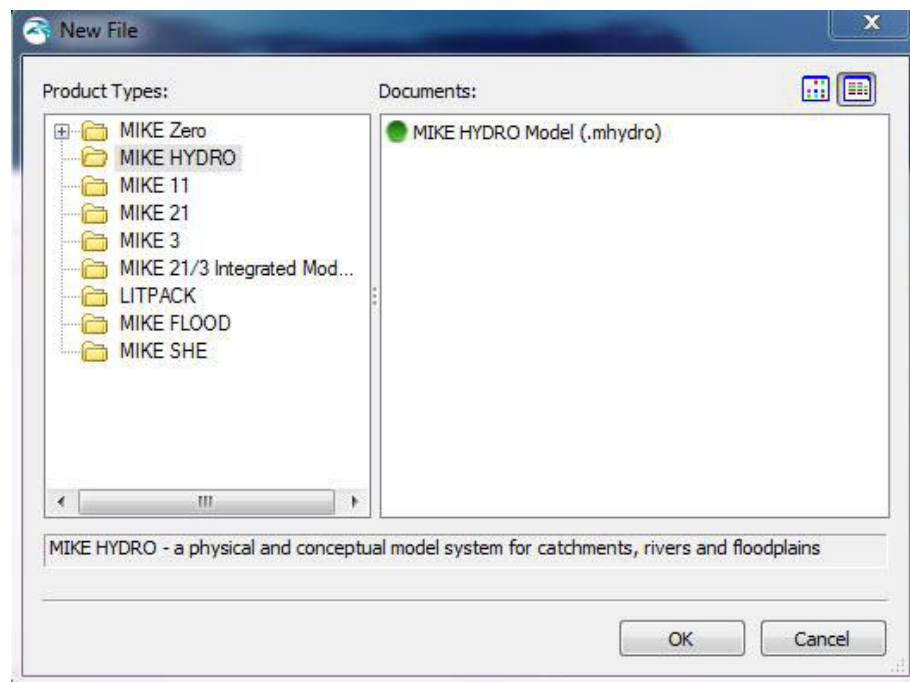
2 Exercise steps

2.1 Step 1: Create a MIKE HYDRO document

The initial tasks when conducting a Water Resources analysis study with MIKE HYDRO is to define the MIKE HYDRO document. This will contain all overall model settings as well as specific definitions for features included in the Water Resources model.

First task is therefore to start creating a new MIKE HYDRO document:

- Open MIKE ZERO and select 'File' -> 'New'
- Choose MIKE HYDRO from the Product Type list
- Select MIKE HYDRO MODEL (.mhydro).
- Press OK or double-click to create new document.



A setup Wizard is available for MIKE HYDRO. This wizard will open automatically when creating a MIKE HYDRO document the first time (file-type: *.mhydro).

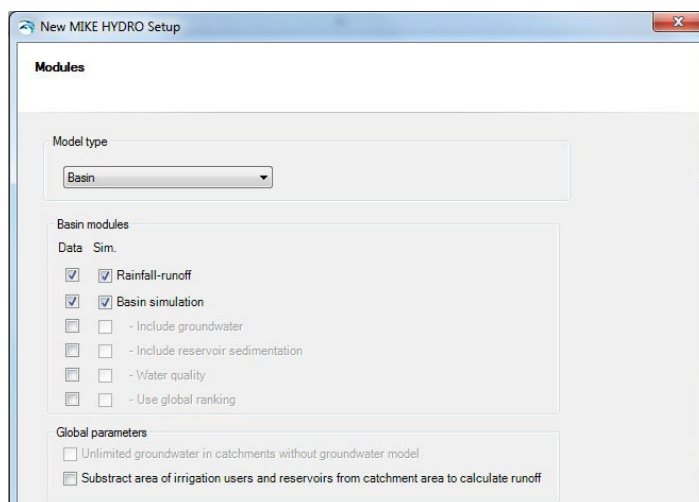
Please follow the steps in the wizard:

On the opening page it is possible to switch off the option for presenting the wizard next time a new mhydro document is created. It is advised to keep this option active.



Click **'Next'** to continue to the **'Modules'** page.

On the Modules page we can select the model type and the modules to be activated within the selected model. In Release 2014 onwards two model types are available: Basin and River. The Basin model type includes features of MIKE BASIN, while the River model type includes features of MIKE 11. This training exercise uses the Basin model type and includes the Rainfall-runoff module, which must be enabled here:



Click **'Next'** to continue to the **'Description'** page



In the Simulation Description page we must supply a title for the simulation. This is an important step as this title will be interpreted as the Name for simulations – and later used as a default name for in output files from simulations.

For this exercise, specify the Title to be: “Sim0_Catchments”

Specifying text in the Description field is optional and it can be left blank for this exercise. Generally, this field will be used to specify information and details about the actual model setup – and all other kind of information relevant to store with the model-file.

The screenshot shows a window titled 'New MIKE HYDRO Setup' with a 'Simulation Description' section. It contains a 'Title:' label followed by a text input field containing 'Sim0_Catchments'. Below it is a 'Description:' label followed by an empty text area.

Click **'Next'** to continue to the **'Coordinate System'** page

The Coordinate System page allows you to define coordinate system for the Map view and the Features (catchments, branches etc.) stored in the setup respectively

Change the coordinate system selections to fit with the locality as presented below.

The screenshot shows the 'Coordinate system' configuration page. It has three main sections: 'Map view coordinate system' with a dropdown set to 'WGS 84'; 'Coordinate system for features stored in setup file' with a dropdown set to 'WGS_1984_UTM_Zone_44N'; and 'Datum shift' with a dropdown set to 'None'. Below the datum shift dropdown are input fields for dx, dy, dz (in meters) and Rx, Ry, Rz (in arcseconds), along with a 'Scale' field in ppm. An 'Apply datum shift parameters' button is at the bottom.

Click **'Next'** to continue to the **'Background map'** page



Different options are available for background maps; None, Google map and Country shape file.

Select Countries/Coastline shape file as the background map:

Background map

Visible

Background map overlay

None

Google map
Google map type:

Countries/Coastline shape file (Network connection not required)
 Color ramp

No additional information should be entered through the wizard and you can continue through the following steps of the wizard without additional actions by clicking 'Next' till you reach the final page of the wizard:



The final page states that MIKE HYDRO setup wizard is complete.

Click '**Finish**' to close the wizard and enter the MIKE HYDRO Basin editor:

The last step after defining initial settings through the wizard is to save your model file.

Choose 'File' -> 'Save' from the main menu bar to save the mhydro file.

File-name: 'Bargi_model.mhydro'
Location: choose your working directory for this exercise (preferably where you have the model input data)

2.2 Step 2: Defining model Catchment and River network

The present model consists of a single Catchment and a number of river branches. These will be defined in this section through usage of the delineation tool in MIKE HYDRO.

2.2.1 Add shape overlays

Add shape overlays to help identify the locations to be used in the catchments delineation.

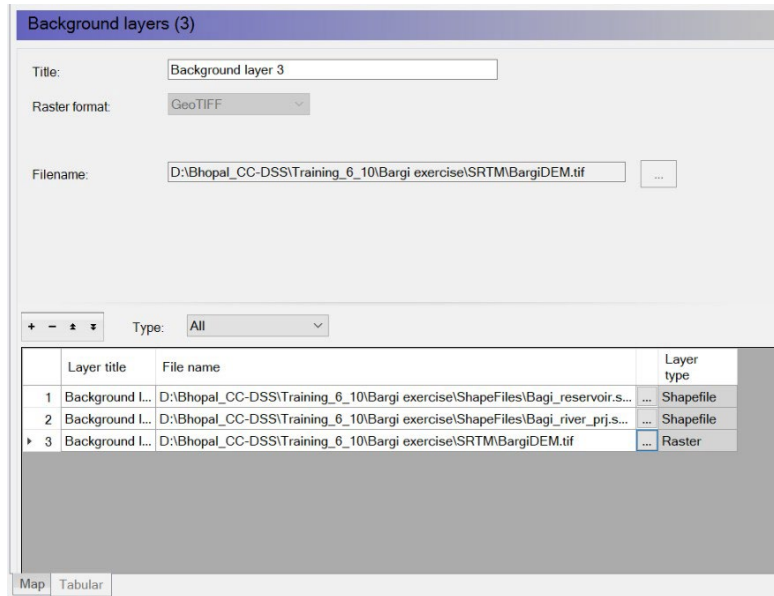


Note that all shape overlays added to the MIKE HYDRO interface will be transferred to the catchment delineation view.

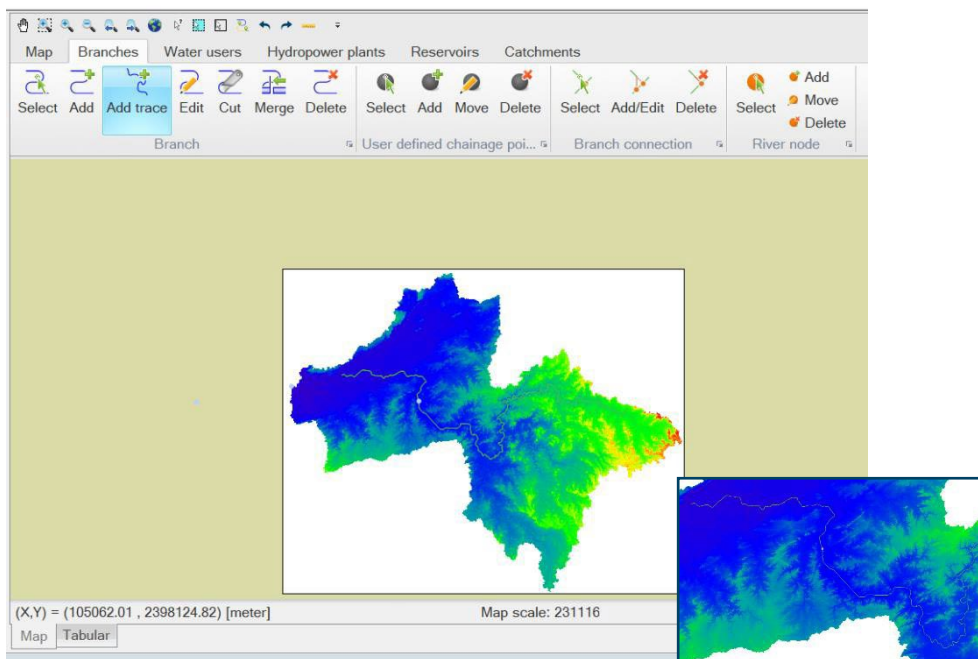


Add the following shape files as “Background layer”:

Bargi exercise\ShapeFiles\Bargi_dam.shp
Bargi exercise\ShapeFiles\Bagi_reservoir.shp
Bargi exercise\SRM\BargiDEM.tif



The shape files will appear in the map view as illustrated in the figure below.



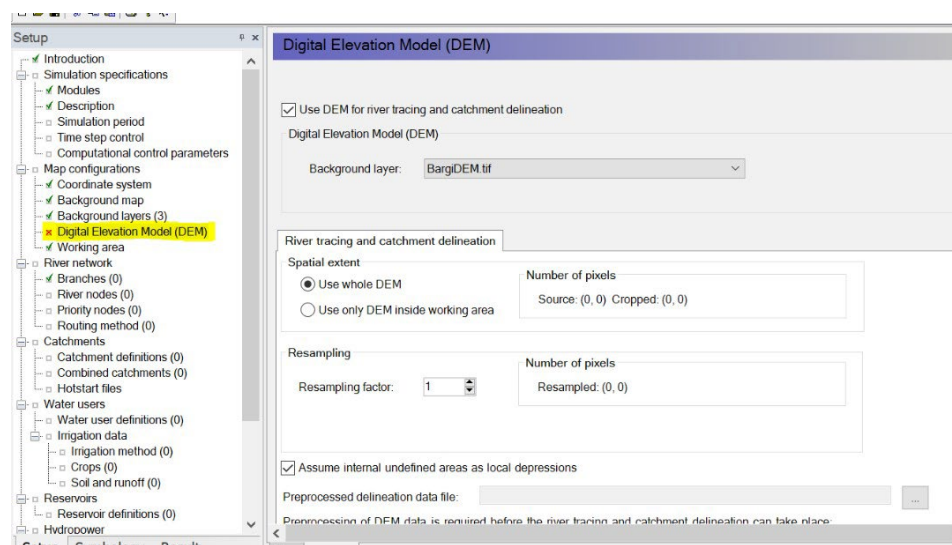


2.2.2 Create catchment from DEM

In this task a river network and a catchment will be created by using a DEM-file (Digital Elevation Model).

Once DEM is added to the background layer. In the Digital Elevation Model (DEM), The DEM layer will be activated.

We are going to create catchments using River tracing and Catchment delineation features in MIKE HYDRO, which requires import and processing of a Digital Elevation Model in advance. Activate the Digital Elevation Model (DEM) entry from the tree view as shown below.





Digital Elevation Model (DEM)

Use DEM for river tracing and catchment delineation

Digital Elevation Model (DEM)

Background layer: BargiDEM.tif

River tracing and catchment delineation

Spatial extent

Use whole DEM
 Use only DEM inside working area

Number of pixels
Source: (0, 0) Cropped: (0, 0)

Resampling

Resampling factor: 2

Number of pixels
Resampled: (0, 0)

Assume internal undefined areas as local depressions

Preprocessed delineation data file: D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\SRM\Bargi_1.pdd

Preprocessing of DEM data is required before the river tracing and catchment delineation can take place:

Preprocess digital elevation data

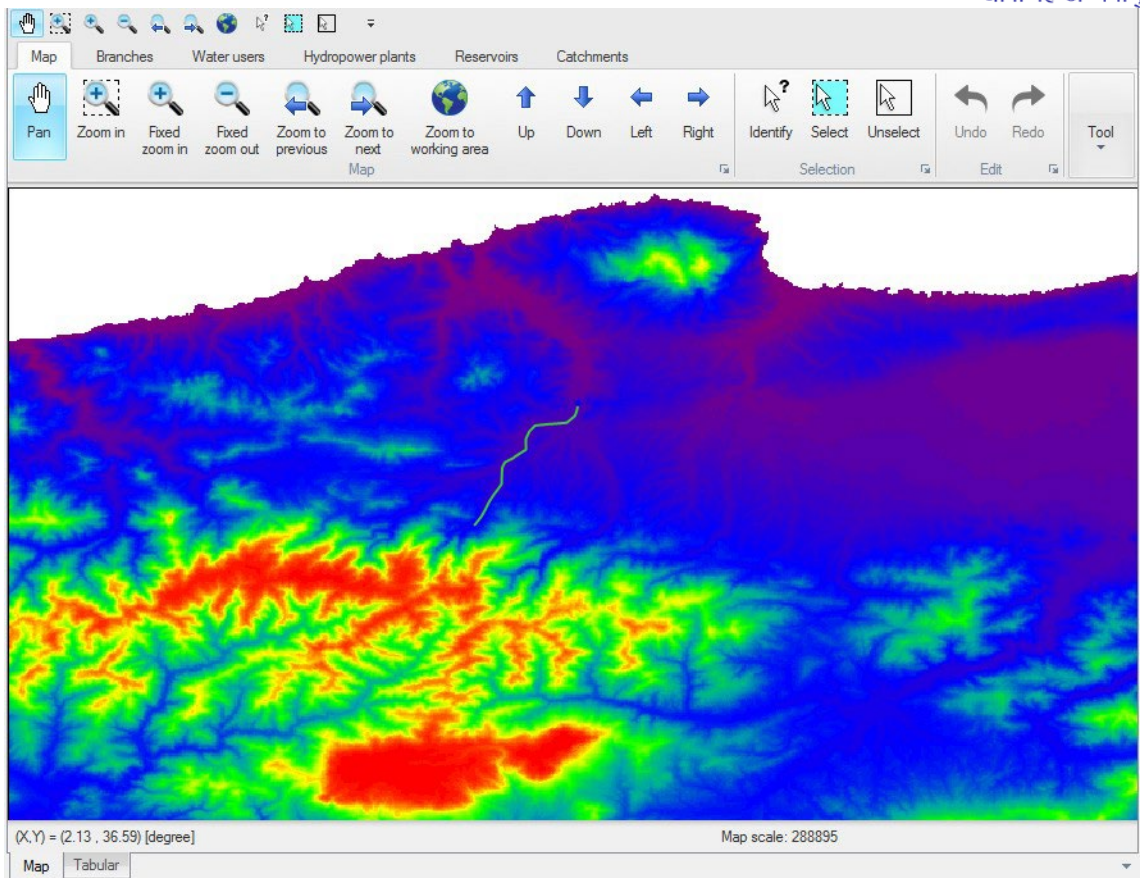
Status of preprocessed delineation data file: **Not up to date**

2.2.3 Tracing rivers and delineating catchments

Before rivers can be traced and catchments delineated, it is required to process the elevation data in the DEM-file.

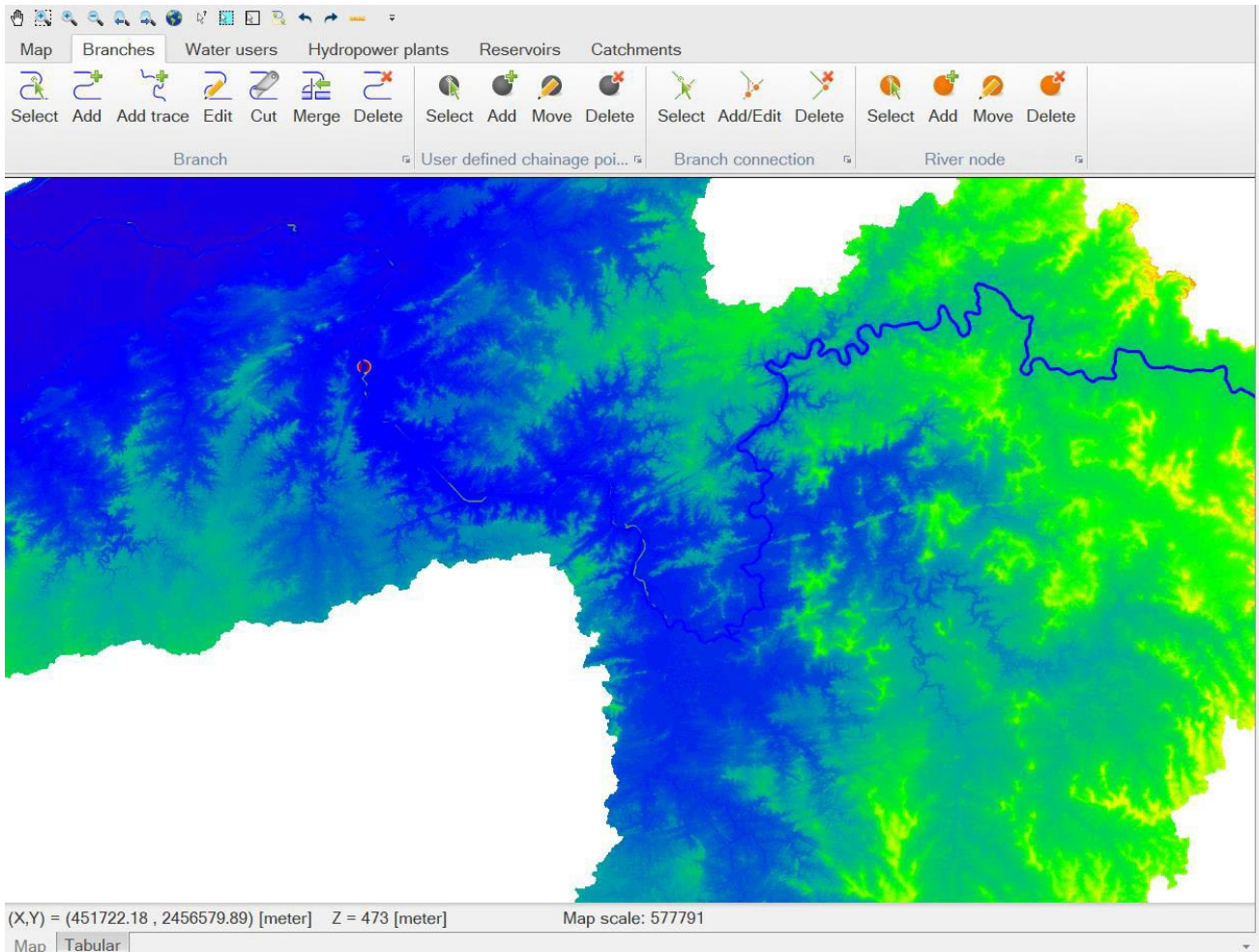
Press “Preprocess elevation data” button. This will start the processing. After processing has completed, ‘Status of pre-processed delineation data file’ will change to ‘Up To Date’.

Change to the Map view and Zoom in to the area as shown below:



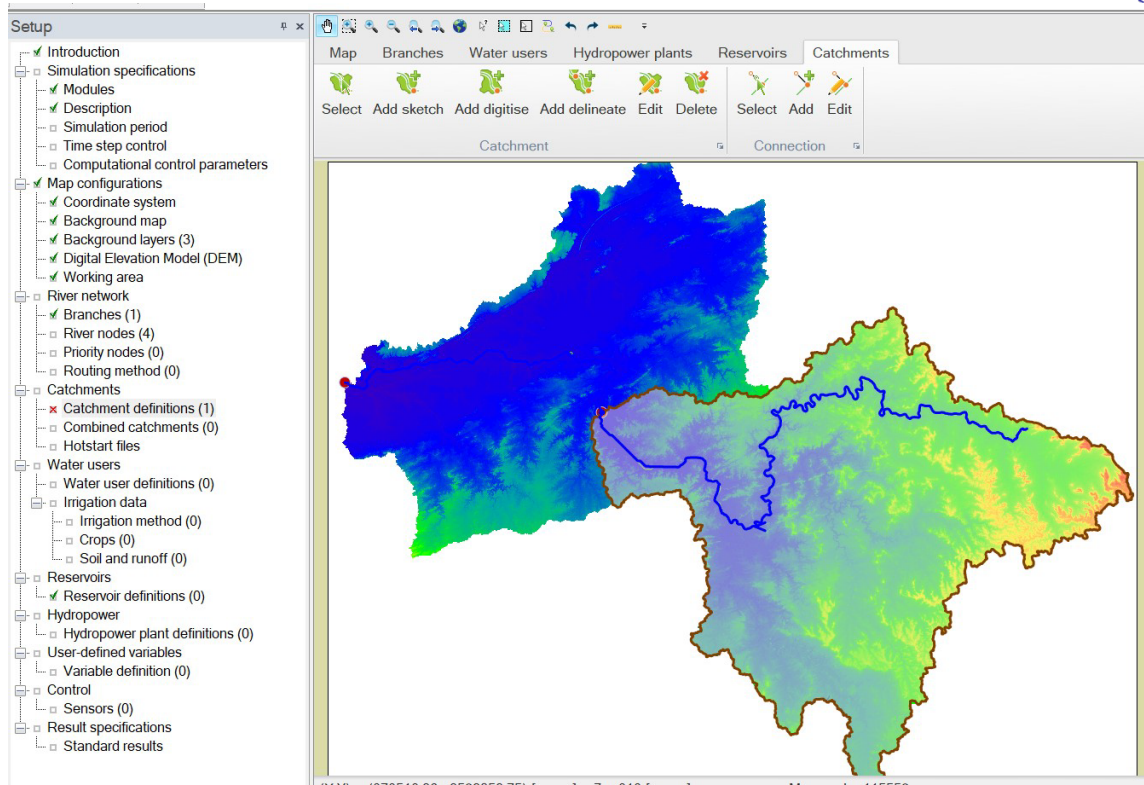
Find the area by looking for the shape file layers. The shape file layers will illustrate the location of the dam and one of the main rivers running down to the dam.

Initially we want to trace the river. On the Map view, activate the Branches toolbar. Activate the 'Add trace' feature and click at the upstream node of the river that you want to trace. The tracing tool will automatically find the flow direction for the river. In this case, the river that needs to be traced is flowing from east to west (toward the Arabian sea). Therefore to trace the river you need to click on the east of the mountain (The upstream point of the river outlined in the shapefile).



After the river has been traced, we need to find the location of the Bargi dam and insert a Catchment node at that location in order to allow the delineation of the catchment upstream of Bargi dam.

Activate the Catchments toolbar and activate the 'Add delineate' button to start the Catchment Delineation. Click once with the mouse on top of the delineated river branch at the location where the Bargi dam symbol is located and the catchment will be delineated and a Catchment node also automatically generated.



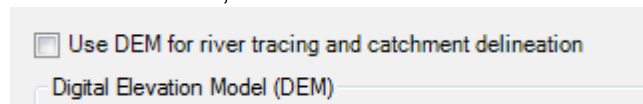
NOTICE on Google map as a background map:

The current version of MIKE HYDRO does not allow to combine raster with Google maps and consequently, when digitising rivers and catchments using a processed DEM, it is not possible to select Google map as a background layer during this process. This issue will be addressed and corrected in a future release of MIKE HYDRO.

It is however, possible to change to Google maps as background after the river and catchment delineation has been finalised – at the time where we in reality do not need the DEM any longer.

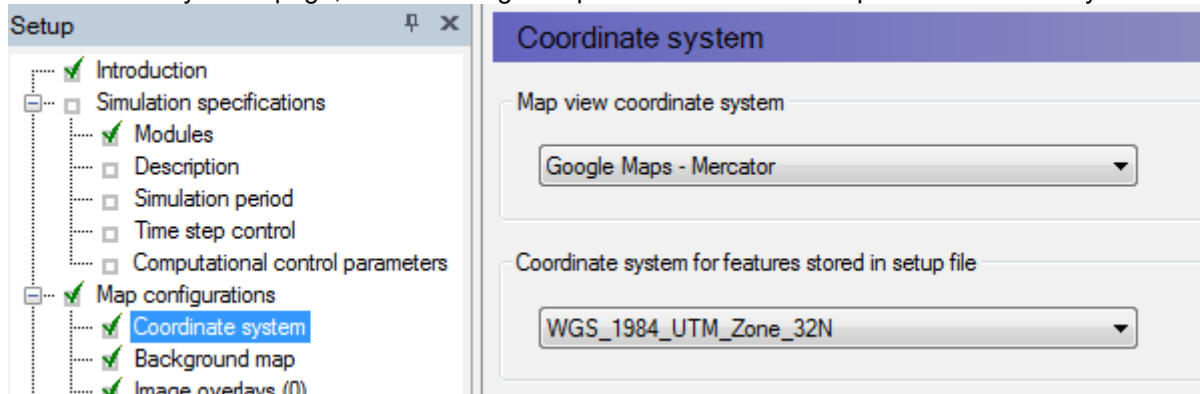
If you would like to switch to Google map as a background map (requires internet connection) then please follow the steps outlined below:

1. In the Digital Elevation Model (DEM) page, de-activate the checkmark for using DEM in the model;



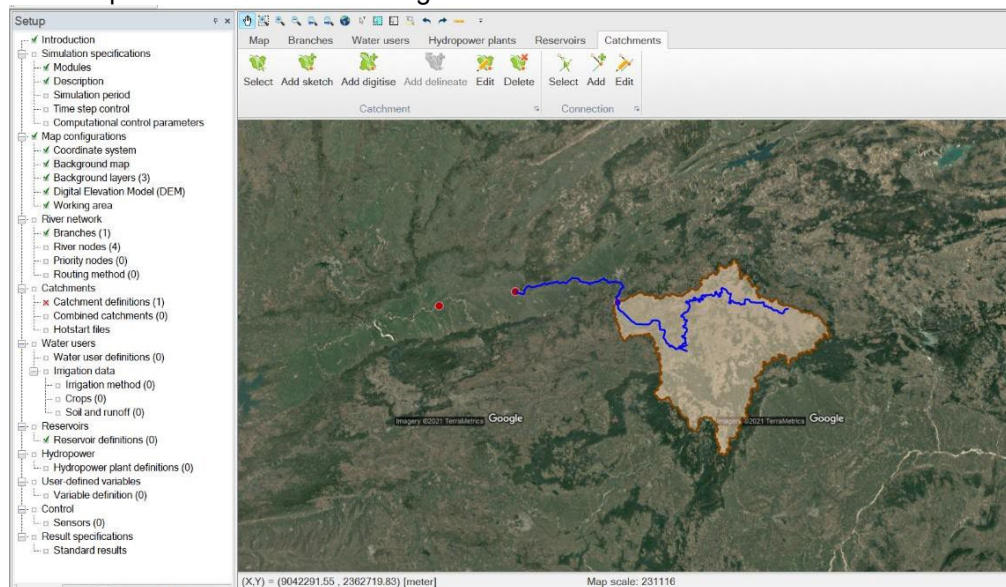


2. In coordinate systems page, activate Google Maps – Mercator in the map view coordinate system :



3. If you would still like to see the shapefile data (river and dam symbol) then it may be required to re-load these files after changing the coordinate system for the map view (to update shapefile location with new map coordinate system).

Your map would not look something like this:



2.3 Step 3: Specifying data for rainfall-runoff modelling

The NAM rainfall-runoff model will be used to calculate the runoff of the catchment.

The Bargi dam was constructed back in 1988. Following the construction, inflow to the catchment has been measured continuously and the NAM model will be calibrated against this data.

One of the benefits of applying a continuous rainfall runoff model like NAM is that once the model is calibrated, it is possible to calculate the runoff from the catchment for periods even before the dam was built. Once a rainfall-runoff model is calibrated for a catchment,



it is possible to use meteorological (precipitation) measurement for previous years and thereby extend the period where runoff data are available.

To setup rainfall-runoff model details, activate 'Catchments definitions' in the tree-view and select the 'Tabular' view to see the Catchment property dialogue.

2.3.1 NAM model including Autocalibration

We will now define some catchment characteristics and activate the Autocalibration tool for the rainfall runoff model:

In the catchment property dialogue, change the Rainfall-runoff type to NAM and enable Calibration plot as shown below. Please note that specifying any Rainfall-runoff model will activate an additional tab named "Rainfall-Runoff".

Catchment definitions (1)

General Rainfall-runoff

Catchment name: Catchment 1 Identifier: C4

Use catchment shape to calculate area

Area: 14992

Groundwater model: None

Rainfall-runoff model: NAM

Runoff time series: RainfallRunoff_Bargi_sim.dfs0

Calibration plot

Load sh

Filter in Show all catchments

	Name	Area	Branch name	Chainage	RR-mode
▶ 1	Catch...	14992	Branch 1	337746.44	NAM

Activate the Rainfall-Runoff tab and you will see a number of different data-pages presented on different tabs. These are all specific data used by the NAM model.

Now, go to the 'Autocalibration' tab, and activate "Include autocalibration".



General Rainfall-runoff

Surface-rootzone Groundwater Snow melt Irrigation Initial conditions Autocalibration Seasonal variation Time series

Include autocalibration

Calibration parameters

	Parameter	Fit	Initial Value	Lower Bound	Upper Bound
1	Umax	<input checked="" type="checkbox"/>	10	10	20
2	Lmax	<input checked="" type="checkbox"/>	100	100	300
3	CQOF	<input checked="" type="checkbox"/>	0.5	0.1	1
4	CKIF	<input checked="" type="checkbox"/>	1000	200	1000
5	CK1,2	<input checked="" type="checkbox"/>	10	10	50
6	CK2	<input checked="" type="checkbox"/>	10	10	50
7	TOF	<input checked="" type="checkbox"/>	0	0	0.99
8	TIF	<input checked="" type="checkbox"/>	0	0	0.99
9	TG	<input checked="" type="checkbox"/>	0	0	0.99
10	CKBF	<input checked="" type="checkbox"/>	2000	1000	4000
11	CQLow	<input checked="" type="checkbox"/>	0	0	100
12	CKLow	<input checked="" type="checkbox"/>	10000	1000	30000

Objective function

Overall water balance

Overall root mean square error

Peak flow RMSE Peak flow > 0

Low flow RMSE Low flow < 0

Maximum number of evaluation 2000

Initial number of days excluded 0

Autocalibration implies that the model uses an automatic optimisation procedure to calibrate the 12 most important parameters in the NAM model.

The calibration routine used in NAM is based on a multi-objective optimisation strategy, the SCE algorithm.

Keep default settings to include optimisation of all model parameters.

Finally, in order to run the NAM simulation, it is necessary to specify model input time series. To do this, activate the 'Time series' tab and specify time series as defined below.

The 'Time series' file can be selected or created by clicking on the '...' button.

The time series input for this simulation is:

Rainfall: Bargi exercise\TimeSeries\Bargi_rainfall.dfs0
 Evaporation: Bargi exercise\TimeSeries\Evaporation.dfs0
 Observed discharge: Bargi exercise\TimeSeries\Reservoir_inflow.dfs0

Catchment definitions (1)

General Rainfall-runoff

Surface-rootzone Groundwater Snow melt Irrigation Initial conditions Autocalibration Seasonal variation Time series

Time series for Rainfall-runoff

Rainfall: D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Bargi_rainfall.dfs0 ... Use weighted time series

Evaporation: D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Evaporation.dfs0 ... Use weighted time series

Observed discharge: D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Reservoir_inflow.dfs0 ... Use weighted time series

Temperature: ... Use weighted time series

Irrigation: ... Use weighted time series

Prior to launching the simulation, you must specify 'Simulation Period'

Navigate to 'Simulation Period' in tree view and set the simulation period as follows:

Start date: 01-01-2001 00:00 (January 1st, 2001. 12 o'clock)
 End date: 01-01-2010 00:00 (January 1st, 2010. 12 o'clock)



Simulation period

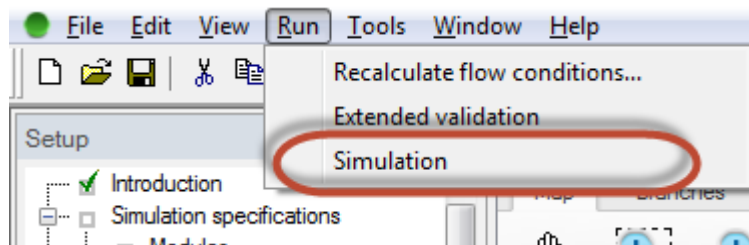
Simulation start 2001-01-01 00:00:00

Simulation end 2010-07-01 00:00:00

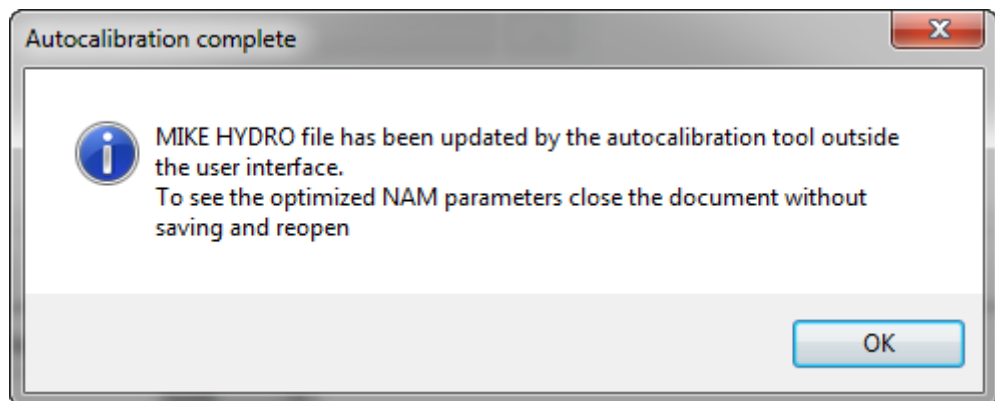
You can now run the simulation, which will include:

- Rainfall-runoff simulation including the NAM autocalibration, and
- Basin simulation

To run the simulation, go to the Main menu bar -> Run and press 'Simulation'.



At the end of the simulation a message will appear:



Click OK, and as indicated close and re-open your mhydro file.

Note: Your changes are always saved when running a simulation. Even if you do not press the button Save prior to starting the simulation.

The simulation will create a result folder with the name; 'MHydro-filename' + ' – Result Files' (example "Sim0_Catchments.mhydro – Result Files").

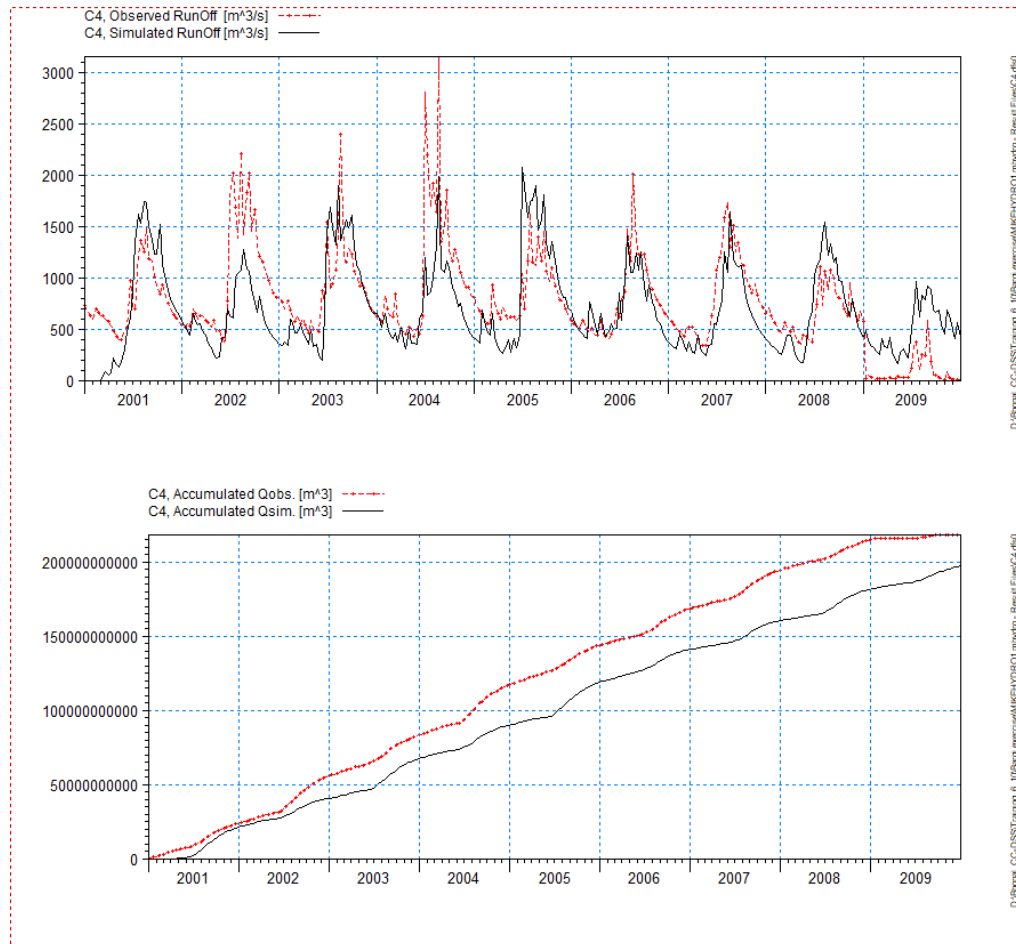
In the result file folder, you will find a Calibration plot file. The file has the name of the Catchment ID and the extension '.plc' (in this exercise, typically name is 'C1.plc').

When opening the file you can analyse the results of the Autocalibration.

The first plot shows the observed runoff together with the simulated runoff.



The second graph shows the accumulated values of these two results.



Before going to the next step, make sure to disable the Autocalibration. The NAM parameters have now calibrated and saved, so it is not necessary to run the Autocalibration every time a simulation is run.

2.3.2 Additional tasks – Rainfall-runoff modelling

Changing objective functions for autocalibration

Note: for this task the Autocalibration needs to be activated under rainfall-runoff model.

It is possible to change the objective function, which are the used to calculate the goodness of fitness. For example, if flood peaks are important in a study, it is possible to select an objective function, which will give more weight to large runoff value.



Objective function

<input checked="" type="checkbox"/>	Overall water balance		
<input type="checkbox"/>	Overall root mean square error		
<input checked="" type="checkbox"/>	Peak flow RMSE	Peak flow >	5
<input type="checkbox"/>	Low flow RMSE	Low flow <	0

If needed, the NAM model can also be calibrated manually, for example by changing some parameters which is not part of the Autocalibration routine.

Note: If you want to make some additional exercises with the Autocalibration tool then it is recommended to save the MHydro-file to another name to prevent to overwrite the NAM-parameter values just obtained through the more general autocalibration task.

Extending reservoir inflow time series

Note: for this task the Autocalibration must be disabled.

The inflow to Bargi Reservoir is based entirely on the runoff from the surrounding catchment and observations are only made since the construction of the dam. However, it is possible to use the calibrated rainfall-runoff model to extend the duration of inflows to the area of the present Bargi dam.

If meteorological data are present for a longer period we can extend the runoff simulation.

Precipitation data is available for a period from 2010 to 2020.

Evaporation data is available 2010 to 2019 and it is therefore necessary to extend the Evaporation time series if we want to generate a longer reservoir inflow time series (otherwise the NAM model cannot be executed for the long period present for precipitation data).

Task

Open the evaporation time series file used in previous step and extend the time series with an average value of 4 mm for the period 2019to 2020

Save the evaporation data file with a different name and select this for the simulation.

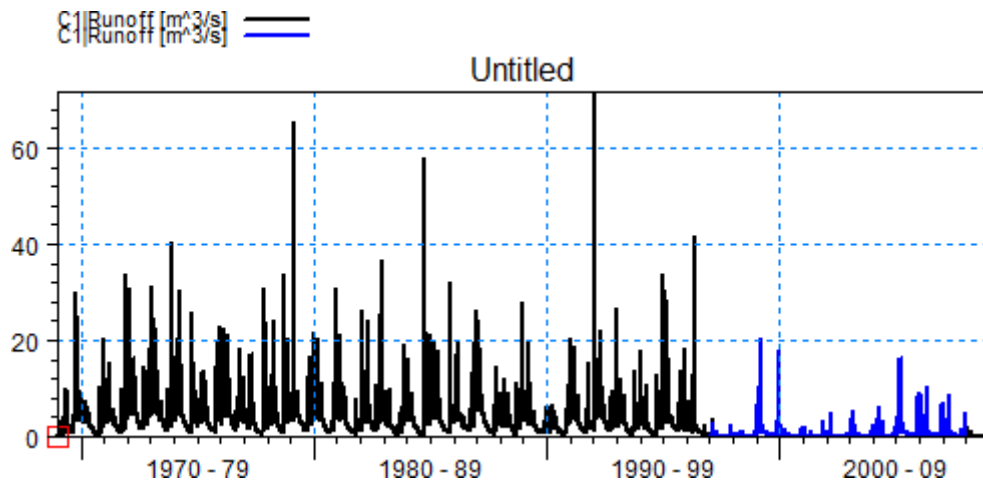
Reset the simulation period to cover a longer period.

Start-date: 1/1/2001, at 00:00

End-date: 1/1/2020, at 00:00

Run the simulation.

Plot runoff from catchments in new simulation and compare to the results of the previous simulation.



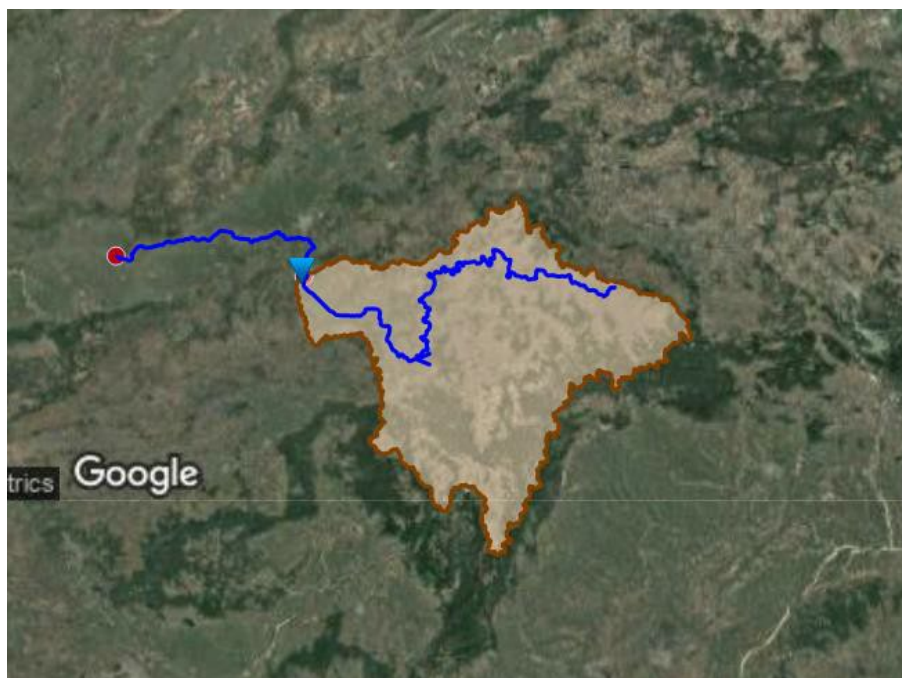
Thereby, we have made a longer inflow time series for the reservoir that potentially could be used to optimise water usage and create statistics for a longer period of time. In conclusion, when using this approach, we are not restricted to only analyse for periods where stream or reservoir gauging exist.

2.4 Step 4: Add Bargi dam reservoirs characteristics

Note: for this task the Autocalibration must be disabled.

Now, we will add the Bargi dam to the model.

The Bargi dam needs to be digitised at the catchment node as illustrated below (Select 'Add Reservoir' in the Graphical View to digitise a new Dam/Reservoir):





Dam and reservoir characteristics are defined as follows:

- Name: Bargi
- Initial Reservoir Water level = 424.9m
- Reservoir type is: 'Rule Curve' (see documentation for type description)
- Storage curve is provided as a Level-Area-Volume relation
- Characteristic levels (provided in time series input file):
 - Bottom level = 377 m
 - Dead storage level = 403.5 m
 - Dam Crest level = 425 m
- Reservoir losses and gains are available.
 These include precipitation gain, Evaporation losses and Infiltration losses

Reservoir data should be entered as specified below:

Reservoir definitions (1)

General Operations Users Remote flow control Storage demand Outlets

Name: Bargi Identifier: R6

Branch: Branch 1

Chainage: 340329.18

Reservoir type: Rule curve reservoir

Initial water level: 424.9

Level area volume table: exercise\TimeSeries\Level area volume table.dfs0 ...

Characteristic levels: TimeSeries\Characteristic levels time series.dfs0 ...

Include losses and gains:

Losses and gains: meSeries\Losses and gains time series_Bargi.dfs0 ...

Sediment distribution type: Type I

	Name	Branch name	Chainage	Reservoir Type
▶ 1	Bargi	Branch 1	340329.18	Rule curve reservoir

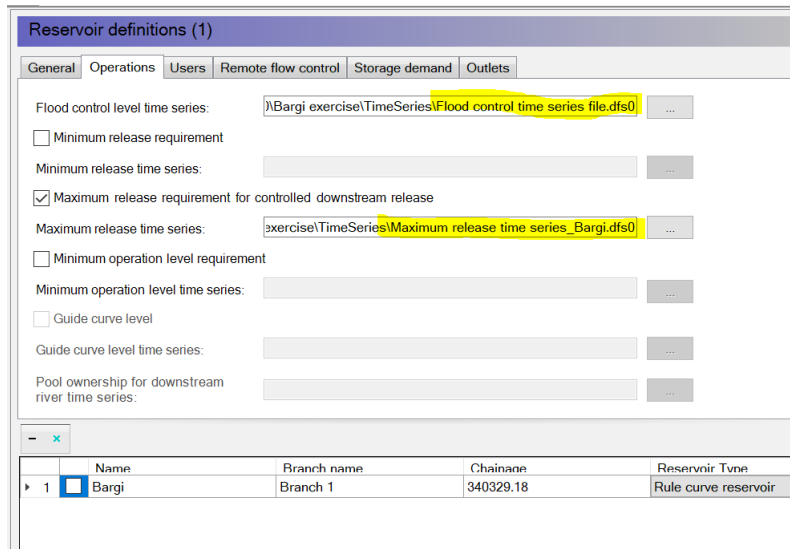


Note: for the gain and losses time series, all items are optional. Using the specified file the different gain and loss data should be selected as follows:

Name	Item
Precipitation	R268 Precipitation
Potential evap	R268 Potential evap
Infiltration	Don't use

Reservoir flood control level must be defined as well.

Flood control level is defined in the 'Operations' tab.



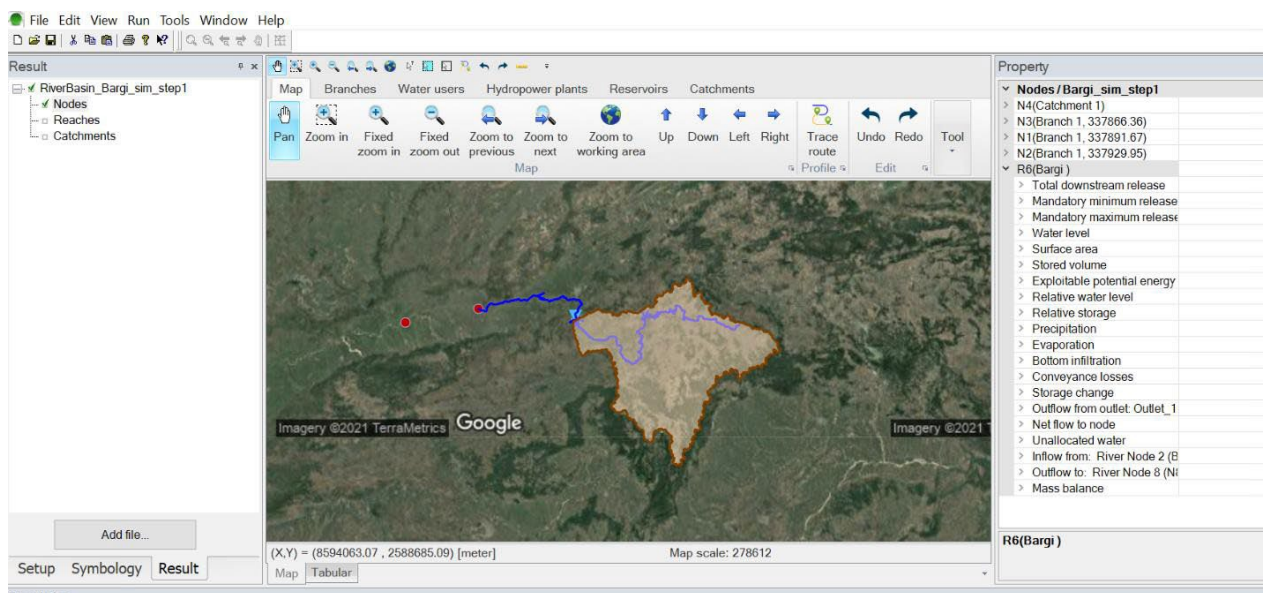
You can now run a simulation including the Bargi dam and reservoir

Initially you should make a different name for this simulation.

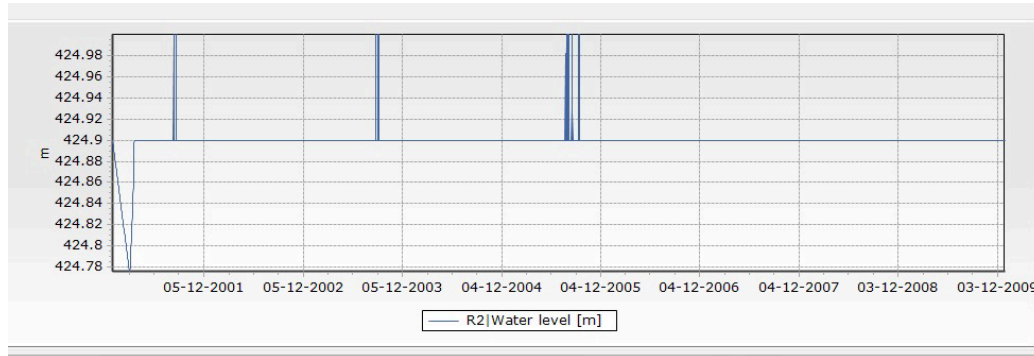
Go to the 'Simulation Description' page and rename the Title to "Step_1"

Run the simulation and analyse the results:

After completion of simulation, open the Results View ('Result' tab under tree view) and plot time series output.



Initially, plot the Water level of the reservoir and you should see something similar to the plot below.



Additional interesting output to plot and analyse can include:

- Downstream Release (when does reservoir release water – and why)
- Water loss from reservoir (Infiltration/Seepage, Evaporation)
Note: input for infiltration and Evaporation is in mm/day. Lost volume is calculated by engine as a function of surface area of reservoir
- Relative storage of reservoir (in %)
- Unallocated water
- ...and other results that you would like to analyse from the results of the Catchment, the Nodes and the Reaches

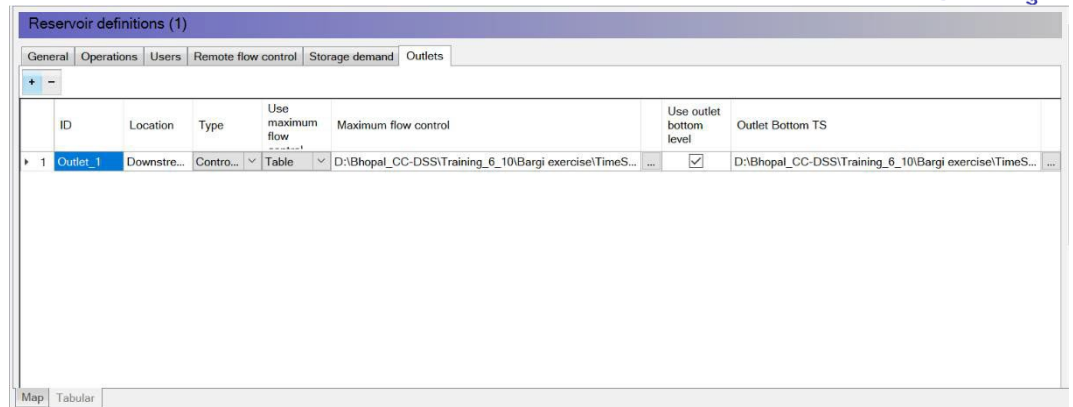
2.5 Step 5: Adding reservoir spillways

We will now further extend the definition of the Bargi dam by adding reservoir spillway data. The Spillway is defined through information stored in time series files.

The data for spillways include:

- Spill capacity table defined as a h-Q(h) table.
That is, a relationship between reservoir Water level and Reservoir outflow table
- Spillway bottom level

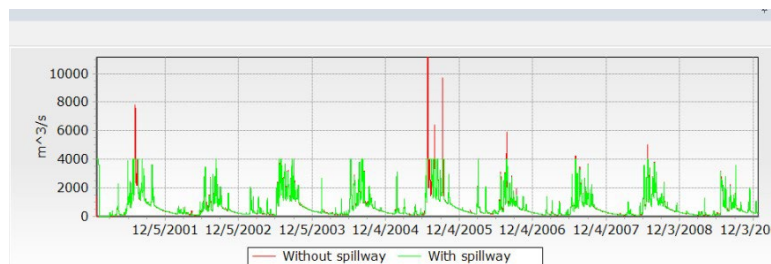
Specify the spillways data as follows:



Now you can run a new simulation including spillways.

Before you run the simulation, change the name of simulation (Title of Simulation description or eventually the result-file name in storage of results). Change the name to "Step_2"

After simulation complete you can compare results of this simulation with results of previous simulation without spill levels. E.g. plot and compare downstream release results with Step 1 simulation for the year 2005.



The effects of the spillways are clearly illustrated!

You should also plot other result items and compare with previous simulation to see the impact on reservoir dynamics after including the spillways in the model framework.

2.6 Step 6: Adding Water users

There are a number of water users present within the Bargi basin – utilising water from the reservoir for different purposes. In this exercise, we will include and define properties for two water users.

Water Users are defined through the following basic steps:

1. In the Graphical View, activate the 'Water Users' tab and click the 'Add' icon.
2. Digitise water users by clicking at the desired location(s) at the map
3. Define connections for the water users using the Add Connections icon on the same page. Connections for Water users include supply connections as well as return flow connections.



- Supply connection is defined by digitising connection from a feature in the model to the water user
- Return flow connection is defined by digitising from the water user to the feature in the model where it should be connected

In this model, add two new Water Users.

Type of Water users must be defined as 'Regular', and both users have the water usage provided for this exercise as a Water Demand time series:

1. Water User 1: Domestic
Water demand time series: "Water use time series_domestic"
2. Water User 2: 'Industry"
Water demand time series: Water use time series_Industry



Following the creation of water users of the reservoir, we must now define the priority of water usage from the different users.

Setup of the reservoir rule curves for water users are done in the Reservoirs page using the 'Users' tab page.

Initially, we will make a simple priority of users with the domestic user being the first priority user and 'Industry' the second priority user as illustrated below.

Additionally, when using a rule curve reservoir it is required to define at least one Reduction level and fraction of reduction. Use the file 'RuleCurve.dfs0' for this purpose

Reservoir definitions (1)									
General Operations Users Remote flow control Storage demand Outlets									
Name	Identifier	Priority	No. of Reduction L...	Pool ownership tim...	Has flow loss	Flow loss timeseries	Has flow capacity	Flow capacity times...	
1	Domestic	E2	1	1	<input type="checkbox"/>		<input type="checkbox"/>		
	Reduction level and fraction file								
	<ul style="list-style-type: none"> 1 D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Rule_curve.dfs0 								
2	Industry	E3	2	1	<input type="checkbox"/>		<input type="checkbox"/>		
	Reduction level and fraction file								
	<ul style="list-style-type: none"> 1 D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Rule_curve.dfs0 								

You are now ready to run the simulation including water users.



Initially, go to the simulation specification and change the title of simulation to 'Step_3'

Run simulation and analyse the results.



In the analysis of results, investigate details on water users and reservoir.

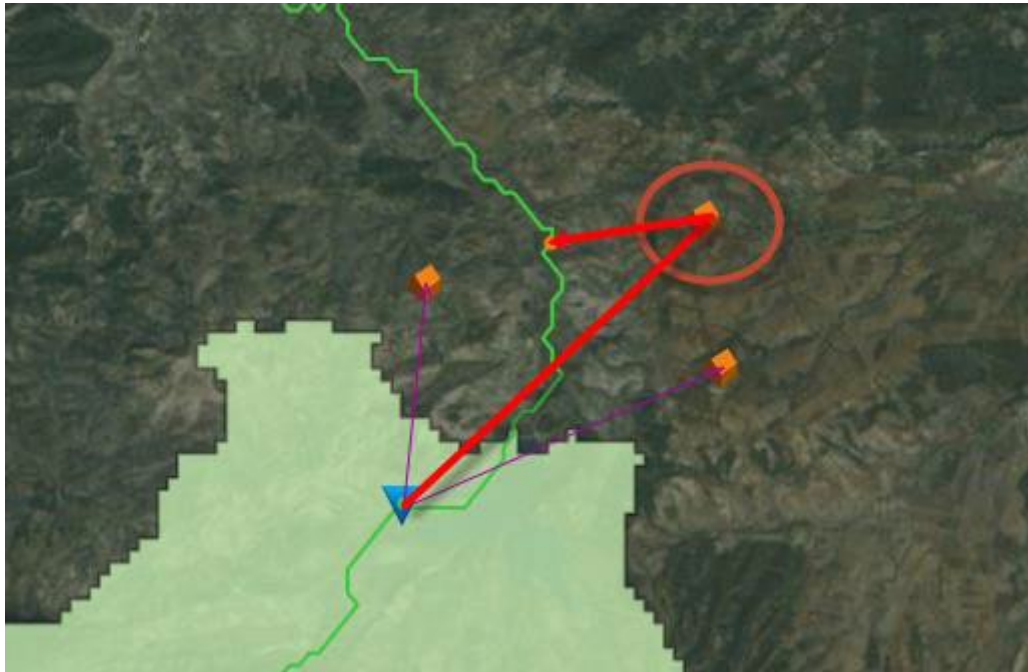
- Are full water usage obtained? Any deficit for water users?
- Reservoir water level dynamics (plot water level with used water)
- Spill of water through spill channels?
- Etc. etc.

2.6.1 Additional tasks – Water users

Additional Water user with return flow

In this task we will define an additional water user to the model defined in Step_4.

Insert a new water user and connect the supply connection from the reservoir AND make a return flow connection and connect it to the river downstream of the reservoir (cf. the figure below).



Characteristics of new water user:

- Name: 'ADD-USER'
- Type: 'Regular User'
- Water Demand: Constant flow = 15 m³/s
Note: You must create a new time series file for the water demand for ADD-USER and select this for Water use time series.
- Supply connection must be defined as 'Call by priority'

Secondly, the Priority of water users from the reservoir must be adjusted.

- In the Reservoirs page, change the priority of ADD-USER to 3 (last priority) and specify one for 'Number of reduction levels'
- Select the file 'RuleCurve.dfs0' as the Reduction level and fraction file (same as for other water users.)

Return flow time series is defined by using the below option under water user tab



Water user definitions (1)

General Supply connections Return flow connections

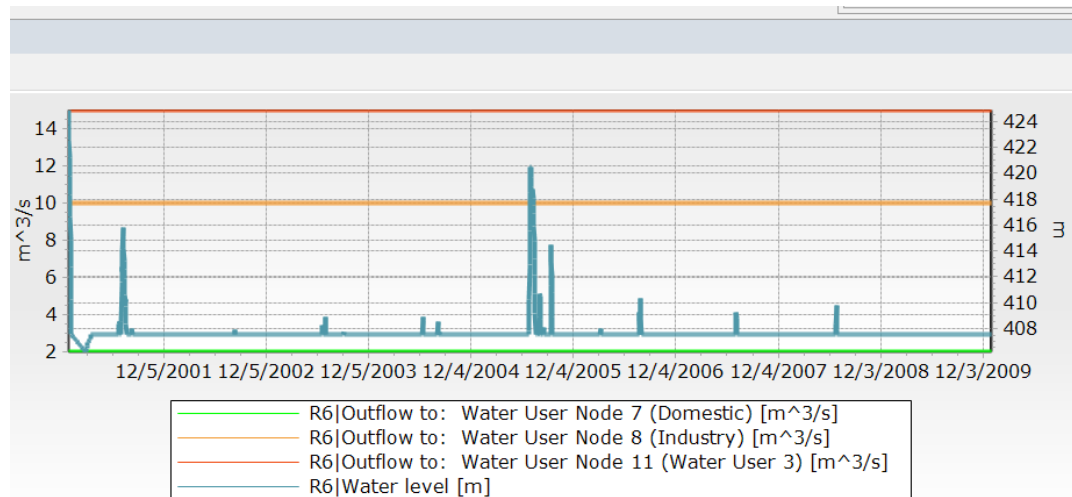
	Identifier	Return flow to	Chainage	Return flow file	Has flow loss	Flow loss timeseries	Has flow capacity	Flow capacity timeseries
▶ 1	E2	Branch 1	216178.23	...	<input type="checkbox"/>		<input type="checkbox"/>	...

Run the simulation.



Analyse results of simulation:

- Water demand fulfilled for all users?
- Water shortage / supply deficit? Why?
- Plot outflow of 3 water users from reservoir together with Reservoir Water level.
- Plot Return flow from ADD-USER



The present implementation results in a total cut-off of water supply to all users in longer periods at dry years.

Additional activities for this task could include different scenarios where the reservoir controls are optimised to allow an improved water usage (e.g. adjusted Reduction levels and Fraction values).

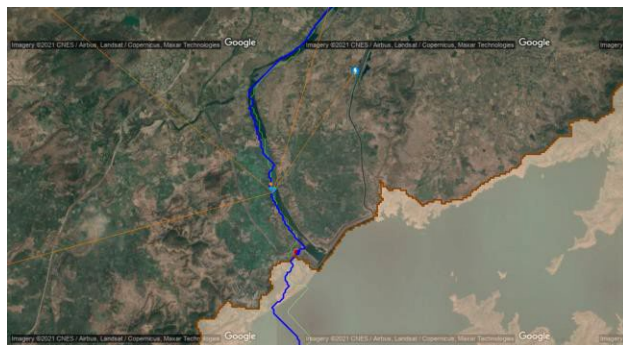
2.7 Step 7: Adding Hydro power

Add hydropower element from map view. Make connection to Reservoir.

Provide the minimum requirement of Hydropower element

Add the following time series files

1. Power demand time series.dfs0
2. Turbine maximum flow table_H271.dfs0
3. Power efficiency table_H271.dfs0





To add turbine maximum flow and power efficiency table the items have to be separately checked

Reservoir: Bargi Reservoir Branch: Narmada Chainage: 3.8564E+05

Power demand time series
 Required items: Target power, Installed capacity
 Optional items: Surplus capacity fraction, Minimum head, Minimum flow
 ...

Head approximation: **Explicit**

Use minimum releases from reservoir

Tailwater
 Use Tailwater table Use downstream release from reservoir
 Has backwater from reservoir below
 Tailwater table: ...

Use head constraint for maximum turbine flow
 Turbine flow constraint table: ...

Use power efficiency table
 Power efficiency table type: **Efficiency as a function of head**
 Power efficiency table: ...

Use head loss table
 Head loss table: ...

Do not forget to give Rule curve for hydropower under Reservoir's users tab

Reservoir definitions (1)										
General		Operations		Users		Remote flow control		Storage demand		Outlets
Name	Identifier	Priority	No. of Reductio...	Pool ownership...	Has flow loss	Flow loss times...	Has flow capac...	Flow capacity ti...		
1	Domestic	E2	1	1	<input type="checkbox"/>		<input type="checkbox"/>			
2	Industry	E3	2	1	<input type="checkbox"/>		<input type="checkbox"/>			
3	Water User 3	E4	3	1	<input type="checkbox"/>		<input type="checkbox"/>			
4	Hydropower ...	E5	4	1	<input type="checkbox"/>		<input type="checkbox"/>			
Reduction level and fraction file										
1	D:\Bhopal_CC-DSS\Training_6_10\Bargi exercise\TimeSeries\Rule_curve.dfs0									

Save the simulation as step_5, Run the simulation and analyse the results.

Running simulation successfully ?

Yes, Hydropower return flow must be added. Provide return flow connection to ds of river.

Property

>	N4(Catchment 1)	
>	N3(Branch 1, 337866.36)	
>	N1(Branch 1, 337891.67)	
>	N2(Branch 1, 337929.95)	
>	N10(Branch 1, 340641.86)	
>	N9(Branch 1, 342692.59)	
>	N13(Branch 1, 345119.87)	
>	W7(Domestic)	
>	W8(Industry)	
>	W11(Water User 3)	
>	H12(Hydropower plant 1)	
>	Generated power	
>	Generated energy	
>	Power deficit	
>	Deficit as flow	
>	Relative deficit	
>	Effective head	
>	Efficiency	
>	Net flow to node	
>	Unallocated water	
>	Inflow from: Reservoir No	
>	Outflow to: River Node 13	
>	Mass balance	

What are the results available at Hydropower node?

How is the demand of HP is fulfilled since giving the lowest priority?

Adjust the priority and run different scenarios



2.8 Step 8: Adding irrigation users

Note: To use ground water model, Under modules, include groundwater option should be checked

Model type

Basin

Basin modules

Data Sim.

Rainfall-runoff

Basin simulation

- Include groundwater

- Include reservoir sedimentation

- Water quality

- Use global ranking

Navigate to Catchments in the Tree View and specify the following input in the “General” tab in Properties view. Delineate downstream catchment. Add the following file

Catchment Name: Bargi ds

Ground water model: 2 Layer

Runoff Time series: Catchment runoff time series_bargi_ds.dfs0.

General Groundwater

Catchment name: Bargi_ds Identifier: C2

Use catchment shape to calculate area

Area: 13187

Groundwater model: Two-layer

Rainfall-runoff model: None

Runoff time series: Catchment runoff time series_bargi_ds.dfs0

Calibration plot

Load sh

Groundwater Tab specify following values for “Depths” and “Time Constants” parameters and use “Recharge.dfs0” for Groundwater recharge time series.



Catchments

General Groundwater

Depths

Initial water table:	Shallow aquifer: 3.9999	Deep aquifer: 20
Outlet:	4	20
Bottom:		20

Time constants

Shallow aquifer: 4	Interface shallow to deep: 4	Deep aquifer: 120
-----------------------	---------------------------------	----------------------

Groundwater recharge time series: ...

2.8.1 Water users

Add a wateruser as Irrigation user, by clicking Water user in tree view and change user type in "General Tab". Also name the node as LBC.



Water user definitions (7)

General | Supply connections | Return flow connections | Irrigation scheme | Irrigated field

Name: Bargi LBC Identifier: I269

Category:

Type: Irrigation user

Water use time series: bargi_updated\Water use time series_W269.dfs0

Groundwater

Groundwater options: Fraction of total demand

Supply Catchment: Bargi_ds

Groundwater fraction use time series: fraction use time series_irrigation.dfs0

Groundwater absolute use time series:

For Groundwater options in this exercise “Fraction of total demand” will be used.

- **Fraction of total demand.** This method will attempt to fulfill the Water user demand by taking a fraction of the demand from the groundwater. This option corresponds to a specified sharing of the surface water and the groundwater resources. If there is limited water available either in the surface water or the groundwater the demand will not be fulfilled.

Open the Irrigation Scheme Tab and specify Bargi_rainfall.dfs0 for Rainfall time series and ET_reference.dfs0 for Reference ET time series.

Water user definitions (7)

General | Supply connections | Return flow connections | Irrigation scheme | Irrigated field

Climate

Climate model: Rainfall only

Rainfall time series: exercise\FAO_irrigation\Bargi_rainfall.dfs0

Climate time series:

Reference ET time series: exercise\FAO_irrigation\ET_Reference.dfs0

Coordinates

Latitude: 23.15519

Altitude: 0

Disaggregate

Deficit distribution (Equal short):

Use a Soil and Runoff model for all fields in the irrigation scheme (this model will be applied to)

Soil and Runoff model:

2.8.1.1. Irrigation method

For the FAO 56 irrigation model the following parameters must be specified:

- Spray loss
- Wetting fraction
- Trigger option
- Application options.

Start to add a new Irrigation method, click on the 'Append' button (+) then a new line is added to the tab displayed at the bottom of the page and the input for the new model can be filled in.

Irrigation strategy TAW = 0.65, use following information:

Name: TAW = 0.65
 Type: FAO56
 Spay loss time series: Irrigation_SprayLossTS.dfs0
 Wetting fraction time series: Irrigation_WettingFractionTS.dfs0

Irrigation method

Name:

Type:

Spray loss time series : ...

Wetting fraction time series : ...

Trigger option

Option :

Time series : ...

Application option

Option :

Time series : ...

+ - X

Irrigation name	Irrigation Method	Spray loss time series	Wetting fraction time series	Trigger
TAW = 0.65	FAO 56	C:\2-DSP_work\10 - Mike Hydro Trani...	C:\2-DSP_work\10 - Mike Hydro Trani...	Fraction of T

Trigger option

Set the trigger option as follows:

Option: Fraction of TAW
 Time series: Irrigation_TriggerTS.dfs0

Trigger option

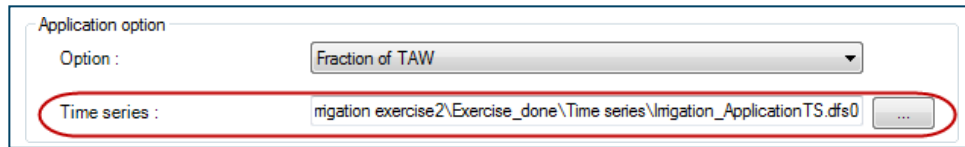
Option :

Time series : ...

Application option

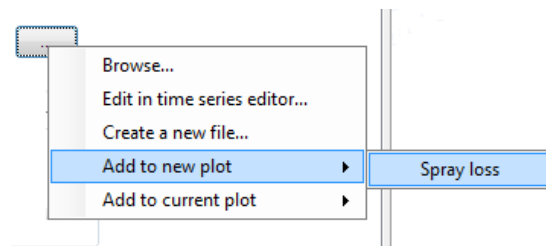
Set the application option as follows.

Option: Fraction of TAW
 Time series: Irrigation_ApplicationTS.dfs0



Also try to plot each time series.

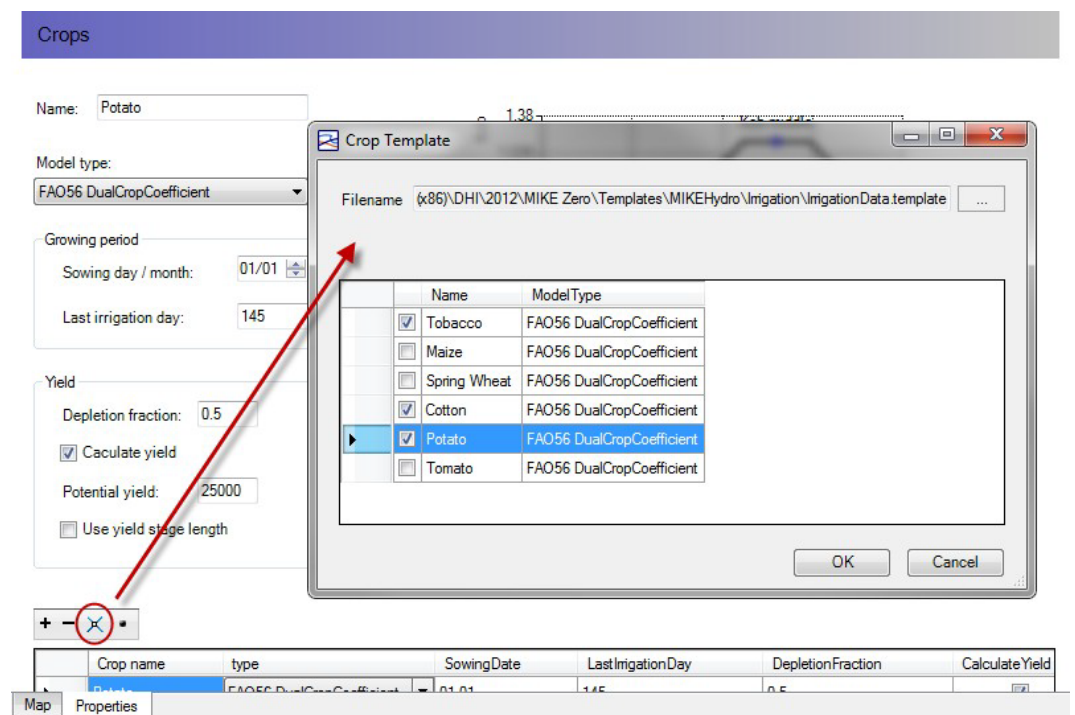
Tips: to plot the time series click on (...) button and “Add to new plot”.



2.8.1.2. Crops

For the Crops specification we will use 3 different crops, which are rice, wheat and Sugarcane by replacing the three crops already available in MIKE HYDRO template.

First, navigate to crops under Tree view and click on Load Template Icon. Then brows to the irrigation template called IrrigationData.template and select Spring wheat, Cotton and Potato.



Edit crop names to rice wheat and sugarcane. The three crops have different sowing dates and the last irrigation day.

Keep parameters as default but explore the information for each crop.

Crops (12)

Name: Sugarcane

Model type: FAO56 DualCropCoefficient

Growing period
Sowing day / month: 01/01
Last irrigation day: 395

Yield
Depletion fraction: 0.5
 Calculate yield
Potential yield: 6000
 Use yield stage length

	Initial	Development	Mid season	Late season
Length	30	40	50	30
Kcb	0.3		1.2	0.5
Root depth	300		1000	
Max height			2.5	
Length (Yield)	46	101	181	71
Ky	0.4	1.4	1.3	0.5

Crops (12)

Name: Rabi Wheat

Model type: FAO56 DualCropCoefficient

Growing period
Sowing day / month: 01/10
Last irrigation day: 110

Yield
Depletion fraction: 0.5
 Calculate yield
Potential yield: 6000
 Use yield stage length

	Initial	Development	Mid season	Late season
Length	20	25	60	30
Kcb	0.3		1.15	0.25
Root depth	300		1200	
Max height			1	
Length (Yield)	20	25	60	30
Ky	0.2	0.65	0.55	1.15

Crops (12)

Name: Kharif Rice

Model type: FAO56 DualCropCoefficient

Growing period
Sowing day / month: 01/05
Last irrigation day: 150

Yield
Depletion fraction: 0.33
 Calculate yield
Potential yield: 780.25
 Use yield stage length

	Initial	Development	Mid season	Late season
Length	30	30	60	30
Kcb	0.15		1.2	0.9
Root depth	75		150	
Max height			1	
Length (Yield)	30	30	60	30
Ky	1	1	1	1



2.8.1.3. Soil and Runoff model

For the Soil and Runoff model, we will use “FAO 56 - Clay Loam” from the template. Similar to how we load crops model, click “Load Template” and select “FAO 56 - Clay Loam”.

Name:

Soil model

Type: FAO 56
 ZIMsched
 ZIMsched for Rice field

Soil moisture content

Initial :	Field capacity :	Wilting point :
<input type="text" value="0.22"/>	<input type="text" value="0.38"/>	<input type="text" value="0.379"/>

Porosity :

Depth of evaporable layer :

Runoff model

Type: None
 Linear
 Modified SCS
 Modified SCS for Rice field

Get back to the Water user “Irrigation Field” and create a new Crop shift and add 3 fields with Field’s names:

ID	Name	Priority	Area
F1	Wheat	1	660
F2	Rice	2	400
F3	Sugarcane	3	140

For all fields, activate Recycle crop sequence and set:

Min. cycle time = 1
 Soil and Runoff model = FAO 56 Clay Loam

Select the Crop model for each field accordingly. The Sowing year for all fields use the year 2001 and select TAW = 0.65 Irrigation method for all fields.

2.8.2 Running the simulation

Before running the simulation, we need to specify the simulation period and time step control

Simulation period

Simulation start: 2001-01-01 00:00:00

Simulation end: 2010-12-31 00:00:00

Set the Time step length to 1 day.

MIKE Zero - [IrrigationFAO.mhydro - Modified]

File Edit View Run Tools Window Help

Introduction

- Simulation specifications
 - Modules
 - Simulation description
 - Simulation period
 - Time step control
 - Computational Control Parameters
- Coordinate System
- Background map
- Shape file overlay
- Working area
- River Network
 - Branches
 - Connections
 - Water users
 - Reservoirs
 - Catchments
 - Hydropower plants
 - Priority nodes

Time step control

River basin management

Time step length: 1 Days

Time step sub multiplier: 1

Stochastic analysis (Reset to initial conditions yearly)

Frequency update for the reservoir surface storage curve (number of time steps between update): 1

Rainfall runoff

Time step length: 1 Days

Then run the simulation.

2.8.3 Examine the results

After simulation run completely, direct to the “Results” tab in Tree view try to plot different item from Irrigation user node.

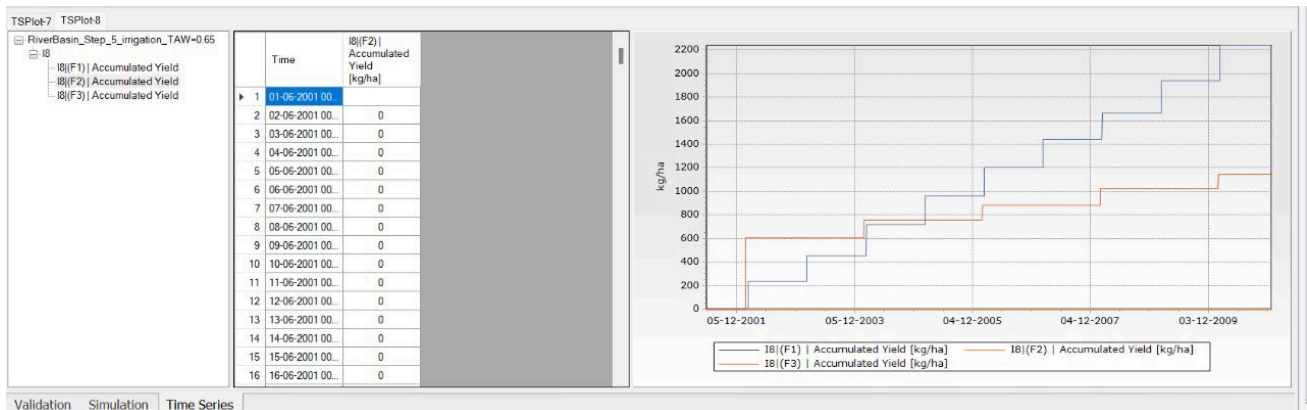
Analyse the stress on the crops by plotting



▲ **Nodes / TAW=0.65**

- ▷ N1(Catchment 1)
- ▲ I3(Irrigation User1)
 - ▷ Total irrigation demand
 - ▷ Evapotranspiration
 - ▷ Runoff
 - ▷ Deep percolation
 - ▷ (F1) | Average root zone soil moisture content
 - ▲ (F1) | Accumulated Yield

Item Name	I (F1) Accumulated Yield	<input type="button" value="Add to new plot"/> <input type="button" value="Add to current plot"/>
Item No	12	
Item Type	Crop Yield	
 - ▷ (F2) | Average root zone soil moisture content
 - ▷ (F2) | Accumulated Yield
 - ▷ (F3) | Average root zone soil moisture content
 - ▷ (F3) | Accumulated Yield
 - ▷ Relative deficit
 - ▷ Water demand deficit
 - ▷ Used water
 - ▷ Groundwater abstraction
 - ▷ Net flow to node
 - ▷ Unallocated water
 - ▷ Mass balance



- How are the results for each crop?
- Try plotting Water demand for all crops.
- Is there any Water demand deficit?



2.9 Step 9: Irrigation method TAW = 0.5

Now you can try to adjust Irrigation Strategies by changing Trigger options for the crops, in this exercise TAW adjust Irrigation methods. Then try to run other simulations from you adjustment.

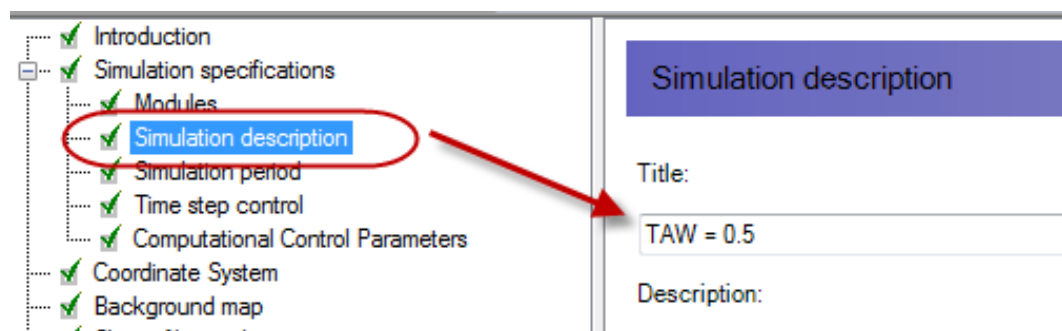
For the second Simulation, we are going to run another strategy by creating a new Irrigation method which lowered Fraction of TAW to 0.5.

Before starting to modify parameters for the 2nd simulation, please make a copy of your fist mhydro file. In case there is some disorder, you have a backup

2.9.1 Parameters modification

Simulation title

Simulation Title: TAW = 0.5



Irrigation method

Create a new Irrigation strategy TAW = 0.5, use following information:

Name:	TAW = 0.5
Type:	FAO56
Spay loss time series:	Irrigation_SprayLossTS.dfs0
Wetting fractions time series:	Irrigation_WettingFractionTS.dfs0

Trigger option

Option:	Fraction of TAW
Time series:	Irrigation_TriggerTS_TAW 0.5.dfs0

Application option

Option:	Fraction of TAW
Time series:	Irrigation_ApplicationTS_TAW 0.5.dfs0



Irrigation fields (in Water User)

Select the new Irrigation method model we just crate for all fields and keep the rest of parameters unchanged.

Name	Priority	Area	Min. cycle time	Recycle crop sequence	Soil and Runoff model
Sugarcane	1	441.7	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Kharif Rice	1	126.2	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date	
Kharif Rice	2001	TAW 0.5	5/1/2001	9/28/2001	
Peas	1	252.4	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date	
Green Peas	2001	TAW 0.5	11/1/2001	2/9/2002	
Rabi Wheat	1	414.7	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date	
Rabi Wheat	2001	TAW 0.5	10/1/2001	2/13/2002	

2.9.2 Run the simulation

Now run the 2nd simulation and check the result as you just done in the previous step.

Compare the water demand and crop stress with the 1st simulation.



2.10 Step 10: Irrigation method TAW = 0.35

Similar to the 2nd simulation, this simulation we will lower the fraction to 0.35 and use the following details for the 3rd run.

2.10.1 Parameters modification

Simulation Title

Change the Simulation Title: TAW = 0.35

Irrigation method

Create a new irrigation method and use following information:

Name: TAW = 0.35
 Type: FAO56
 Spay loss time series: Irrigation_SprayLossTS.dfs0
 Wetting fractions time series: Irrigation_WettingFractionTS.dfs0

Trigger option

Option: Fraction of TAW
 Time series: Irrigation_TriggerTS_TAW 0.35.dfs0

Application option

Option: Fraction of TAW
 Time series: Irrigation_ApplicationTS_TAW 0.35.dfs0

Irrigation filed (in Water User)

Select the new Irrigation method model we just crate for all fields and keep the rest of parameters unchanged.

Name	Year	Area	min cycle time	Region crop sequence	Soil and Water model
Sugarcane	1	441.7	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Kharif Rice	1	126.2	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year		Irrigation method model	First sowing date	First harvest date
Kharif Rice	2001	TAW 0.35		5/1/2001	9/28/2001
Peas	1	252.4	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year		Irrigation method model	First sowing date	First harvest date
Green Peas	2001	TAW 0.35		11/1/2001	2/9/2002
Rabi Wheat	1	414.7	1	<input checked="" type="checkbox"/>	FAO 56 - Clay Loam
Crop model	Sowing year		Irrigation method model	First sowing date	First harvest date
Rabi Wheat	2001	TAW 0.35		10/1/2001	2/13/2002

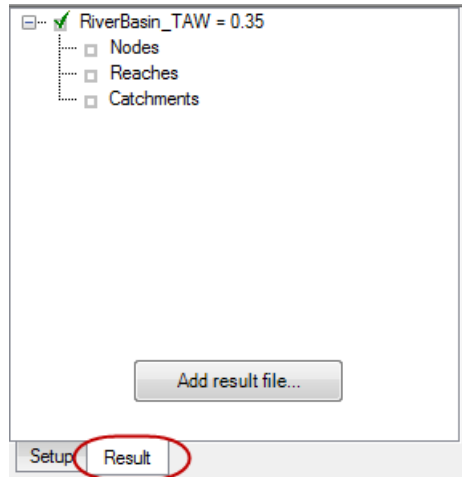
2.10.2 Run the simulation

Now run the simulation and check the result and compare the water demand and crop stress with the previous simulation again.

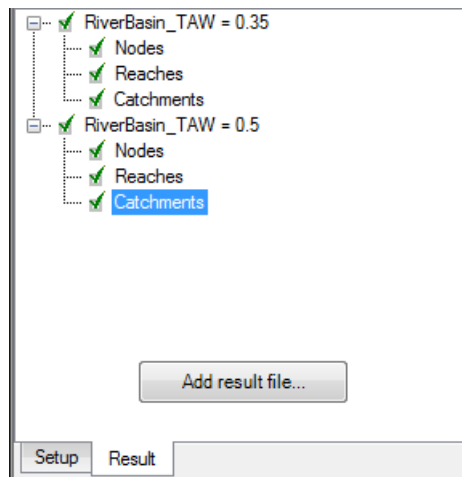


2.10.3 Compare results from 3 simulations

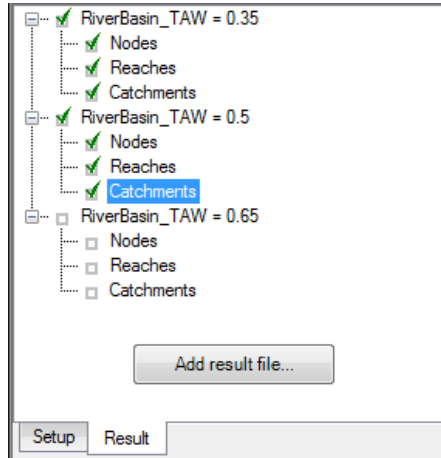
After the running the simulation, we will compare the results of the 3 different simulations. In tree view, select the Result tab and click "Add result file"



Then browse to the result folder of the 2nd simulation where we set TAW = 0.5. In the result folder you will find RiverBasin_TAW = 0.5.mdh which is the result group of the 2nd simulation. Select this file to load then your result should contain 2 groups of result files.

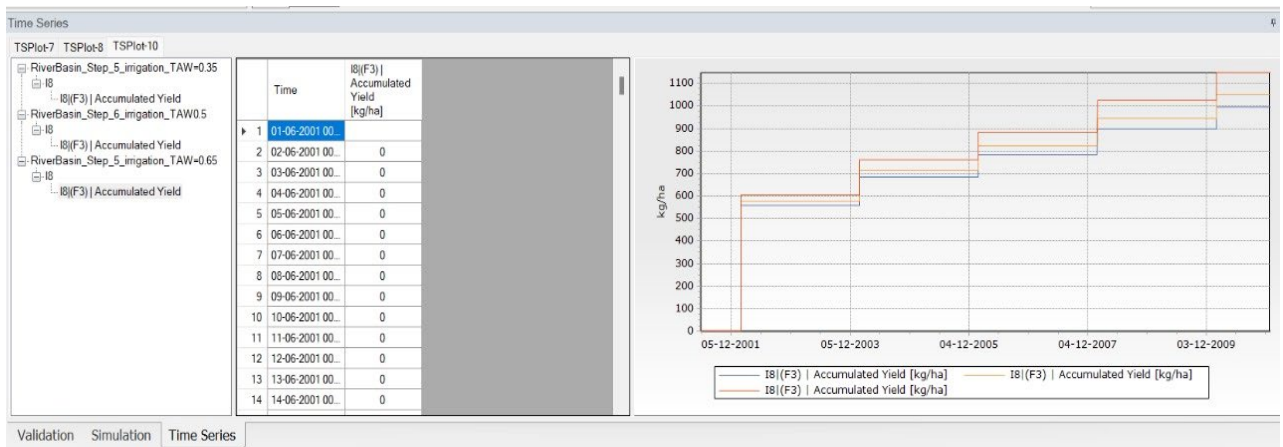


Repeat the same step to load result of the first simulation, find RiverBasin_TAW = 0.65.mdh and load the result group.



Note: if you use the same mhydro file the result for each run will be automatically added. Thus there is no need to add the results groups.

When all result groups are loaded, try to plot the 3 result of Accumulated Yield for Kharif Rice.



Try to compare different item for each crop (e.g. Water Demand deficit, Total Irrigation demand)



2.11 Step 11: Irrigation method RAW = 0

2.11.1 Parameters modification

Simulation Title

Change the Simulation Title to: RAW = 0

Irrigation method

Create a new irrigation method and use following information:

Name: RAW = 0
 Type: FAO56
 Spay loss time series: Irrigation_SprayLossTS.dfs0
 Wetting fractions time series: Irrigation_WettingFractionTS.dfs0

Trigger option

Option: Fraction of RAW
 Time series: Irrigation_TriggerTS_RAW 0.dfs0

Application option

Option: Fraction of RAW
 Time series: Irrigation_ApplicationTS_RAW 0.dfs0

Irrigation filed (in Water User)

Select the new Irrigation method model we just crate for all fields and keep the rest of parameters unchanged.

Water user definitions (7)								
General		Supply connections	Return flow connections	Irrigation scheme	Irrigated field			
ID	Name	Priority	Area	Min. cycle time	Recycle crop sequence	Soil and Runoff model		
1	F2	Sugarcane	1	441.7	1	FAO 56 - Clay Loam	<input checked="" type="checkbox"/>	
2	F3	Kharif Rice	1	126.2	1	FAO 56 - Clay Loam	<input checked="" type="checkbox"/>	
		Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date		
	1	Kharif Rice	2001	RAW 0	5/1/2001	9/28/2001		
3	F4	Peas	1	252.4	1	FAO 56 - Clay Loam	<input checked="" type="checkbox"/>	
		Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date		
	1	Green Peas	2001	RAW 0	11/1/2001	2/9/2002		
4	F5	Rabi Wheat	1	414.7	1	FAO 56 - Clay Loam	<input checked="" type="checkbox"/>	
		Crop model	Sowing year	Irrigation method model	First sowing date	First harvest date		
	1	Rabi Wheat	2001	RAW 0	10/1/2001	2/13/2002		



2.11.2 Run the simulation

Now run the simulation and check and compare results from all simulation as you in step earlier.

2.11.3 Analyse the results

Open the Results_analyse.xlsx and use it as guideline for calculate the Accumulated yields for each crop and discuss what would be the appropriate irrigation method