Scenario Manager Training Module

Revision History

Version	Date	Revision Description
0.1	13/5/2014	Initial draft
0.2	19/06/2014	Updated version to take into account new manager design agreed with NBI-SEC on 12/06/2014 (completed up to the beginner level)
0.3	19/06/2014	Updated version to take into account comments given by the WRMD team on 19/06/2014 at the Nile-SEC
0.4	3/8/2014	Final draft version
0.5	30/12/2014	Final version for approval

Contents

1. Introduction

This document is part of training modules for the Nile Basin Decision Support System (DSS). These modules are developed for use in classroom training that is given to Nile Basin countries and as self-learning training material.

1.1. Purpose

The purpose of this document is to provide a tutorial on the DSS Scenario Manager and its associated components and tools. The tutorial starts with the basics and progressively increases in complexity.

1.2. Module pre-requisites

The following prerequisites are needed before taking this tutorial:
Software prerequisites: The Mike by DHI version 2014 and the DSS version 2.0 have to be installed.
User prerequisites: User is expected to be familiar with or have taken the tutorial of the following:

- DSS Database Manager Utility
- DSS user interface
- GIS Manager
- Time Series Manager
- Indicator Manager
- Script Manager
- Spreadsheet Manager

For advanced lessons such as modifying a model setup and using the optimizer, knowledge of optimization techniques and using Mike Hydro are also needed.

1.3. Expectations

After completing the lessons and exercises and correctly answering the review questions in this document, you should be familiar with most of the Scenario manager functionality.

1.4. Conventions

The following conventions are followed in this document:

 means a tip for the user

 means important information

1.5. Module data

The following files are needed to run this tutorial (copy them from the **..\ScenarioExp\data** folder):

1.6. Links to additional resources

In addition to the information presented in this module, below are links to additional resources that you can access to obtain further information on the following:

- Scenario manager:
  - The DSS help file
- Optimization:
  - http://en.wikipedia.org/wiki/Mathematical_optimization
  - http://www.neos-guide.org/content/optimization-introduction

1.7. Problem Reporting Instructions

This document will be updated regularly. Therefore, it is highly recommended to report any spotted problem to helpdesk@nilebasin.org so it can be corrected in future versions. When reporting the problem, you are kindly requested to provide the following:

- Document title
- Document version
- Page number where the problem was spotted
- A description of the problem

2. Lessons

In this manual the following lessons (with exercises) are included:

- General: This lesson introduces definitions and concepts that apply to all lessons.
- Scenario manager basics: This lesson introduces you to the manager's components and basic tasks such as activating the manager and organizing data within the manager.
- Model registration and visualization: This lesson introduces you to the model registration (i.e. importing) process in the DSS. The process is explained showing the related concepts and prerequisites. Once the model is registered, visualization of its components is also presented.
- Scenario setup and simulations: This lesson focuses on configuration and modification (editing) of scenarios, in the DSS. It also shows how to run a scenario by creating and running a simulation as well as viewing the results.
- Scenario comparison: This lesson describes how different scenario simulation results can be compared within the DSS.
- Model setup changes: This lesson shows how to make changes to a model (i.e. adding a structure to a base scenario).
- Using ensembles in scenarios: This lesson explains the use of ensemble data in scenarios and viewing the results.
- Model linking: This lesson introduces the concept of model linking within the DSS.
- Optimization: This lesson looks at the use of optimization techniques to optimize the modeling results within the DSS (e.g. maximizing the power generated at a dam).

2.1. General

Introduction

This lesson introduces you to some definitions and concepts to be able to follow the exercises in the later sections of this document. If you are familiar with those definitions and concepts you may skip this lesson.

Topics covered:

- Model (model setup)
- Scenarios
- Simulations
- Indicators

Learning Objectives:

After completing this lesson, you will be able to understand the following concepts:

- Model setup
- Scenarios and simulations
- Indicators

Definitions

Model setup (or model): A Numerical model developed for the problem(s) to be analyzed.

Scenario: Possible existing or future situations that need to be analyzed.

Simulation: A time-varying description of certain behavior of the natural system as computed by the mathematical model. A simulation will produce outputs referred to as simulation results.

Indicator (in the DSS): A numerical value expressing the performance of a scenario with respect to a certain goal.

Model Setups, Scenarios and Simulations in DSS

Figure 1 shows the relation between a model setup and scenarios. A model setup is a model that is built, checked and run successfully outside the DSS using a modeling tool

(e.g. Mike hydro or Mike 11). Once this is done, this model setup can be registered (imported) into the DSS. Any number of scenarios can be created based on each model setup (See Figure 1). Those scenarios are based on the same model setup but vary in model parameters or input data (e.g. catchment inflow time series). If model setup changes (i.e. through adding additional model objects) are needed, this needs to be done again outside the DSS using the same or a compatible modeling package to make the changes, verify them and run the model successfully. Following this, the new model setup can be registered in the DSS and can have its own scenarios.

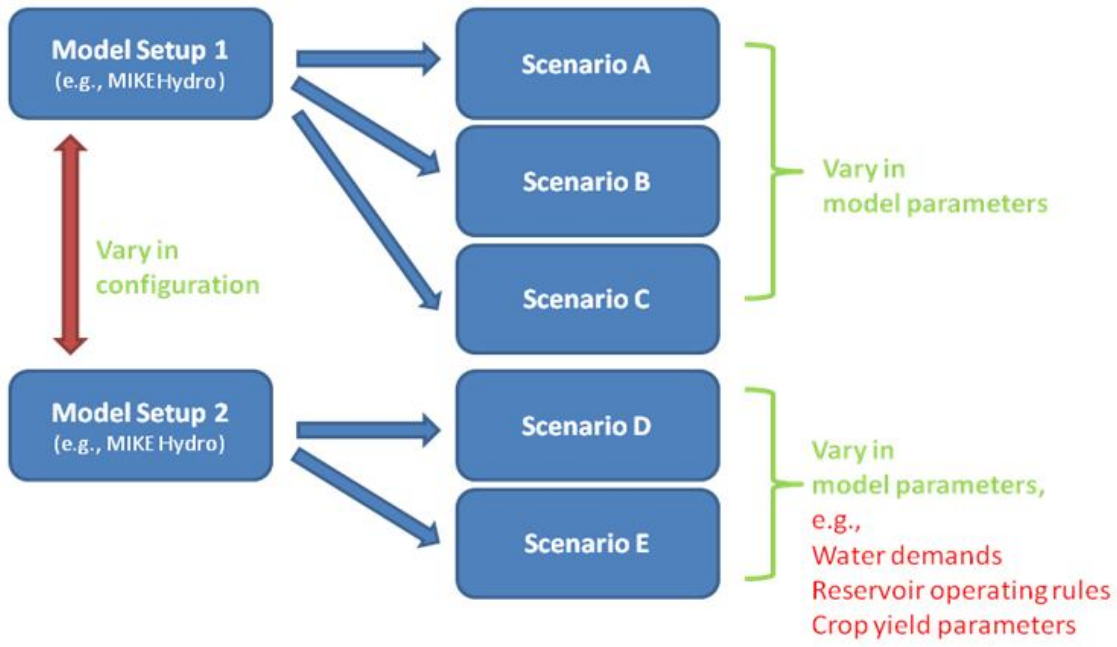


Figure 1: Model setup and scenarios

Each scenario in the DSS needs to run to obtain results. Each scenario run is called a 'Simulation' as shown in Figure 2. For each simulation, outputs are created and stored. If at a later time, changes are made to the same scenario. When it is run a new simulation is created with new outputs.

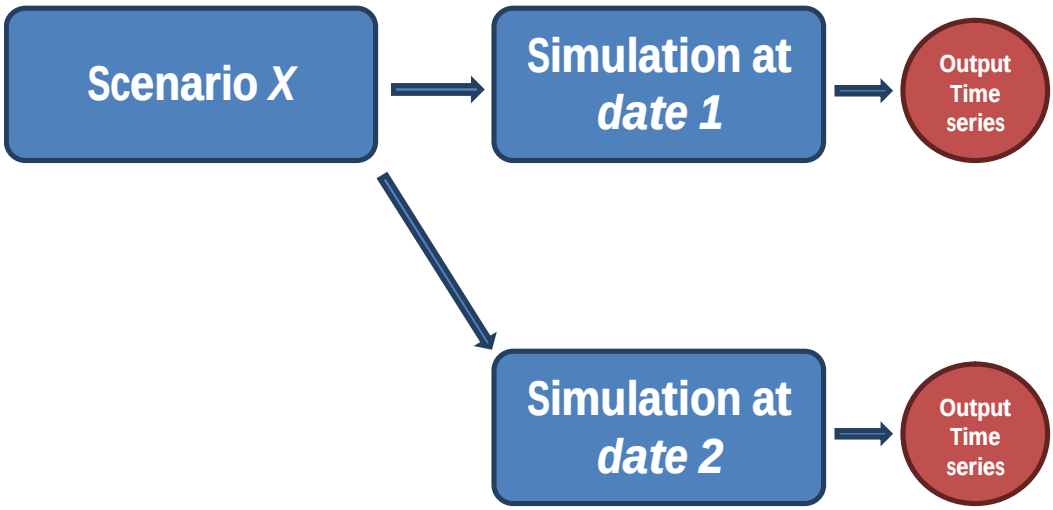


Figure 2: Scenario and simulations

In order to compare scenario results, indicators may be defined for a model setup as shown in Figure 3. These indicators are calculated each time a scenario is run (i.e. a simulation) and stored under the model setup showing their corresponding scenario and simulation.

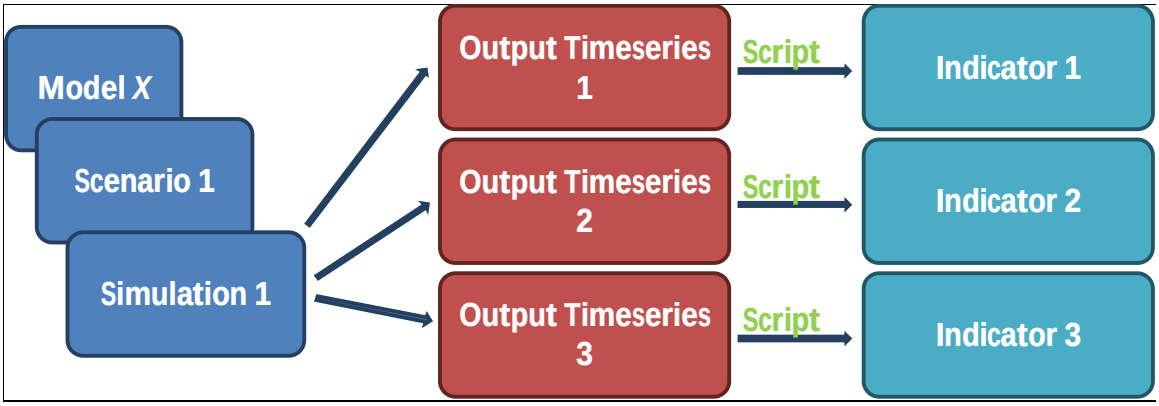


Figure 3: Scenario, simulation and Indicators

Review Questions

1. A scenario run (i.e. simulation) is created outside the DSS.
   - True
   - False
2. A model setup can have multiple scenarios in the DSS
   - True
   - False
3. Model setup changes can be made inside or outside the DSS

- True
- False

4. Indicators are stored under the scenario setup.
    - True
    - False

Answers

1. False (inside the DSS)
2. True
3. False (outside the DSS)
4. False (under Model setup).

2.2. Scenario Manager Basics

Introduction

This section introduces you to the basics of the Scenario manager to be able to follow the exercises in the later sections of this document. If you are familiar with those basics you may skip this lesson.

Topics covered:

- What is the Scenario Manager
- Activating the Scenario Manager
- Scenario Manager components
- Data organization within the Scenario Manager

Learning Objectives:

After completing this lesson, you will be able to understand the following:

- What you can do with the scenario Manager.
- How a manager is activated and how the Its data is organized
- Components of the Scenario Manager.

Lesson pre-requisites

You have to be familiar with the DSS user interface basics to follow this lesson.

What is the Scenario Manager?

The Scenario manager is where a modeler can import models from a number of modeling tools, create scenarios and simulations and use the model linking and optimization capabilities of the DSS. It has also linkages to other managers of the DSS, such as:

- The time series manager where the input to the scenario and output of its simulation can be managed and processed.
- The GIS manager to visualize the modeling objects and the model schematic
- The Indicator manager to define model based indicators

Using the Scenario manager

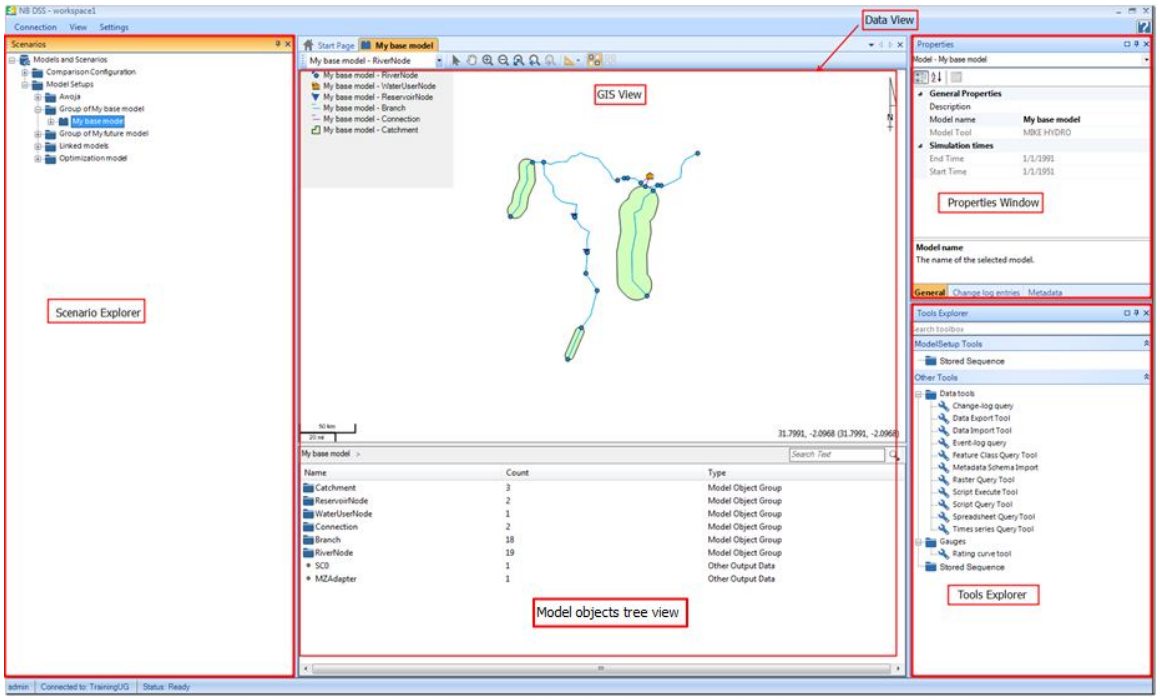
In order to use a manager within the DSS, it has to be activated. Activation is done through the DSS view menu. Once a manager is activated, its explorer window is added within the DSS user interface. It can then be used to handle its corresponding objects (e.g. model setups and scenarios for the Scenario manager).

Scenario manager components

Each manager in the DSS has four user interface components. These components are used to carry operations on objects related to a manager (e.g. running a simulation for the Scenario Manager). For Scenario Manager these are:

1. *The Scenario Explorer:* where models, scenarios and simulations data are organized in groups and can be selected for further operations.
2. *The 'Data View Area:* where the models, scenarios and simulations data are viewed in GIS and table views.
3. *The 'Tools Explorer:* where the tools that are relevant to models, scenarios and simulations are accessed.
4. *The 'Properties' window*: where the selected models, scenarios, simulations data and tools properties are displayed, property values set and selected tools are executed.

The components of the Scenario Manager are shown in the figure below.



5. **Figure 4: Scenario Manager components**

Data Organization within Scenario Manager

Objects (e.g. models or scenarios) that are either registered or added to the Scenario Manager are listed within the scenario explorer. The explorer has a tree structure where groups (or nodes) can be created and data is organized in groups so they can be easily identified and found. By default two groups are created within the explorer. These are the ‘Model setups’ and the ‘Comparison Configuration’ groups. An example of the explorer’s tree structure is given below.

The explorer has a main group called 'Models and Scenarios'. This main group is created by default when a new DSS database is created. Under this main group, two sub groups are also created by default. The first is called 'Comparison Configuration' and is used to compare scenario results. The second is called 'Model Setups' and is used to import models to create scenarios and run simulations. The user can have 'user defined' comparisons and groups under the 'Comparison Configuration' and 'Model Setups' sub groups respectively.

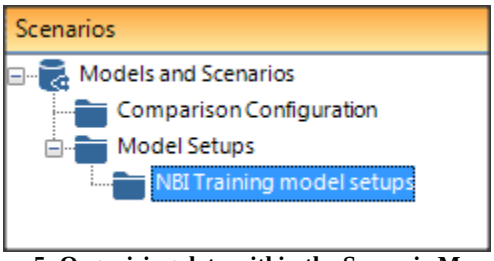
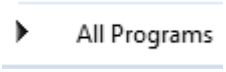
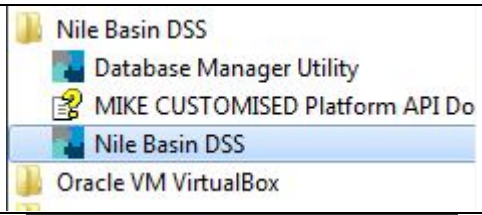


Figure 5: Organizing data within the Scenario Manager

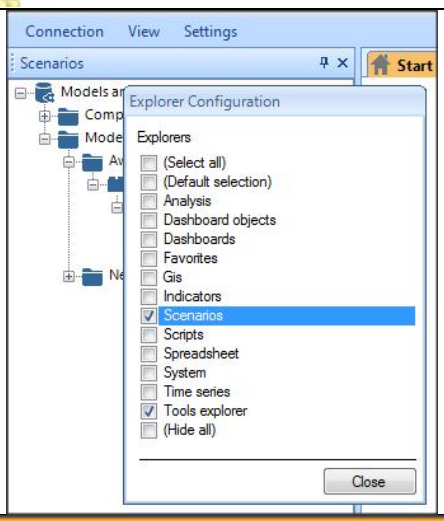
Exercises

Activating the Scenario Manager

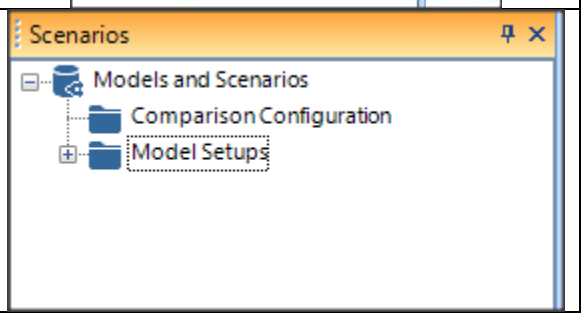
1- Click the  button and start the DSS application from the  menu and then login.



2- In the DSS, click on View Menu, the Explorer Configuration box appears. Tick the box next to Scenarios Manager.

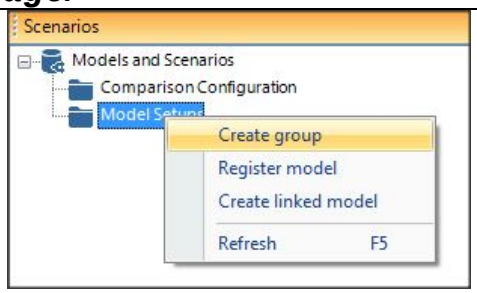


3- Scenario explorer should appear within the DSS window.

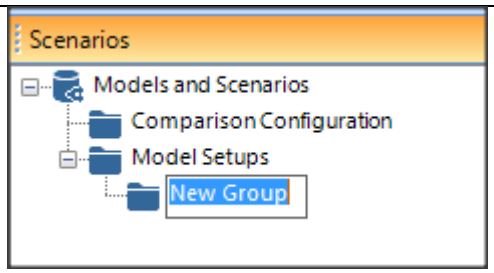
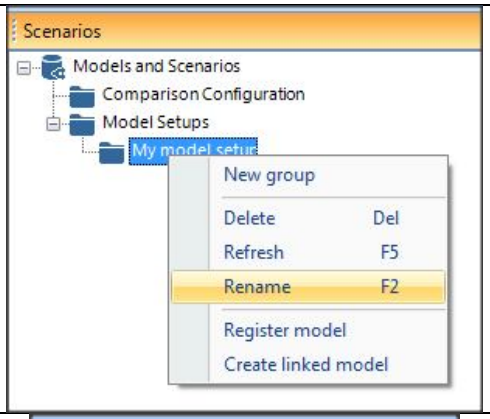
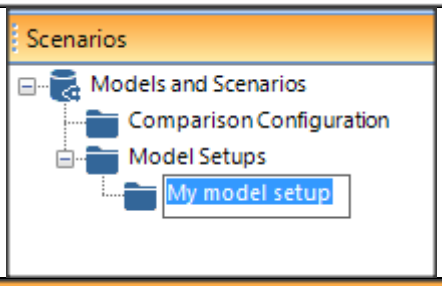
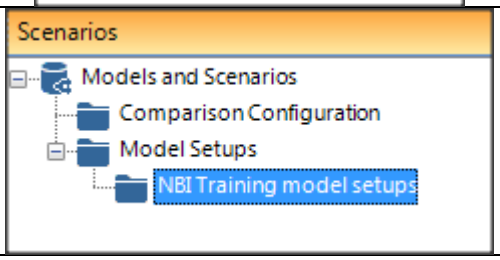


Organizing data within the Scenario Manager

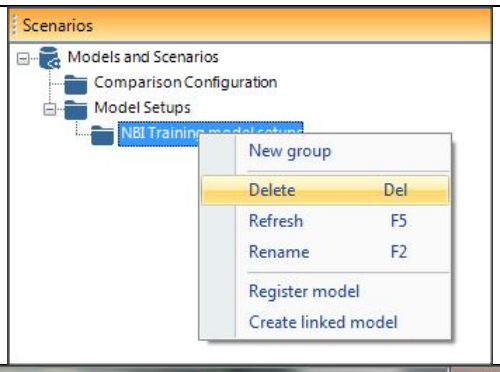
1- To organize data within the Scenario Manager, user defined groups can be added in the scenario explorer. To add a new group, select the 'Model Setups' group and right click. The context menu shown next appears. Select 'Create group'.



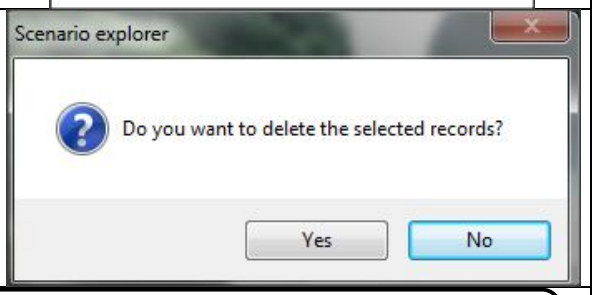
Note that no 'user defined' groups can be created under the 'Models and Scenarios' group.

2- A new group called 'New group' is added to the explorer with its name highlighted to allow the user to enter a suitable name (e.g. My model setup). Under this group model setups can be registered. New groups can also be added under the group but these are only used for comparing model and scenario results.	
3- To rename the group, select the group and right click the mouse or press the keyboard function key 'F2'. The context menu shown next appears. Select 'Rename'	
4- Type in the group name (e.g. NBI Training model setups).	
5- Now the group has been renamed	

6- Finally to delete a group, select the group and right click. The context menu shown next appears. Select 'Delete'. You can alternatively select the group and press the ‘Delete’ buttons on the keyboard.



7- The next confirmation box appears. Click 'Yes' to delete the group.



The delete operation is undoable. Once a 'user defined' group is deleted, it cannot be recovered.

The pre created groups can be deleted and renamed by pressing the keyboard 'Delete' key and the function key 'F2' respectively.

Review Questions

1. What are the pre-created groups of the Scenario Manager?
2. Pre created nodes cannot be renamed or deleted.
   - True
   - False
3. Models can be registered under the 'Comparison Configuration' group or sub groups.
   - True
   - False

Answers

1. The 'Models and Scenarios' group which has the 'Comparison Configuration' and ' Model Setups' groups.
2. False (They can be deleted or renamed)
3. False (Under the 'Model Setups' group)

2.3. Model Registration

Introduction

This lesson introduces you to model registration, management and visualization tasks within the Scenario Manager. If you are familiar with those operations you may skip this lesson.

Topics covered:

- Description of the registration process (using a case study)
- Exploring a registered model elements
- Model setup management (clone, rename, delete and refresh)

Learning Objectives:

After completing this lesson, you will be able to:

- Register a model in the DSS and explore its various elements
- Manage model setups.

Lesson pre-requisites

You have to be familiar with the Scenario Manager basics to take this lesson.

Available DSS modeling tools

The DSS currently supports manipulating models from the following four modeling tools (See the Modeling tools training module for more details):

- MIKE Hydro (a model framework for a large variety of applications concerning allocation, management and planning aspects of water resources within a river basin. See http://www.mikebydhi.com/products/mike-hydro-basin)
- MIKE11 (a software tool for the simulation of flows, water quality and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies. See http://www.mikebydhi.com/products/mike-11)
- MIKESHE (a modeling framework, including a range of numerical methods for each hydrological process. See http://www.mikebydhi.com/products/mike-she)

- EPANET (a software tool that models the hydraulic and water quality behavior of water distribution piping systems. See http://www.epa.gov/nrmrl/wswrd/dw/epanet.html).

Each of these modeling tools is developed to perform a specific task[1]. Selection and application of modeling tool will be determined by the nature of the problem at hand.

The benefits of using the modeling tools within the DSS

Registering models and managing scenarios in the DSS have advantages over ordinary modeling tools in a number of ways, such as:

- Uniform way to configure and compare models, scenarios and simulation results irrespective of the modeling took used
- The flexibility to be used by different users. If for example a team of experts comprising engineers, environmentalists, social experts and economists are working on a project, they will have the chance to work on the same model and build it from their professional point. Modeling based information prepared by the modeler can easily be extracted by experts to conduct further analysis and develop indicators.
- It is possible make comparisons between any number of scenarios and models. The comparison configuration functionality facilitates creation of comparison configuration and post processing of time series for the selected models and scenarios.
- The simulation results can be accessed either from the scenario or time series managers and can be further processed by the built in time series tools.
- The model linker of the DSS is a special tool that facilitates linking of different models that can be linked (See for model linking section details).

[1] If the presently implemented tools are not suitable for an institution or an individual, the DSS provides options to plug in new modeling tools.

Model registration

In order to create scenarios in the Scenario Manager, you need to register (i.e. import) a model into the DSS. This is done through the functionality of the Scenario explorer and is called model registration. A successful model registration adds a 'Model setup' into the DSS. You need to be aware that in order to register a model to the DSS the following is required:

- The model has to be fully developed in a modeling tool (including any necessary calibration)
- The model has to successfully run within the modeling tool. (It is also recommended but not mandatory to thoroughly check the results to ensure that are not flawed for any reason).

Model setup Management

The DSS allows the user to manage the model setups in a number of ways such as:

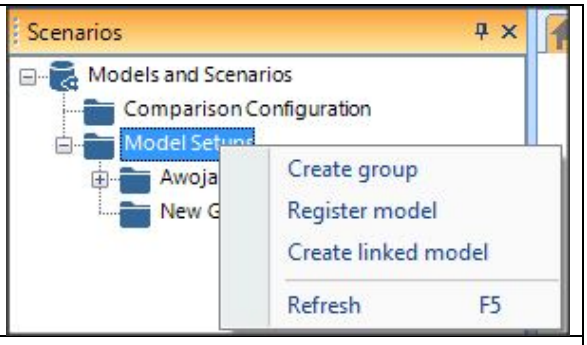
- Cloning (i.e. make exact copy of model set up with all scenarios and indicators but not including simulations).
- Copying full path (e.g. to be used in scripts or indicators)
- Renaming
- Deleting
- Refreshing to update the explorer with background activities progress.
- Opening in native modeling tool

These options are accessible within the explorer component of the Scenario Manager. In the exercises section below, a number of these operations are presented.

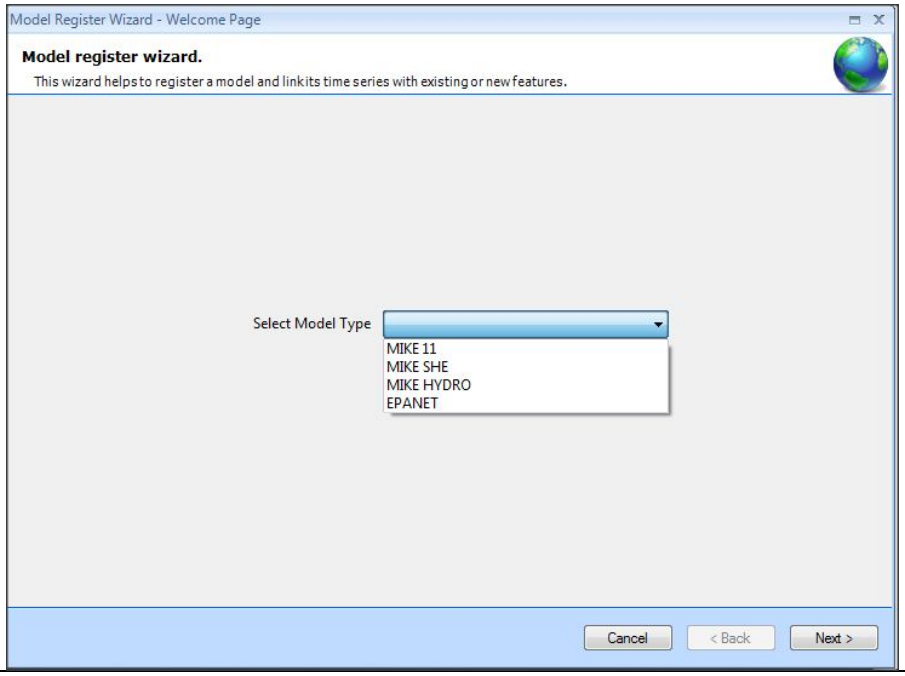
Exercises

Registering (i.e. importing) a model into the DSS

1- Within the Scenario explorer, right-click either the 'Model Setups' sub group or a user defined group that is under the 'Model Setups'. Click the Register model option.



2- Once the selection is made, the 'Model Register Wizard' shown below appears to help the user registering the model. As can be seen, the DSS can register 4 model types. These are Mike11, Mike SHE, Mike Hydro and EPANET. In this exercise, a Mike Hydro model will be registered.



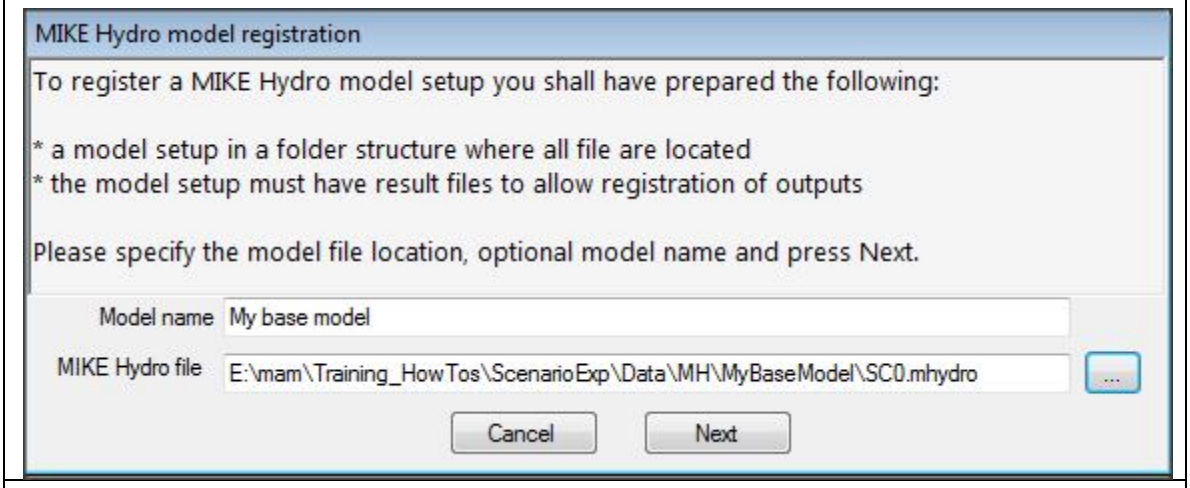
3- Select Mike Hydro and press 'Next'.

The 'Mike Hydro model registration' box appears. This require the user to input the following:

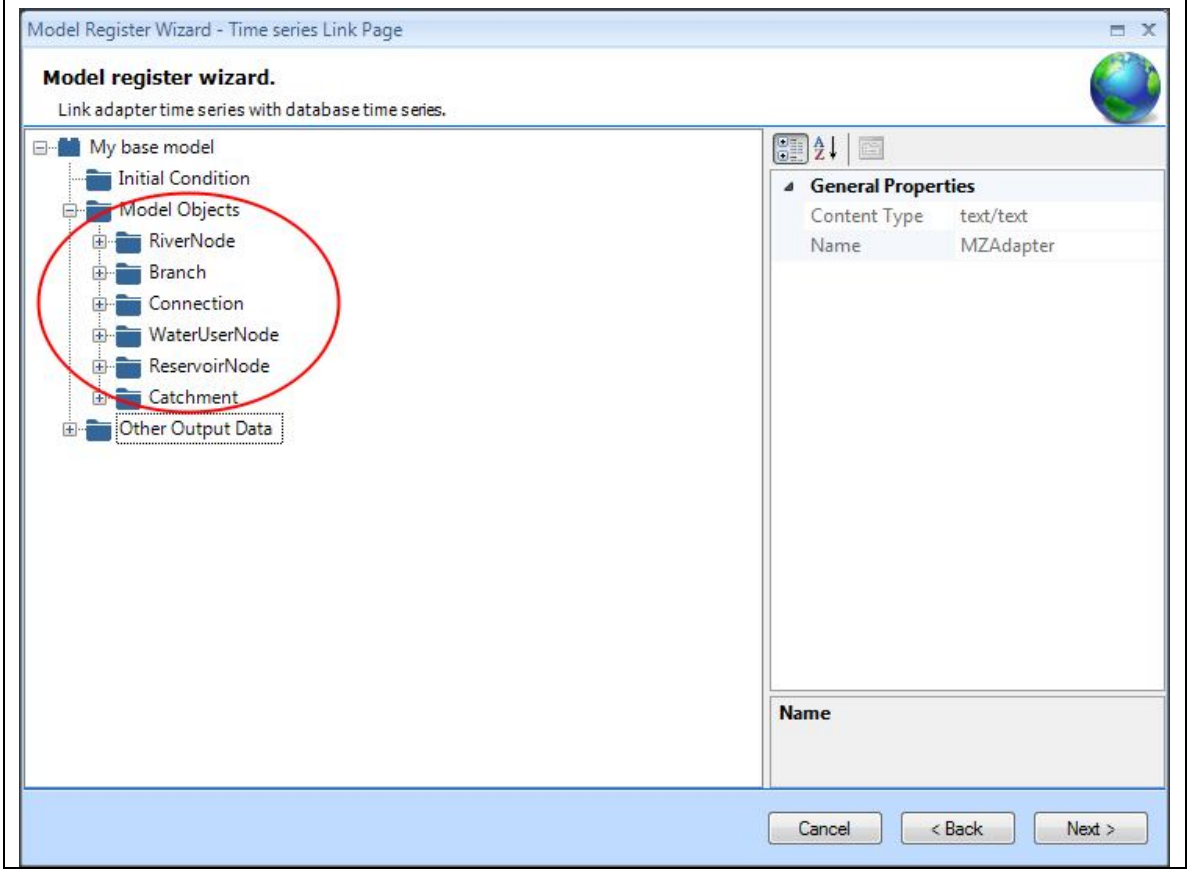
- Model name: this is the name that will be given to the model in the DSS.
- Mike Hydro file: this is the file that will used to register the model into the DSS.

Give your model a name (e.g. My base model) and click the ... button and go to the **..\ScenarioExp\Data\MH\MyBaseModel** folder to select the SC0.mhydro file and then

click Next.



4- The Wizard reads the model file and if it is successful it moves to the next step which shows model initial conditions and objects. For this exercise, the initial conditions group is empty. The model objects group contains the objects that will be imported into the DSS. Use it to check whether the model objects are all read correctly. You rarely need to change data within this dialog box therefore click 'Next'.

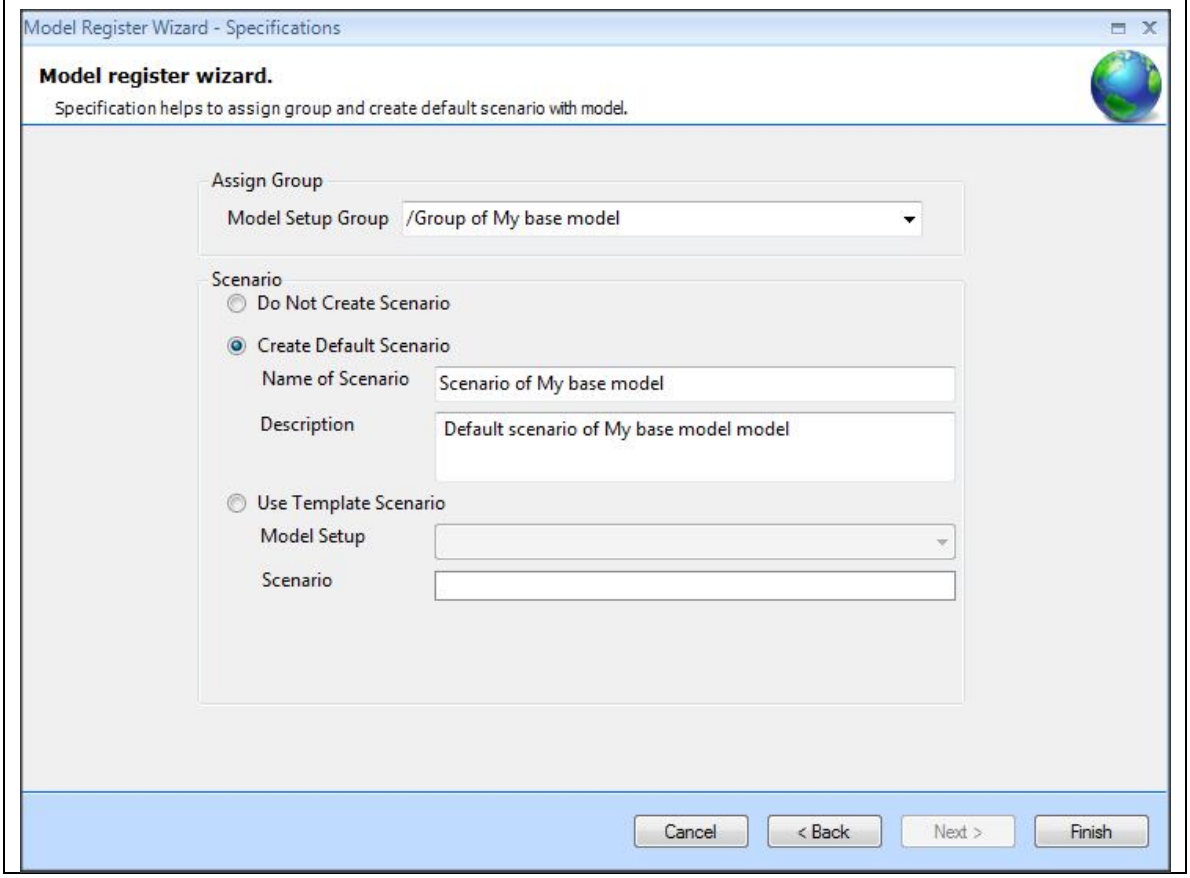


In order to register a model into the DSS, user needs to build the model in a modeling package (e.g. Mike Hydro) and run this model successfully and obtain results. Without results, the DSS will not register the model.

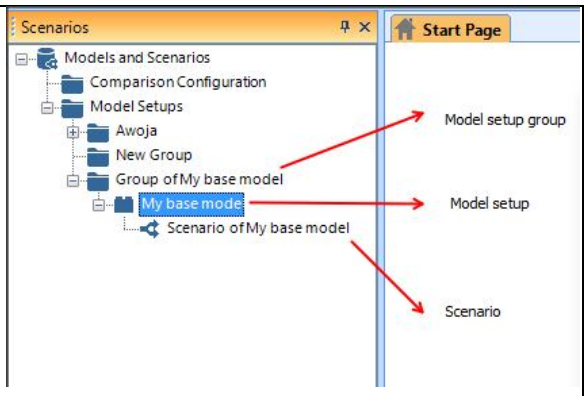
5- Now we reached the final registration step. The wizard now asks for the following:

- The model setup group: This is the name of the model setup in the DSS
- Whether the user needs to create a scenario or not. You have here 3 selections.
  - The first is not to create a scenario and in that case the model will only be registered into the DSS but will have no scenario but scenarios can be later created (See Adding a new scenario).
  - The second is to create a default scenario which is an empty scenario that has to be configured (See Configuring a scenario).
  - The third is to use a template scenario from another model setup. The latter option can only be used if there is a similar model setup that has already been registered into the DSS and has at least one scenario.

Leave the defaults and click finish.



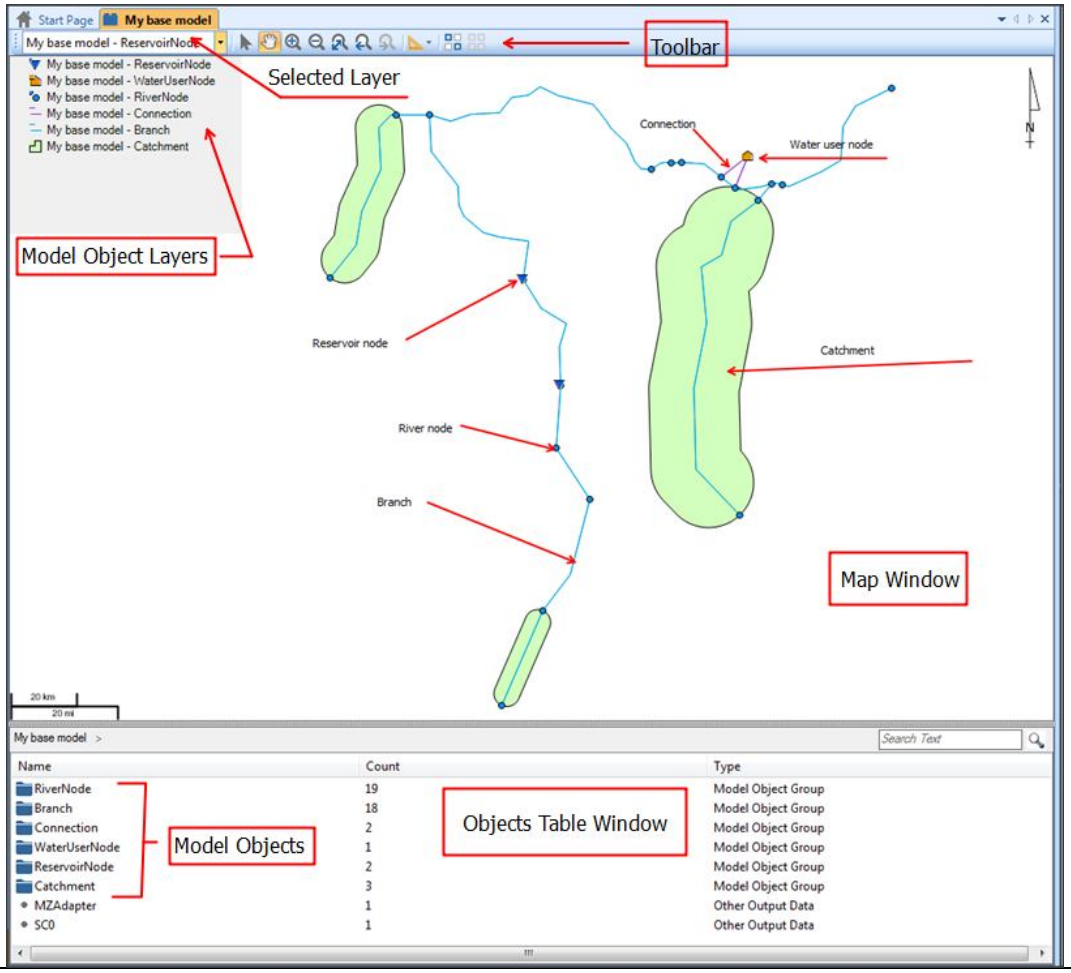
6- The wizard now has registered the model. As you can see, a model setup group has been created (Group of My base model). Under this group, the model setup has been created (My base model) and an empty scenario (Scenario of My base model). Familiarize yourself with the different icons.



The default names given to the 'user defined' model setup groups, model setups and scenarios can be changed by selecting the item and pressing the function keyboard key 'F2' or right clicking the mouse and pressing Rename.

Exploring a registered model elements

1- Open the model setup (My base model) by double-clicking the model setup icon in the Scenario explorer. The data view window looks like the figure below



In the top part of the window, the model schematic is shown in a map view. the map shows that the model consists of:

- 3 catchments (light green polygons)
- 2 reservoir nodes (dark blue triangles)
- one water user node (amber polygon)
- 2 connections
- a number of river nodes and branches

The top part of the map window has a toolbar

You can zoom and pan using the following toolbar icons:

 Zoom in and out

 Pan

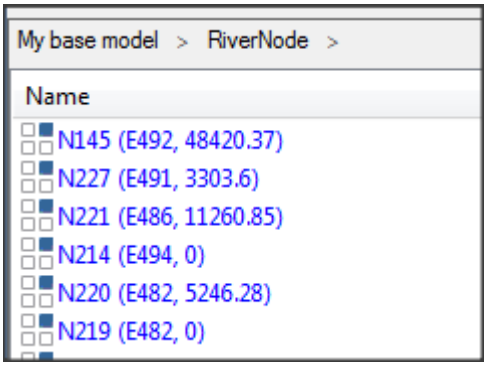
 Zoom to full extent

 Zoom to previous and next extent

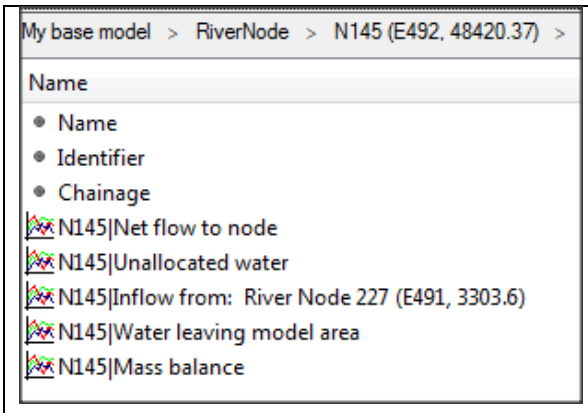
You can also select features on the map by selecting a layer in the layers box (

) and selecting the  and  icons in the tools bar then point to the feature on the map. The  icon allows the user to clear the selected objects (See The GIS Manager training module for details).

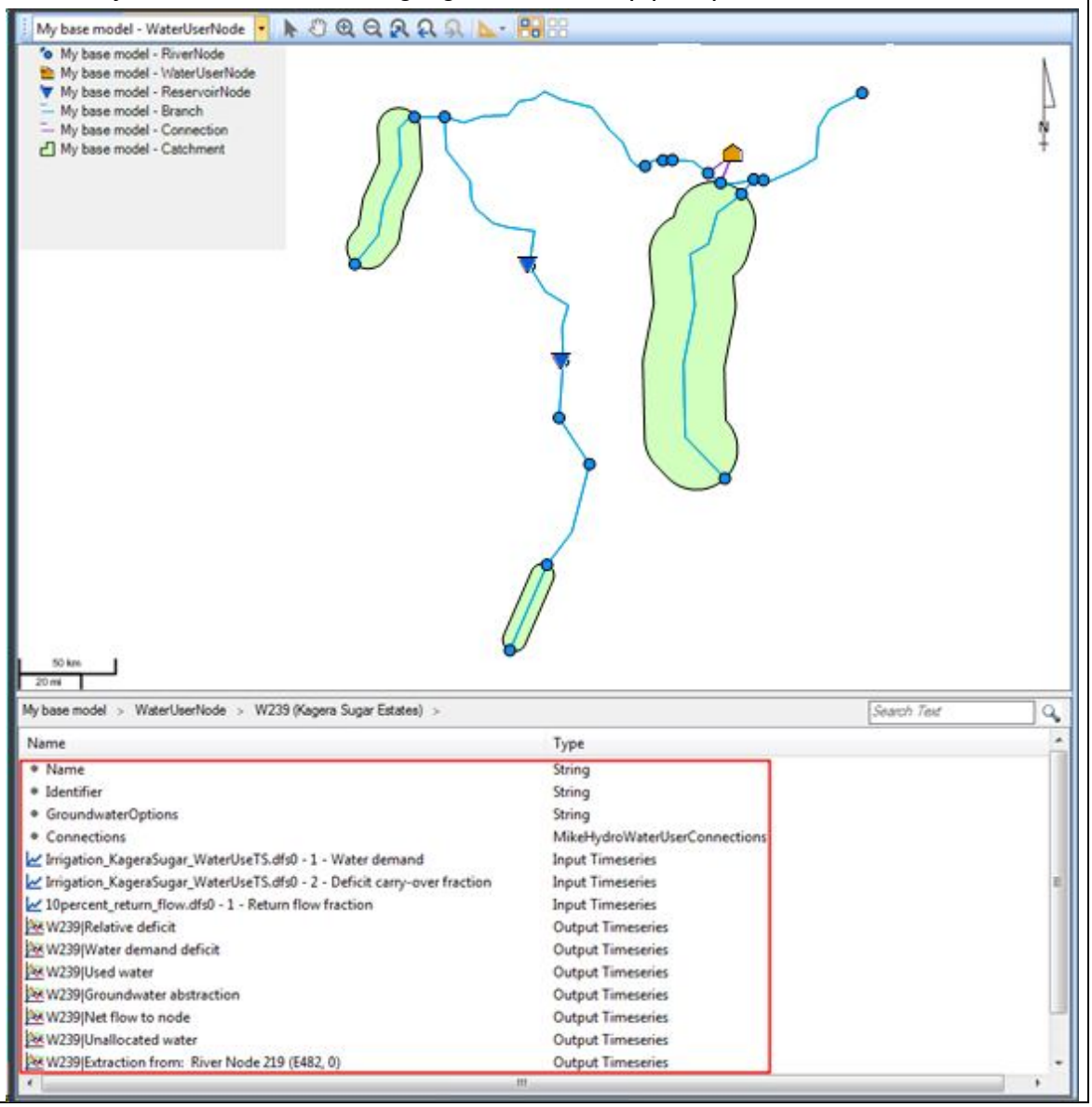
In the bottom pane of the window, the model objects are shown in a tabular tree form grouped by object type. Double-Clicking on group node shows the objects list.



Double-Clicking an object shows the data associated with this object (inputs, ouputs, and parameters).

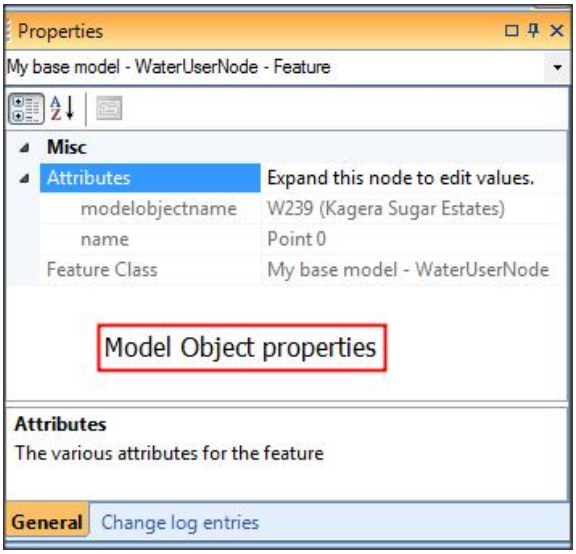


When you select a feature on the map, its elements are shown in the model object table as shown below for a water user feature, and vice versa (i.e. select an object from the model object tree and it will be highlighted in the map pane)



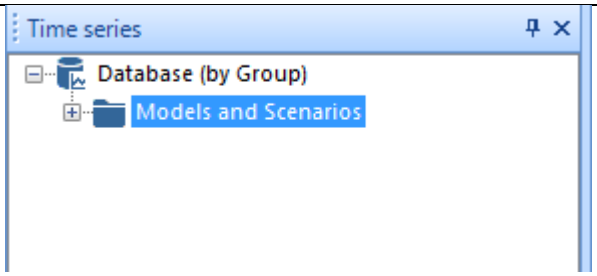
The input time series in the model setups and scenarios has the icon, whilst the output time series has the icon. Parameters have the icon.

When you select a model object, an object data or a layer, its properties appear in the 'Properties' Window.

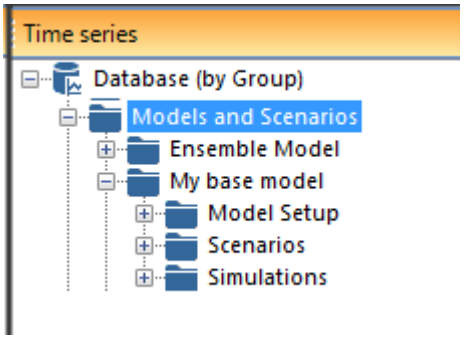


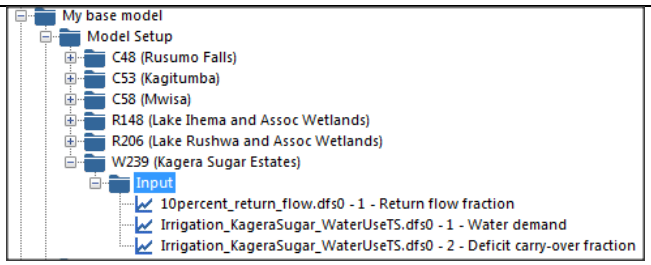
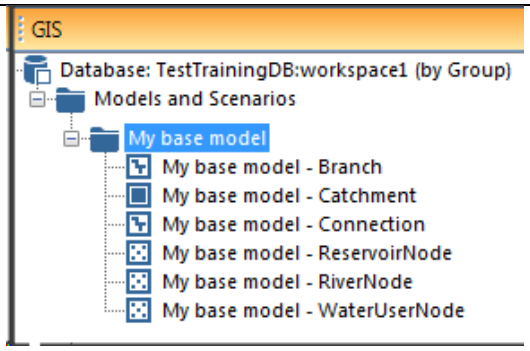
You are encouraged to explore more the model setup objects and their elements.

2- Activate the Time Series explorer (See DSS user interface training module for details) if it is not already activated. There is a group called 'Models and Scenarios' under the 'Database' group.



In the 'Models and Scenarios' group, each registered models is listed along with its model setup, scenarios and simulations as shown next.

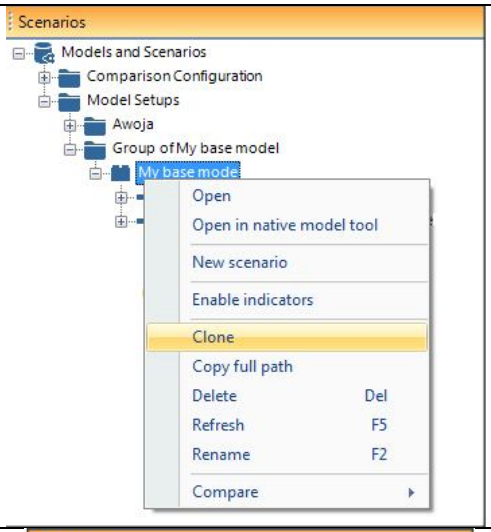
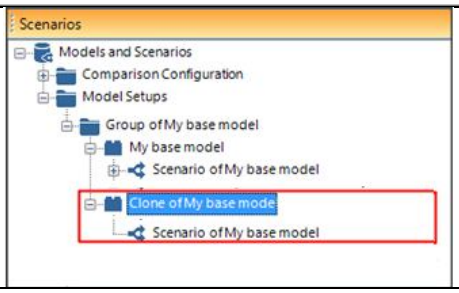


Expand 'My base model' group and then expand the 'Model Setup' node. As you can see the model objects are also listed. Expand a model object (e.g. **W239**). You can the input time series are also listed there. In the Time Series Explorer, these time series can also be view in a chart or table views as explained in the Time Series Manager training module. Under the 'Scenarios' group, only those time series that have been modified (See changing scenario's input data section for details) are listed in the same way. Under the 'Simulations' group, configured inputs and outputs of a scenario (See configuring a scenario section for details) are listed.	
3- Activate the GIS explorer (See DSS user interface training module for details) if it is not already activated. There is a group called 'Models and Scenarios' under the 'Database' group.	

In the 'Models and Scenarios' group, each registered models is listed. Expand 'My base model' group. You can see the different model layers listed there. These can also be viewed in a map or table views as explained in the GIS Manager training module.	

Model setup Management

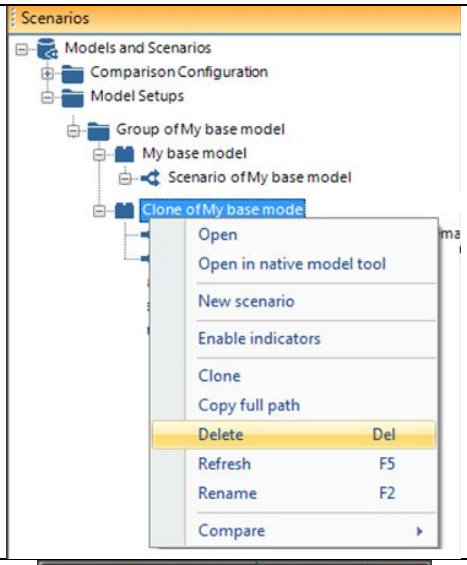
Cloning a model setup

1- Within the Scenario explorer, Select the model setup which you need to clone (e.g. My base model). Right click and select the Clone option.	
2- The model setup is cloned under the same group and it is called 'Clone of My base model'.	

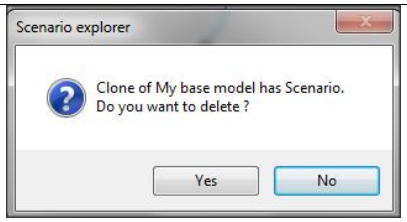
If simulations exist under a scenario, they are not cloned when a model setup is cloned.

Deleting a model setup

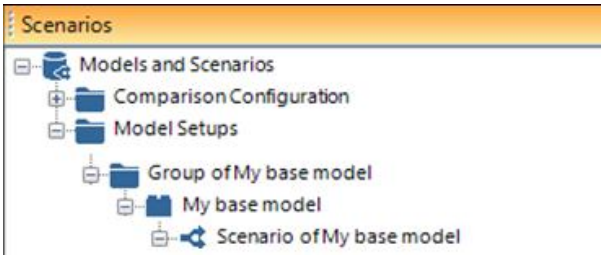
1- Within the Scenario explorer, Select the model setup which you no longer need (e.g. Clone of My base model). Right click it to get the context menu and select the Delete option or, alternatively, press the 'Delete' button on the keyboard.



2- Click 'Yes' on the confirmation message.



The model setup has now been deleted with all scenarios/simulations created under it. This is also reflected in the Time Series and GIS managers as all related time series and GIS layers are also deleted.



The delete operation is undoable. Once a model setup is deleted, it cannot be recovered.

Review Questions

1- What are the pre-requisites to register a model into the DSS?

2- What are the available modeling packages that are compatible with the DSS?

3- What are the scenario creation options when a model is registered?

4- Simulations are cloned when a model setup is cloned.

- True
- False

Answers

1- The pre-requisites to register a model into the DSS are:
   - The model has to be fully developed in a modeling package (including any necessary calibration)
   - The model has to successfully run within the modeling package

2- The available modeling packages that are compatible with the DSS are Mike11, Mike SHE, Mike Hydro and EPANET.

3- The scenario creation options when a model is registered are:
   - Do not create a scenario.
   - Create default (empty) scenario
   - Use template scenario

4- False.

2.4. Scenario management, configuration and simulation

Introduction

This lesson introduces you to scenario operations within the Scenario Manger. If you are familiar with those operations you may skip this lesson.

Topics covered:

- Creating a scenario
- configuring a scenario
- Running a scenario and viewing its results
- Scenario management (clone, rename, delete and refresh)

Learning Objectives:

After completing this lesson, you will be able to:

- Create, configure and run a scenario in the DSS
- View scenario run (i.e. simulation) results
- Manage scenarios and simulations.

Lesson pre-requisites

You have to be familiar with the model registration and visualization to take this lesson.

Creating, configuring, running and managing Scenarios in the DSS

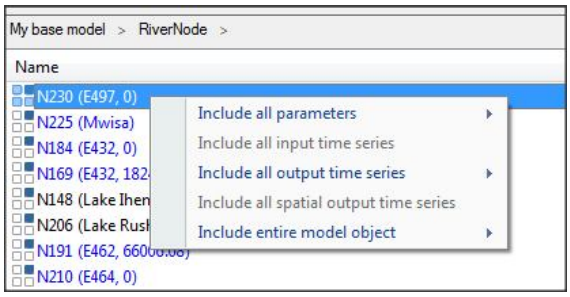
In the Scenario Manager, scenarios can also be managed, configured and run within the Scenario Manager.

Each model setup can have as many scenarios as you need. When a scenario is created in the DSS, it has to be configured so when it is run it shows the model results based upon this configuration. So scenario configuration allows the user to configure what are the inputs and outputs that are presented when the scenario is run.

The Scenario explorer offers the user more flexible options to add input and output time series to a scenario. These can be accessed by selecting and right clicking a model object in the bottom tabular window.

These options are:

- Adding all the parameters of this object
- Adding all the output time series
- Adding the entire model objects



It has to be noted that it is easier to add all entire model objects to a scenario rather than selecting them one by one but this would mean more time to write the outputs and also storage. This can be significant for large models.

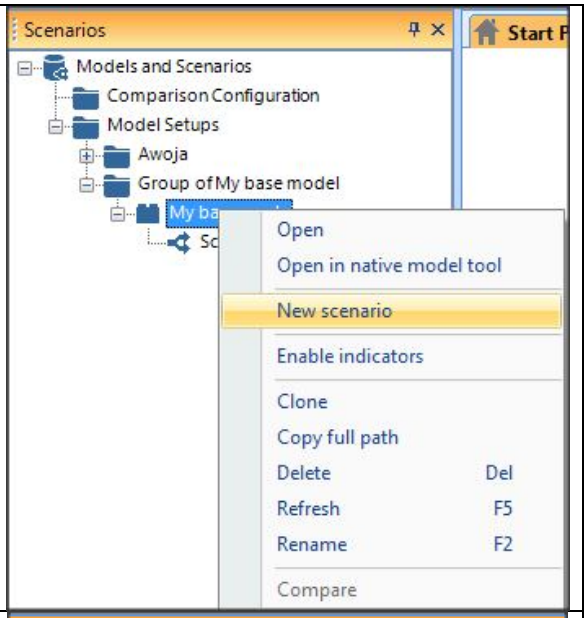
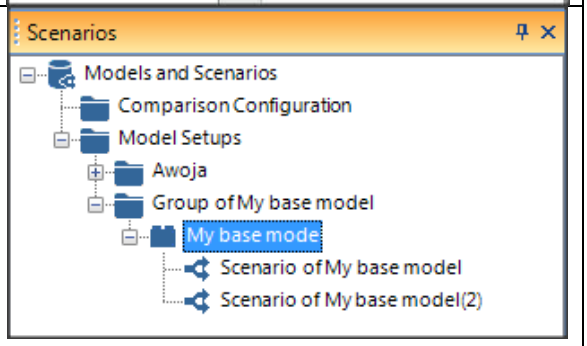
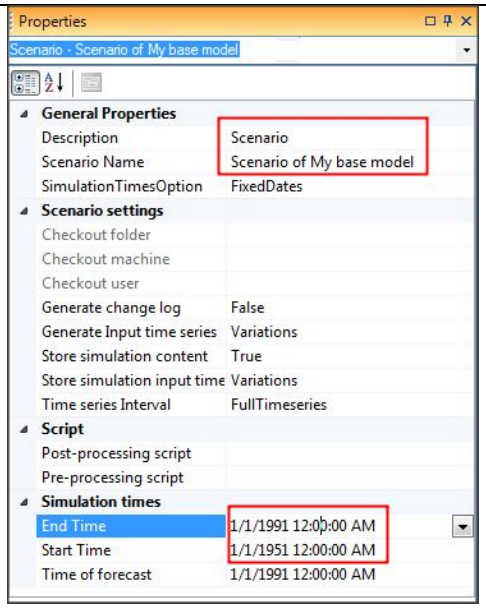
It should also be noted that the scenario inherits all inputs from the model setup (as a blue print). If some input time series need to be changed to create scenarios, they have be included in the scenario configuration and then edited from the scenario. In this case, the DSS will make a copy of it within that specific scenario and will override the original series that came with the model setup when running that scenario.

Once a scenario is configured, it can be run and the results are stored in a simulation. Simulation results can be viewed within the Scenario Manager but more frequently within the time series manager.

Scenarios can be cloned, renamed, or deleted, in the same way as the model setups.

Exercises

Adding (creating) a new scenario

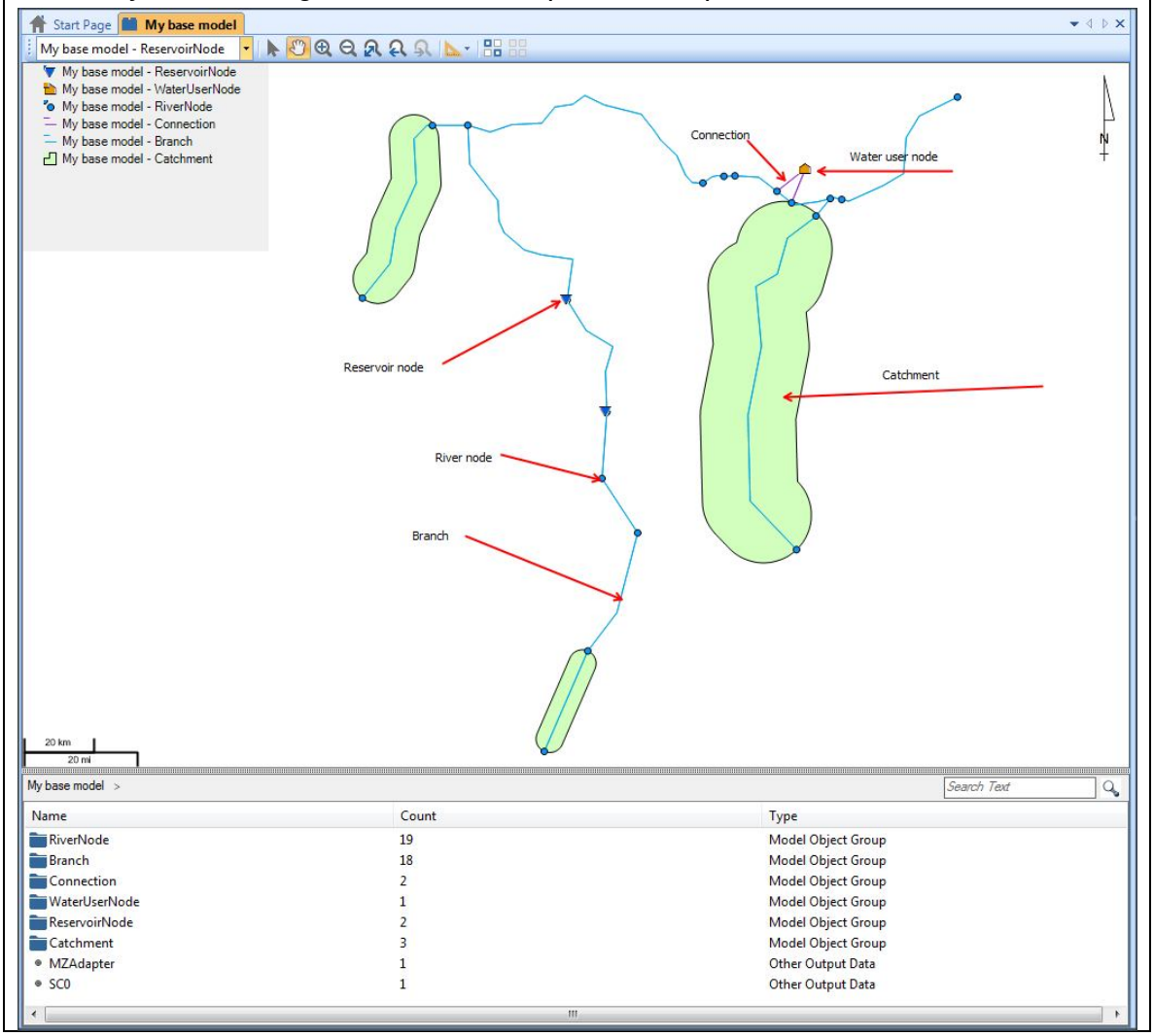
1- In the model registration exercise, a default scenario was created during model registration. In most cases, you may need to add new scenarios after registering the model. This can be done as follows: Within the Scenario explorer, Select the model setup where you need to add a new scenario (e.g. My base model). Right click the mouse and select the New scenario option.	
2- A new scenario has now been added to your model setup. It is named by default 'Scenario of my base model(2)'. Press 'F2' and rename it to 'My new Scenario of my base model'.	
3- When a scenario is selected within the explorer of the Scenario Manager, its properties appear in the 'Properties' window as shown next. Here you see general properties such as description and name. The start and end times for a simulation are also displayed. You can change these if a longer or a shorter simulation run is needed. Other properties such as generating change log and store simulation content can also be set in the 'Properties' window.	

Configuring a scenario

1- Open the model setup by double-clicking the model-setup icon in the Scenario explorer. In the top pane of the window, the model setup is shown in a map. The map shows that the model consists of:

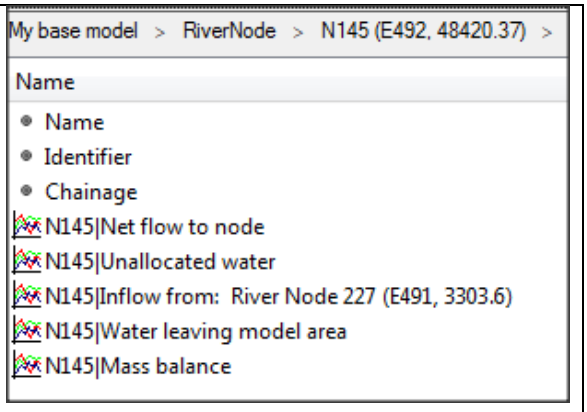
- 3 catchments
- 2 reservoir nodes
- one water user node
- 2 connections
- a number of river nodes and branches

In the bottom pane of the window, the above objects are shown in a tree form. In this window, you can configure the scenario inputs and outputs.



2- In the object tree pane, Add the following to the scenario:

- The inflow to the last node of the model. This can be done by double clicking the RiverNode group then scrolling list to ***N145***. Double click it or select the feature on the map (See Exploring a registered model elements for more details).



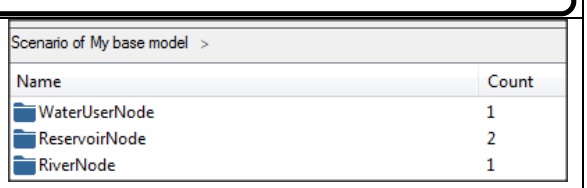
Now you can see all parameters and time series that are associated with the node. Select N145|Net flow to node and right click the mouse. The Include in scenario option appears, click again and finally select Scenario of My base model option.

- Similarly, Add the Evaporation from all Lakes. (Hint: lakes are under reservoir node group).

- Add Water demand and Water demand deficit for Kagera Sugar (Hint: under the water user node group)

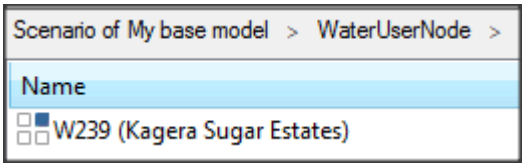
Model objects can also be added to a scenario by selecting a model object and then using drag and drop onto the scenario node in the explorer window.

3- To check whether the addition of the above items has been done correctly, double click the scenario to open it in the viewing area. In the top pane, you can still see the model schematic map but in the bottom pane, you only see the model

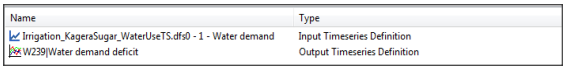


objects that you have added to the scenario.

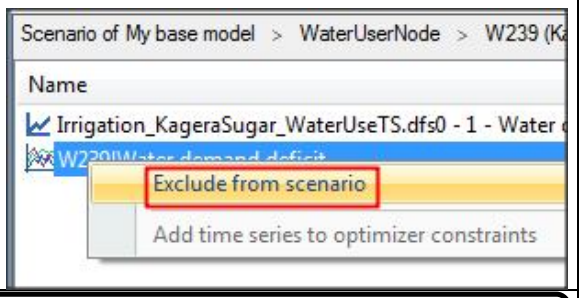
Double click the WaterUserNode group. You can see that the Kagera Sugar Estates has been added.



Double click “the Kagera Suger Estates” node, you see that 'Water demand' and 'Water demand deficit' time series have been added to the scenario. .



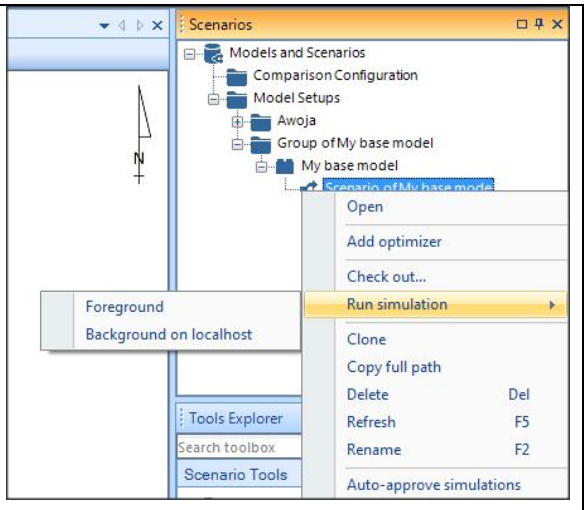
In some cases, you might need to exculde a time series that you added to the scenario. To do so, right click the time series then select 'Exclude from scenario'.



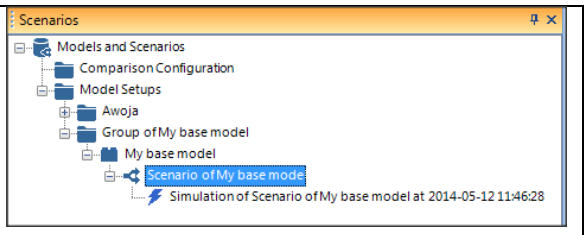
The output time series has that are added to the scenario are only placeholders (i.e. they contain no data).

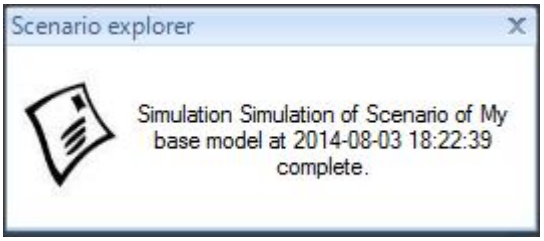
Running a scenario and viewing the results

1- Once you have selected the input and output time series of a scenario within the Scenario Explorer, you are ready to run this scenario. To do so, right click a scenario and select 'Run simulation' and select 'Foreground' – this creates a simulation, and adds its results to the database as time series which can be viewed using the 'Time Series' explorer.



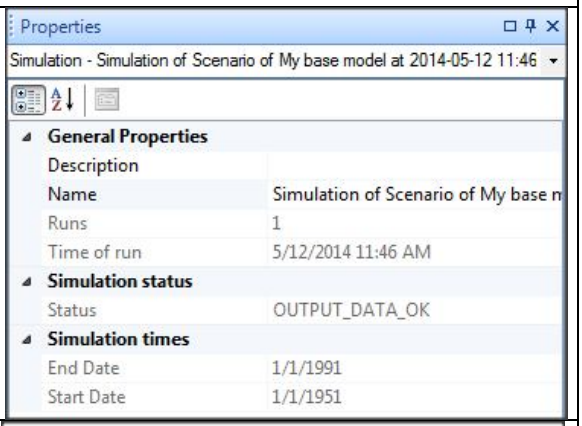
2- When the simulation run is successfully carried out, a new simulation node is created under the parent scenario (you might need to click the + sign next to the scenario to see the simulation node) and a notification appears in the bottom left corner of the DSS window. The simulation node contains the selected scenario inputs and outputs.



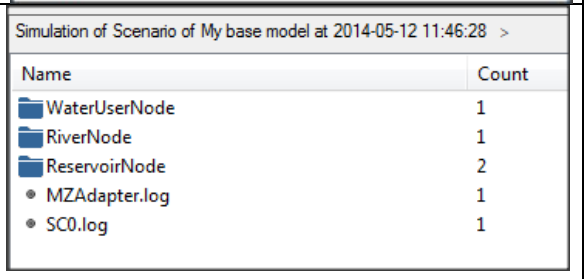


The name of the simulation is by default: Simulation of <Name of scenario> at <Date and time of the simulation>. An example is 'Simulation of Scenario of My base model at 2014-08-03 18:22:39'.

3- The properties of a simulation also appear in the 'Properties' windows when it is selected within the explorer of the Scenario Manager. Most of the properties cannot be changed except the description and name.

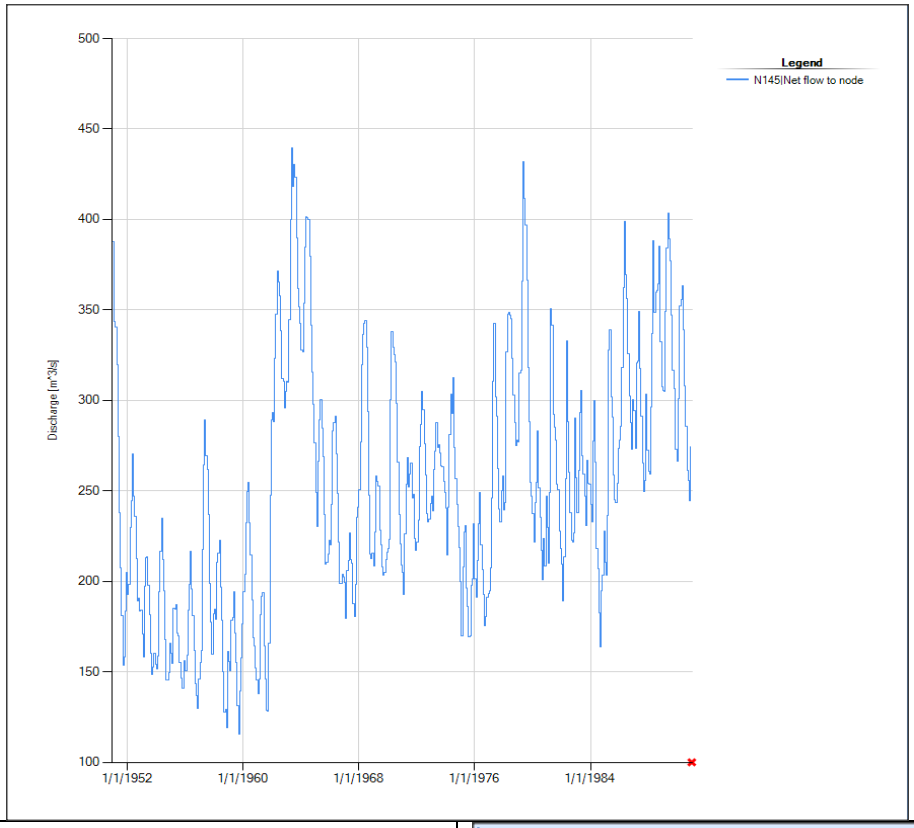


4- To check the results of the simulation, select then double click the simulation. A top pane with the model schematic map appears at the top and the simulation time series appears in the object tree view at the bottom. Click on the RiverNode group and then the N145 (E492, 48420.37) object and then N145|Net flow to node time

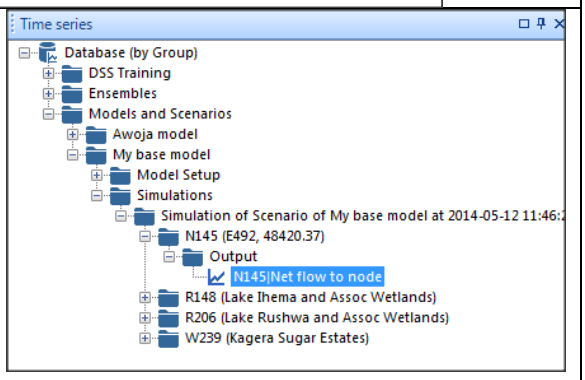


series.

5- The net flow to the node chart appears as shown below. Explore the rest of the results by selecting the model objects under the water user and reservoir nodes.

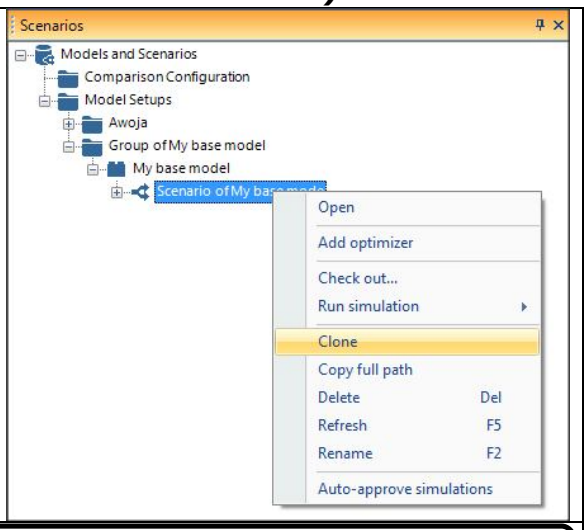


Simulation results can also be accessed from the 'Time Series' Manager under the 'Models and Scenarios' as shown next (See exploring a registered model elements exercise for details) and navigating to the simulation. For details on viewing data in the 'Time Series' Manager, see the 'Time Series' manager training module.



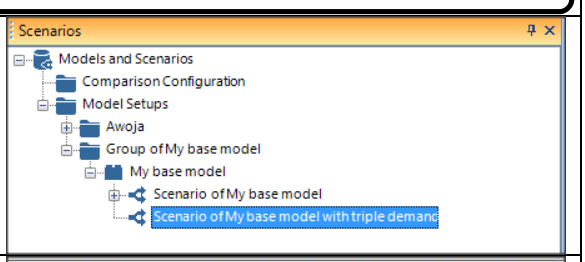
Changing scenario's input data (i.e. create a new scenario)

1- You will usually need to change scenario's input time series data to explore different options[2]. This can be done using the 'Clone' option and then changing the input data.
In this example you will investigate the impact of tripling the demands at the 'Kagera Sugar Estate' on the inflow to the last node in the model.

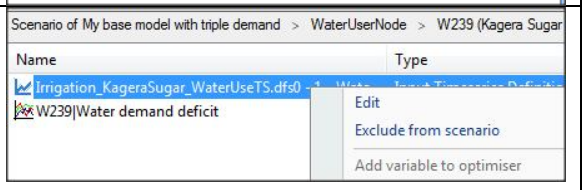


Cloning a scenario, in this case, is better than creating a new scenario as cloning will also copy all the model objects that has been added by the user while creating a new scenario will not.

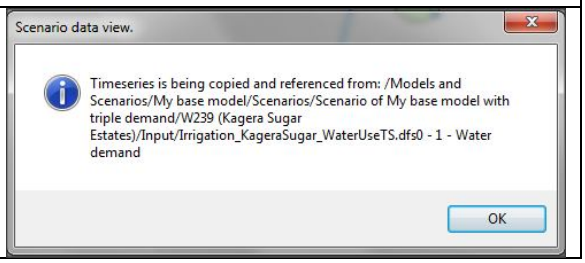
2- Right click the 'Scenario of My base model' and then clone. Rename the cloned scenario to 'Scenario of My base model with triple demand'.



3- Open the new scenario and navigate to 'Kagera Sugar Estate' Water User Node. Right-click the 'Water Demand' and select 'Edit'



4- Read and then Click 'OK' on the information box

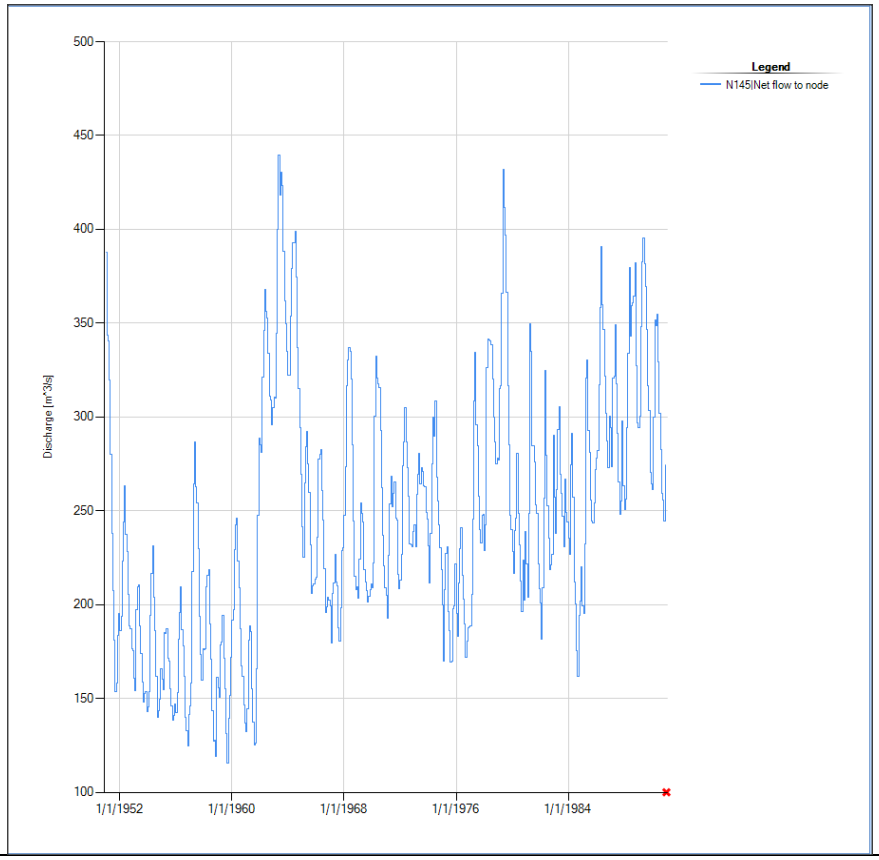


[2] Changing model setups is covered under "modifying a model setup" exercise.

5- Edit the data in the table by copying it into a new spreadsheet within the 'Spreadsheet' explorer or in Microsoft Excel, multiplying by 3 and copying it back to the table and save. When copying back data from spreadsheet, copy only the data rows and leave the header row otherwise data will not be pasted. The modified time series will be used for the new simulation.

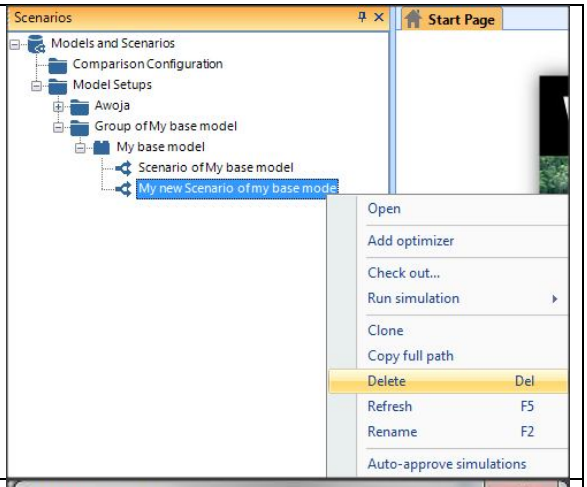
Time	Data Values for Irrigation_KageraSugar_WaterUseTS.dfs0 - 1 - Water demand [m^3/s]
1/1/1951 12:00:00 AM	0
2/1/1951 12:00:00 AM	0
3/1/1951 12:00:00 AM	0
4/1/1951 12:00:00 AM	0
5/1/1951 12:00:00 AM	0
6/1/1951 12:00:00 AM	0
7/1/1951 12:00:00 AM	0
8/1/1951 12:00:00 AM	0
9/1/1951 12:00:00 AM	0.012
10/1/1951 12:00:00 AM	0
11/1/1951 12:00:00 AM	0
12/1/1951 12:00:00 AM	15.915
1/1/1952 12:00:00 AM	10.95
2/1/1952 12:00:00 AM	7.461
3/1/1952 12:00:00 AM	10.737
4/1/1952 12:00:00 AM	0.534
5/1/1952 12:00:00 AM	11.856

6- Run a simulation of the new scenario and plot the results of the net flow at the last node of the model. Flow is slightly lower than the results obtained in the Running a scenario and viewing the results exercise (See results comparison section for more details on how to compare scenario results).



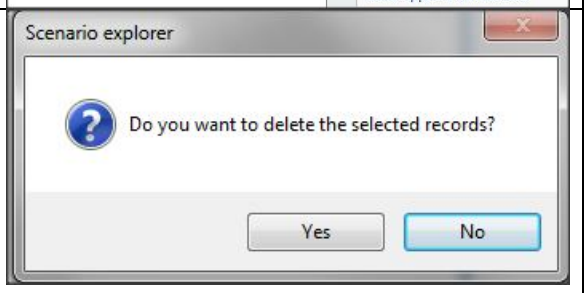
Deleting a scenario

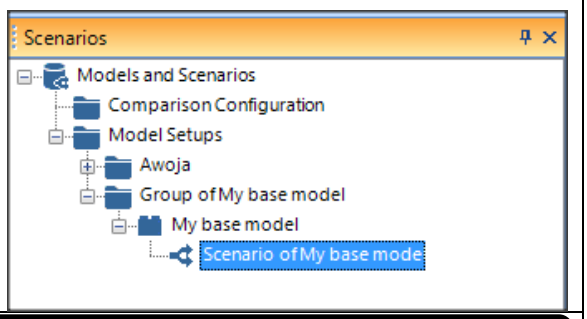
1- Within the Scenario explorer, Select the scenario that needs to be deleted. Either click the keyboard delete key or right click the scenario node and select the Delete option



2- Click 'Yes' on the confirmation message. The scenario has now been deleted.

Other operations such as rename are done in the same way as described above for the delete operation except that no confirmation message is displayed.





The delete operation is undoable. Once a scenario is deleted, it cannot be recovered. Deleting a scenario deletes all simulations under it and that is also reflected in the time series explorer.

Exporting a scenario (i.e. check out a scenario)

Review Questions

1. List 5 scenario management operations in the DSS.
2. A simulation is an instance of a scenario at a specified time with results for configured objects.

- True
- False

Answers

1. the 5 Scenario management operations are:
   - Creation
   - Cloning
   - Modification
   - Renaming
   - Results visualization
   - Deletion
2. True

2.5. Results comparison

Introduction

This lesson introduces you to the available methods to compare simulation results in the DSS. If you are familiar with those methods you may skip this lesson.

Topics covered:

- Directly compare scenario results
- Using the scenario comparison configuration
- Using indicators to compare scenarios

Learning Objectives:

After completing this lesson, you will be familiar with the various available methods to compare scenario in the DSS.

Lesson pre-requisites

You have to be familiar with the scenario management, configuration and simulation to take this lesson.

Comparing simulation results in the DSS

One of the powerful features of the DSS is the ability to compare scenario results within the Scenario Manager without the need to use external tools. Three methods exist to do this task in the DSS, namely:

- Direct comparison where data is plotted or tabulated against each other. This method allows direct visual comparison and can be used when two or three scenarios need to be compared. If more scenarios need to be compared, it is advisable to use one the methods below.
- Using the comparison configuration where a configuration is defined with those scenario elements that need to be compared. This method is useful when more than the direct comparison is needed such as comparing duration curves of an output time series from two simulations or more.
- Using indicators where indicators are defined at the model setup level and they are calculated each time a scenario is run. This method is useful when quantitative comparison is needed between scenarios. These indicators can

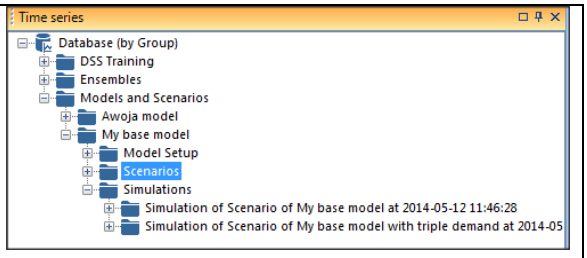
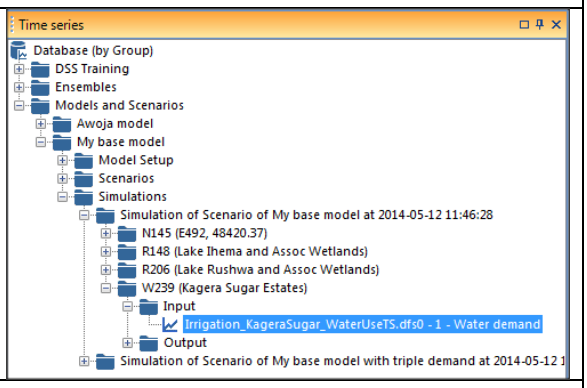
be used in results comparison and/or in advanced analysis such as the Multi Criteria Analysis (MCA).

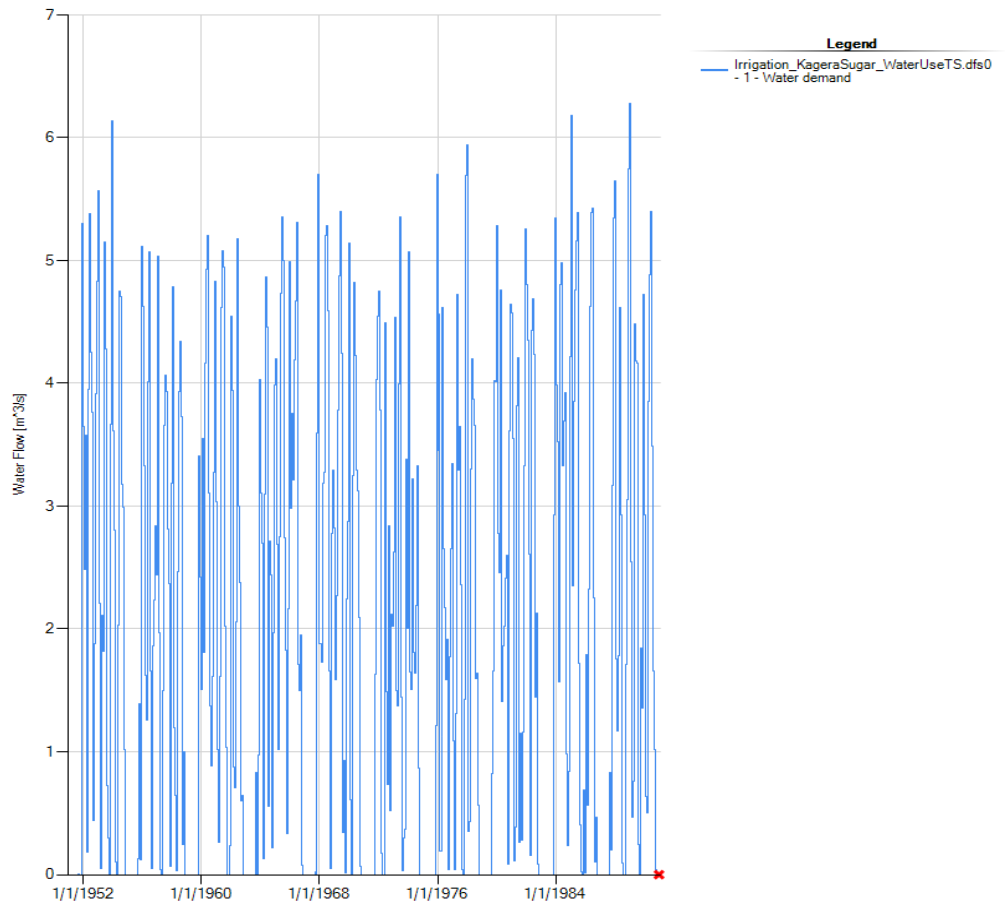
In the next sections, comparing scenarios using the above methods is presented.

Exercises

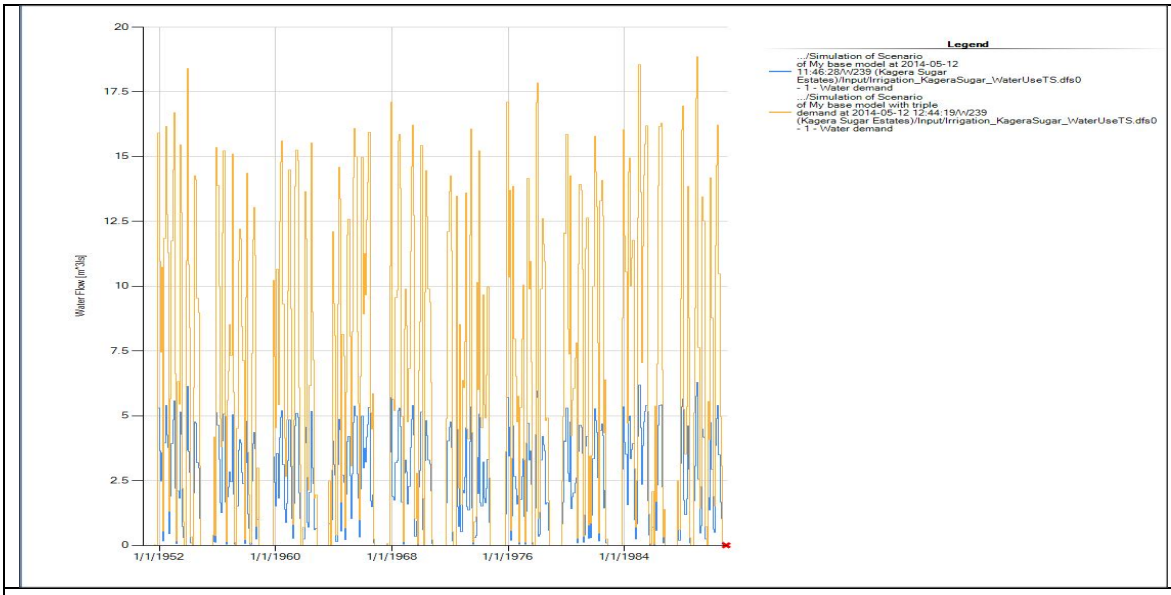
Directly Comparing the input data and results of two scenarios

In the scenario management, configuration and simulation section, two simulations have been undertaken under two different scenarios. This exercise shows how to compare the input data and results of two scenarios.

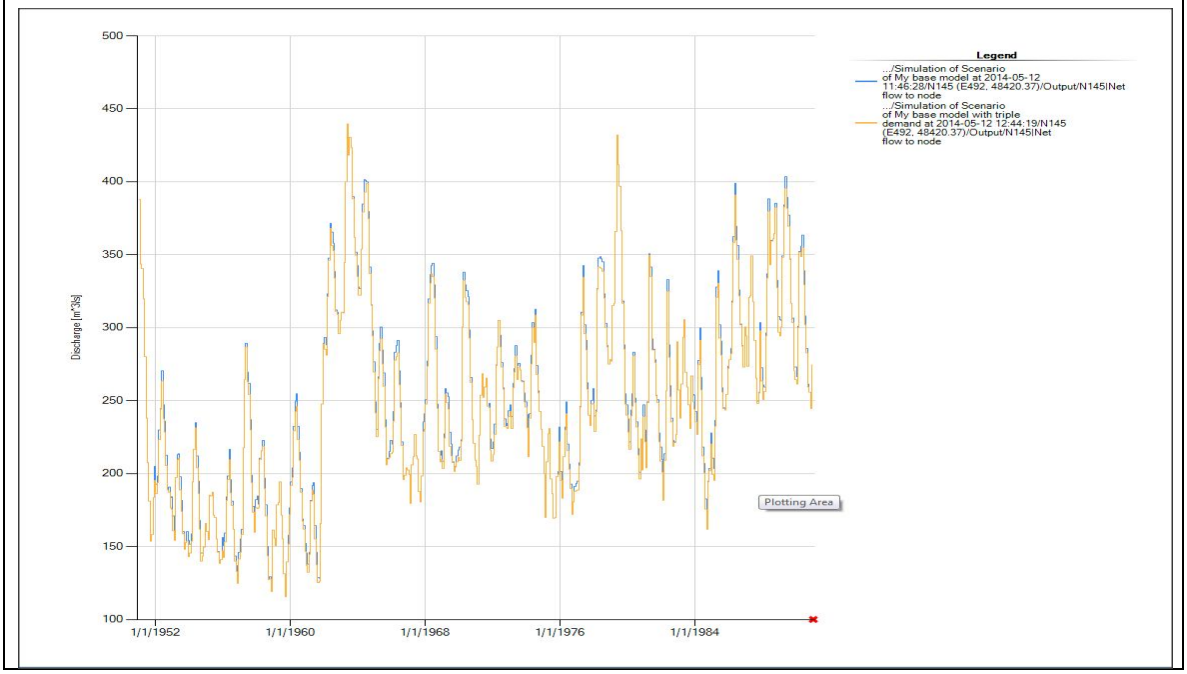
1- Activate the 'Time Series' explorer (See 'Time Series' manager exercises for details). Expand the 'Models and Scenarios' group then 'My base model' group and finally the 'Simulations' group. You can see the two simulations, that were carried out in the above mentioned exercises, listed there.	
2- Expand the first simulation and navigate to the 'Kagera Sugar Estates'. Expand the node and click on the 'Input' group and double click on the 'Water demand' time series.	
3- Water demand time series is plotted.	



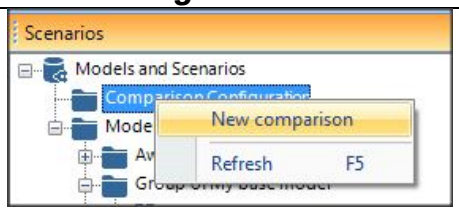
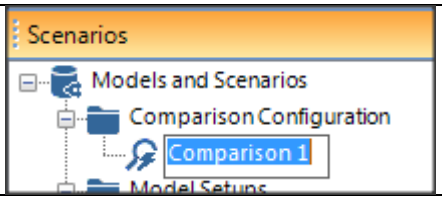
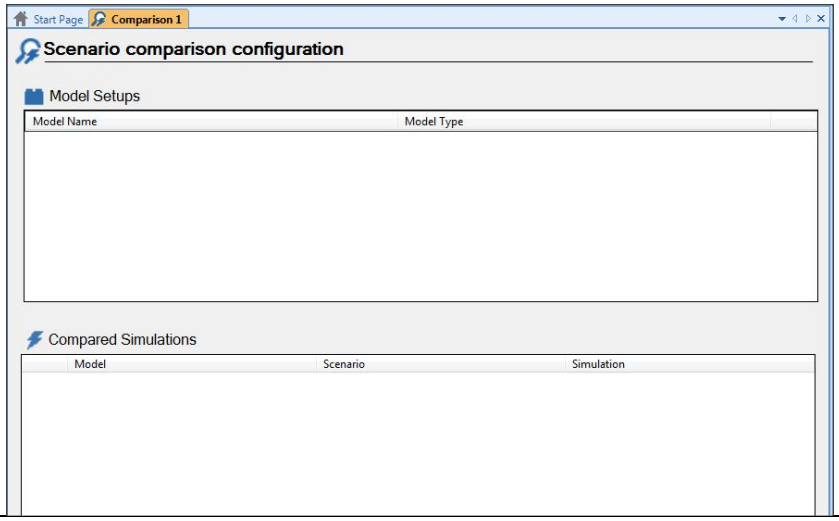
4- Expand the second simulation and navigate to the 'Kagera Sugar Estates'. Expand the node and click on the 'Input' group and double click on the 'Water demand' time series. The second time series is added and it can be seen that the water demand of the second time series is three times the first one's demand.

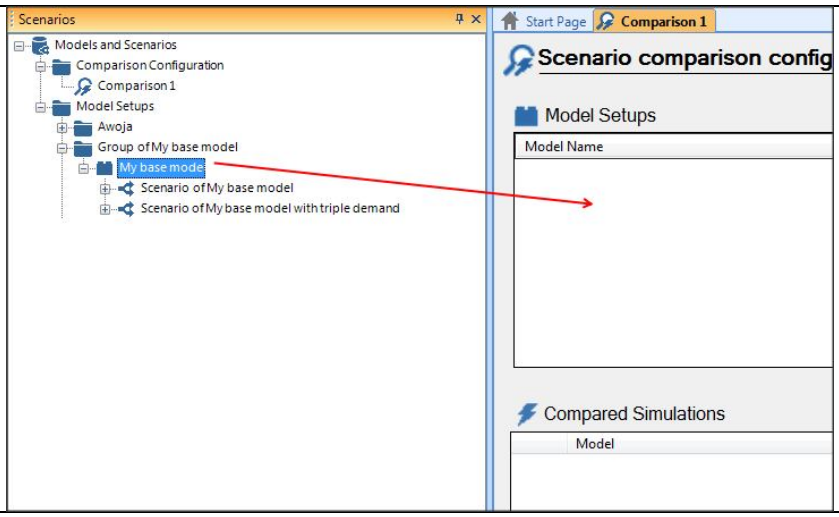


5- Repeat the above steps for the N145 river node net flow (you need to add the first time series to a new chart). It can be noted that under this node only an 'Output' group exists but there is no 'Input' group. This is because no input time series was selected for this node for those scenarios. It is also obvious that the net flow from the second scenario is slightly lower than the first one due to the demand increase.

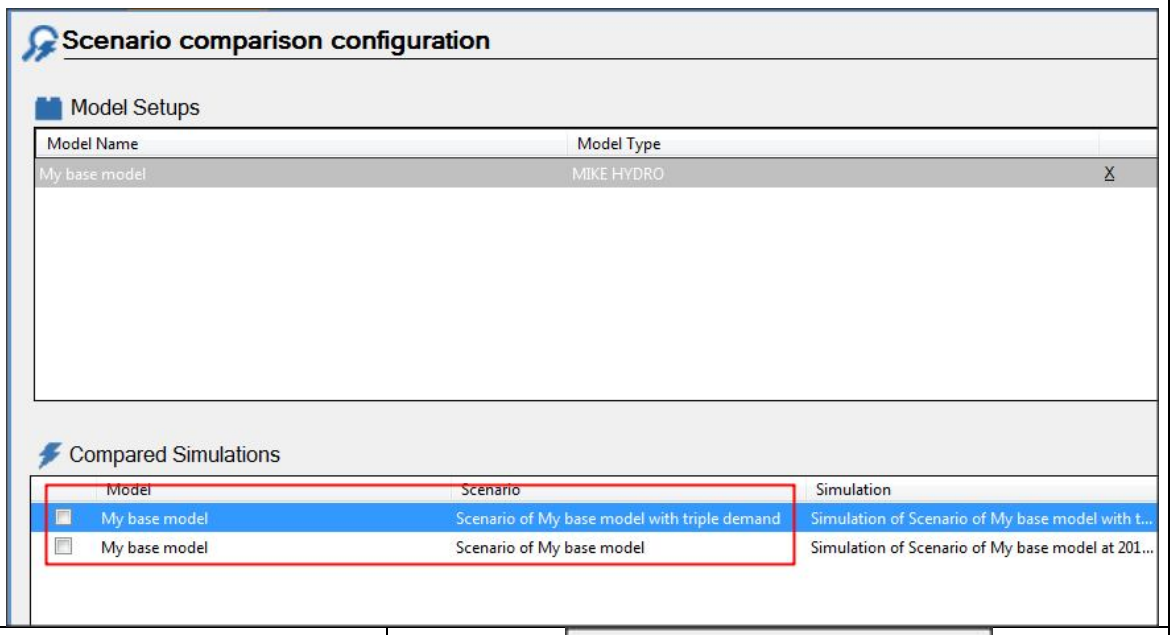


Comparing scenarios using comparison configuration

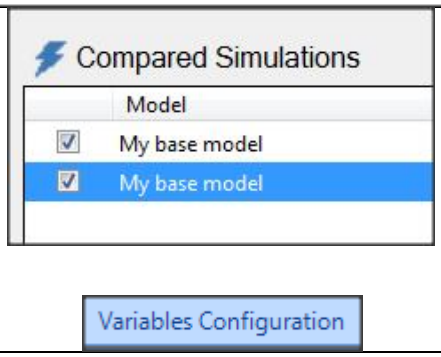
1- To create a new comparison, right click on the 'comparison configuration' group in the Scenario Explorer and select 'New comparison'.	
2- A new comparison is created. Leave the default name as it is.	
3- Double click on 'Comparison 1' to open the comparison configuration window. The window (See below) has a box for model setups and another one for simulations. 	
4- Drag the 'My base model' model setup into the model setup box.	



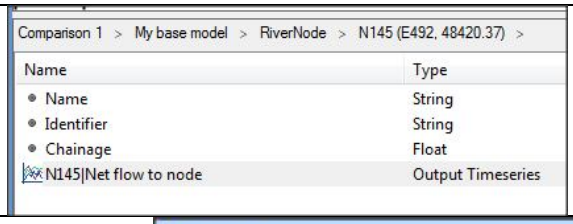
5- The model setup appears in the top box with its corresponding simulations in the bottom box.



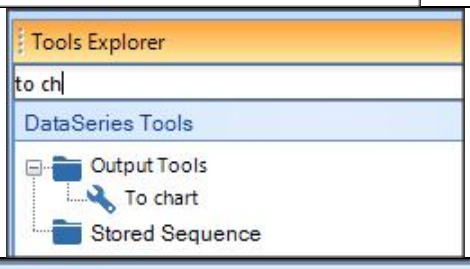
6- Select the two simulations and click the 'Variable configuration' tab at the bottom to configure the variables.



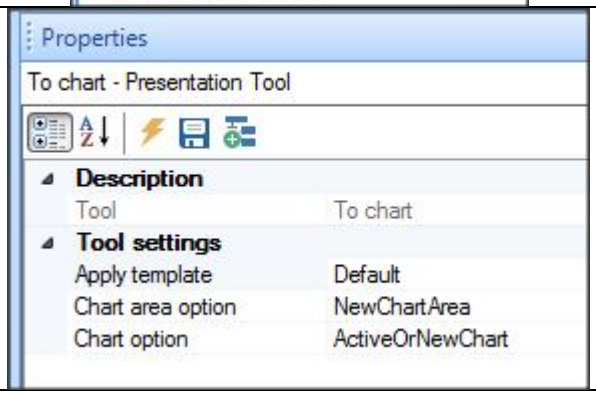
7- Select the N145 river node net flow as done previously.



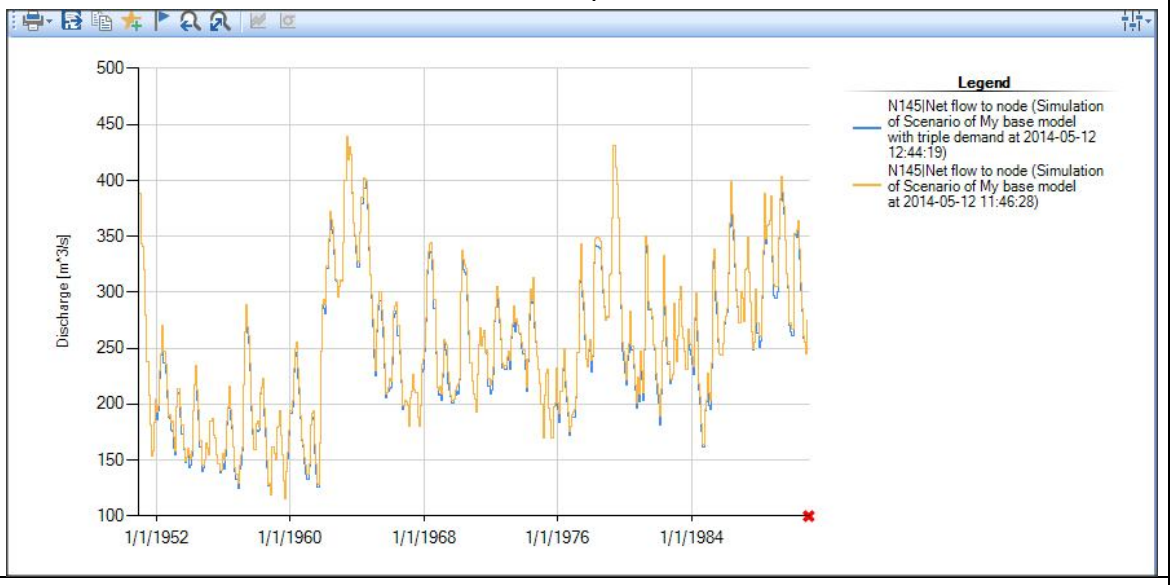
8- Select the 'To chart' tool from the 'Output Tools' category under the tools explorer.



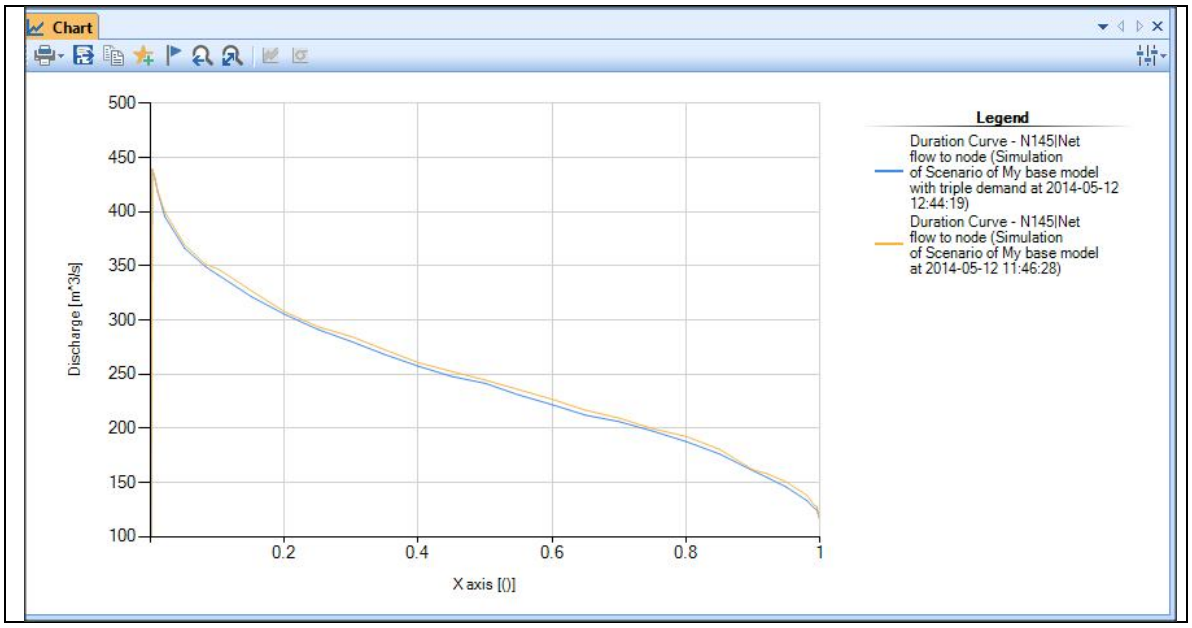
9- Run the tool by clicking the  in the properties window.



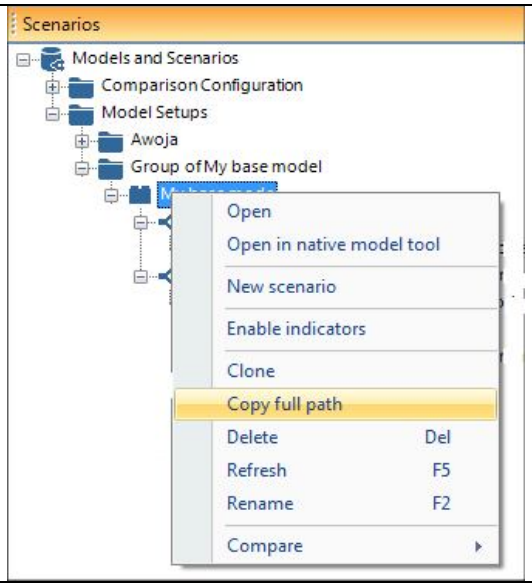
10- The time series for the two simulations is plotted.



11- A duration curve can be also created for the time series using the 'duration curve' tool from the 'Advanced statistics' category under the tools explorer.



Copying the full path a model setup

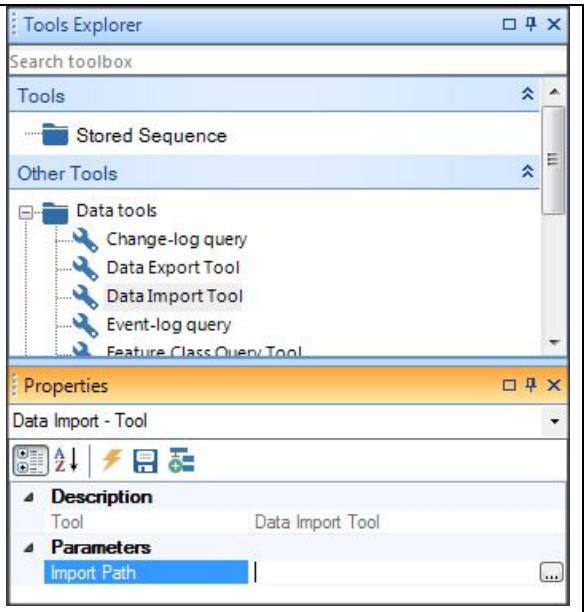
1- Within the Scenario explorer, Select the model setup which you need clone (e.g. My base model). Right click the mouse and select the Copy full path option.	
2- Now the path is copied to the clipboard. Paste in Notepad to check it. This path is required, for example, in scripts or indicators to get the path to a model setup.	/Group of My base model/My base model

Comparing scenarios using indicators

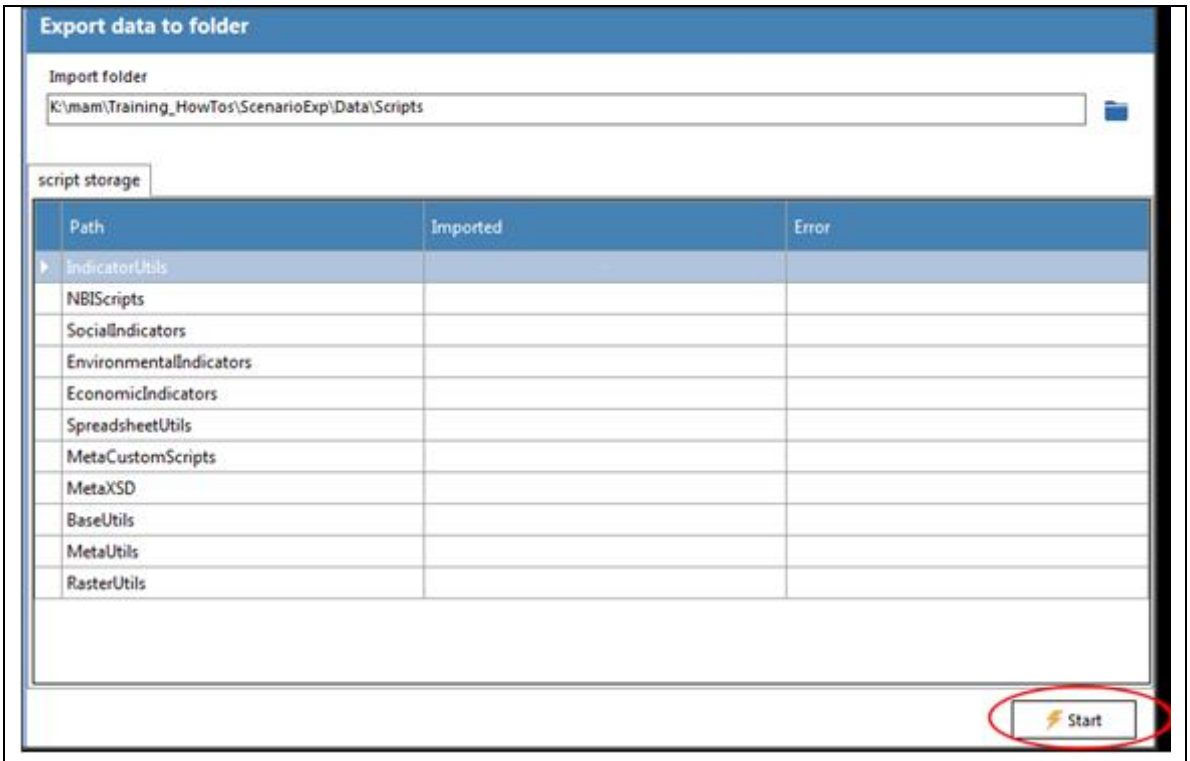
In this exercise, you will compare the two scenarios using two indicators, namely, the average energy in the system and the change in evaporation between the two scenarios.

The average energy in the system indicator calculates the system wide average annual energy. It has two parameters. The first parameter is the path to the Scenario which the average hydropower will be calculated for. The second parameter is a unit divisor. If this divisor is 1.0 then output is in Megawatt. If it is 1000 then it is in Giga watt.
The change in evaporation indicator compares the evaporation between two scenarios. It has 4 parameters. The first two are the path to the base case and the future case. The third parameter is also a unit divisor to change units from Million m3 to Billion m3. The fourth parameter allows the user to calculate the change from the baseline as a volume or a percentage. To calculate the change as a volume use 'VOL'. To calculate the change as a percentage use 'PBC'.

1- In order to use indicators, scripts need to be developed to calculate the values of those indicators. A number of scripts have already been developed as part of the DSS. Two will be used here to calculate the generated power and evaporation. In the 'Tools' explorer, select the 'Data Import Tool' under the “Data tools” category. In the 'Properties' explorer, browse to the import path which is **..\ScenarioExp\Data\Scripts**. Press the  button.

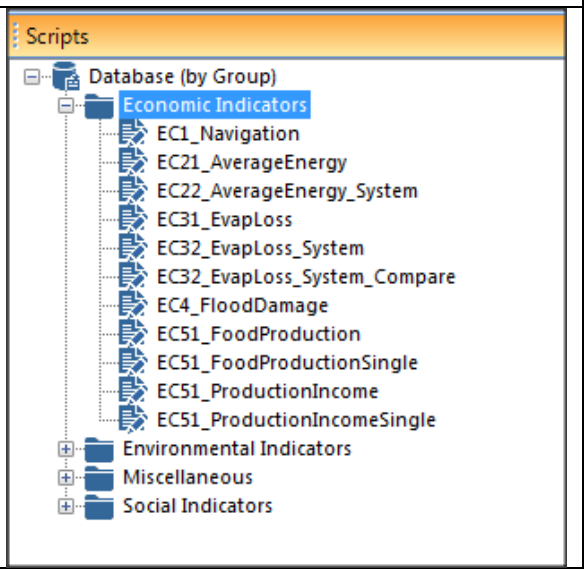


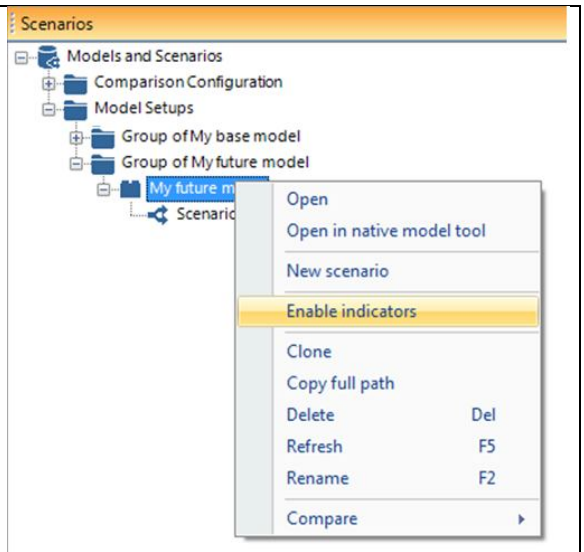
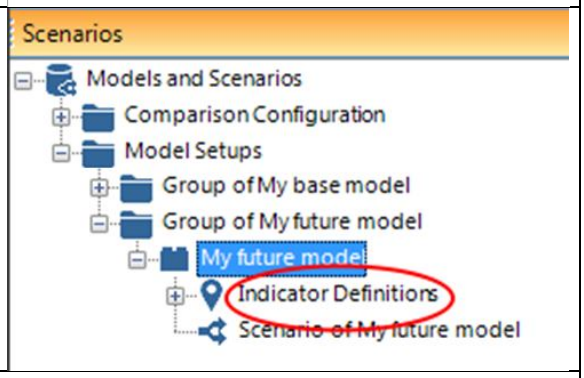
2- The tool now looks into the folder and finds what is suitable to import (i.e. this tool is generic and can be used to import other object types that were previously exported from the DSS. it has to be the same DSS version though.) and lists them as shown below. Click the start button to import all of the scripts as some of them are needed to run the two scripts that will be used in this exercise.

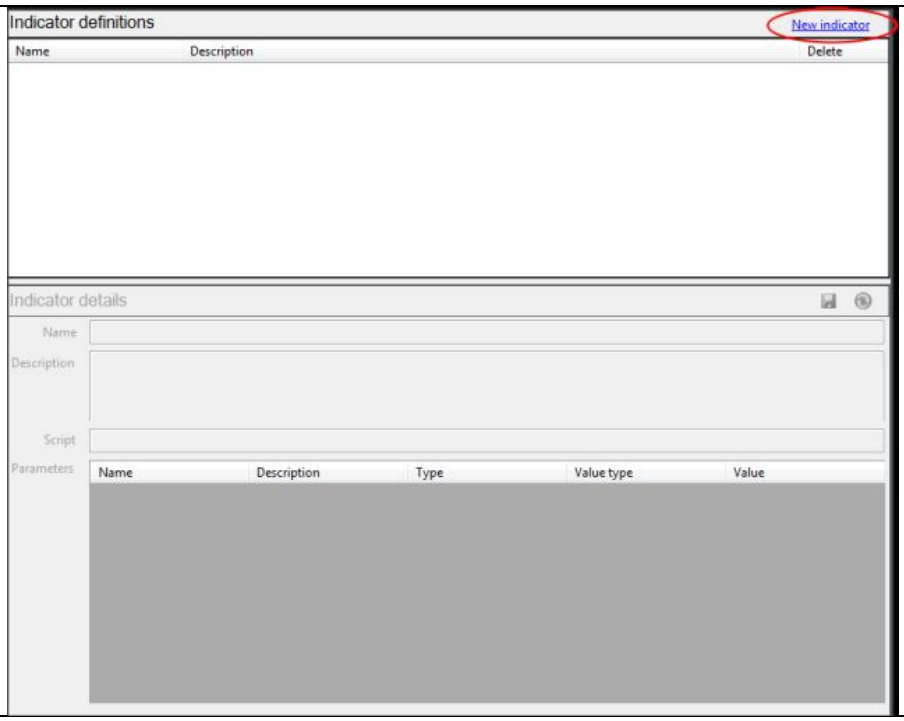


You will see 'green ticks' in the 'Imported' column if import was successful, otherwise 'red crosses' will appear in the 'Error' column

3- View the 'Scripts' explorer after the import and it should look like what is shown next.



4- Go back to the Scenario explorer and select 'My future model' model setup. Right click and select 'Enable indicators'.	
5- Now as can be seen next, a new item has been added to the model setup. This item is called 'Indicators Definitions'. This is where indicators will be defined.	
6- Double click the 'Indicators Definitions'. The window shown below appears (See the Indicator Manager training manual for more details). Click the 'New indicator' link at the top right.	



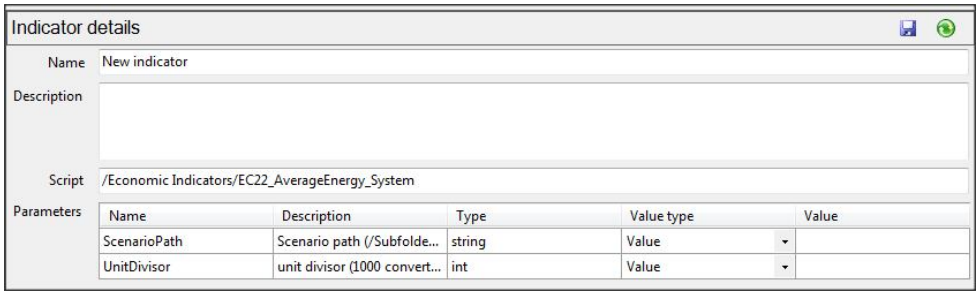
7- The 'Indicator details' window appears. This is where the indicator will be defined. The following is needed to define the indicator:

Name: This is the indicator name. It has to be unique and it is better to be representative (e.g. including some information about the location where the indicator is defined).

Description (optional): This where you give a description of what the indicator will calculate.

Script: This is the script developed to calculate the indicator.

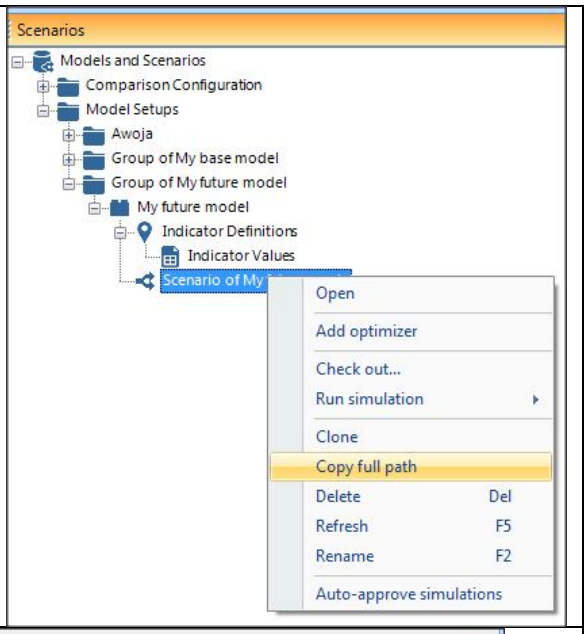
Parameters: If the script requires input parameters then they are listed here. Each parameter will have a name, description, type, value type and value (for more information on this see 'Indicators' manager training module).

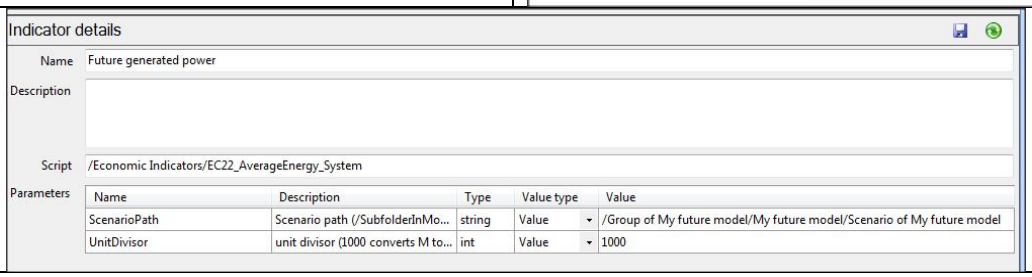


For this exercise drag the' 'EC22_AverageEnergy_System' script into the Script box.

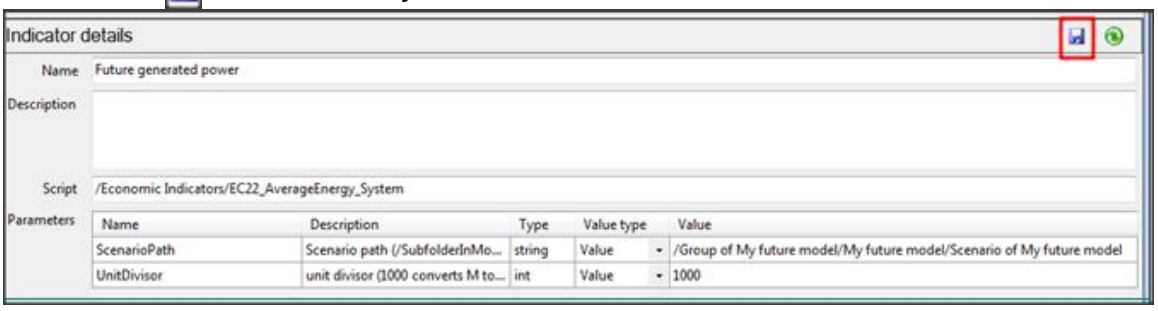
8- First you need to calculate the average energy for the future scenario. Therefore, the first parameter can be obtained by right clicking the 'Scenario of My future model' node in the Scenario explorer and select 'Copy full path'. This copies the scenario path into the clipboard so it can be pasted into the value box.

For the second parameter use 1000 for this exercise. Script should look like the window shown next.



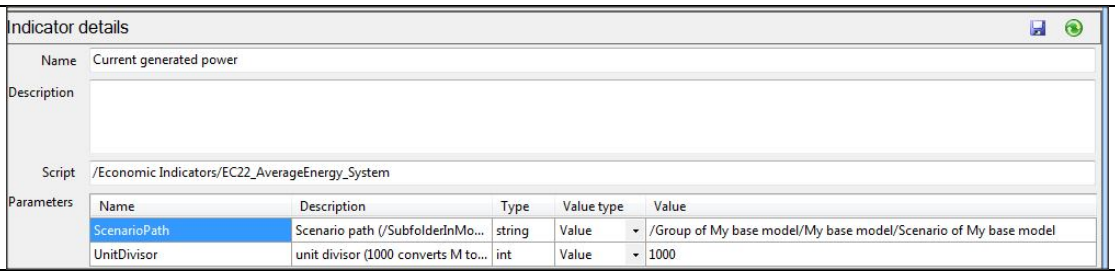


9- Press the button to save your indicator.

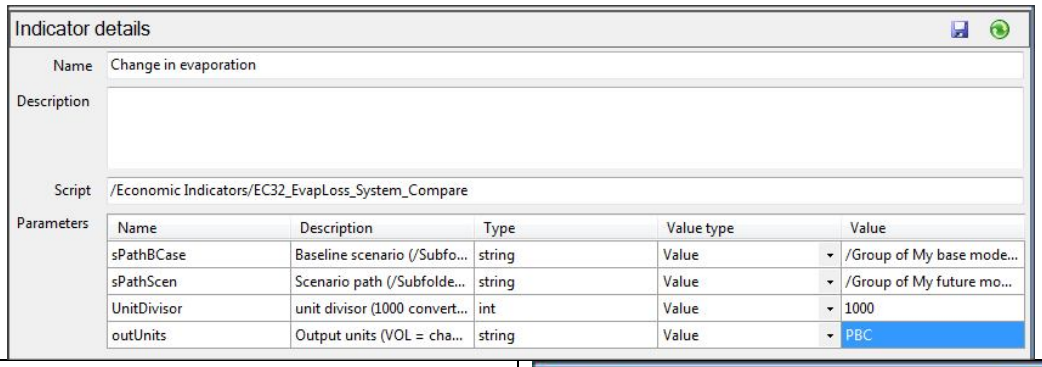


Note that this is the first time you need to save in this module. All model setup, scenario and simulation operation are saved automatically. But the indicator definitions need to be saved by you.

10- Repeat step 8 to calculate the generated power for the 'My base model' model setup. Indicator definition should look like the window shown next.

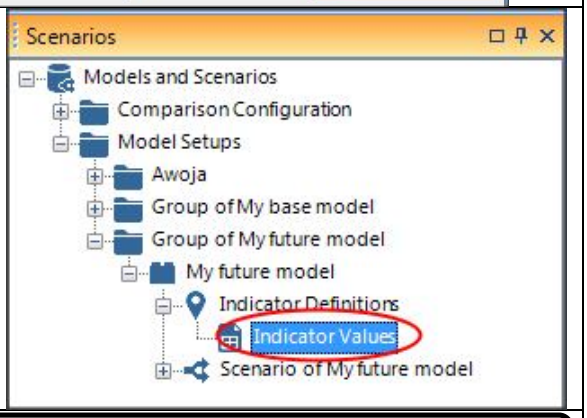


11- Repeat steps 8 to calculate the change in evaporation using the 'EC32_EvapLoss_System_Compare ' script. For this exercise use '1000' and 'PBC' for the unit divisor and out units.



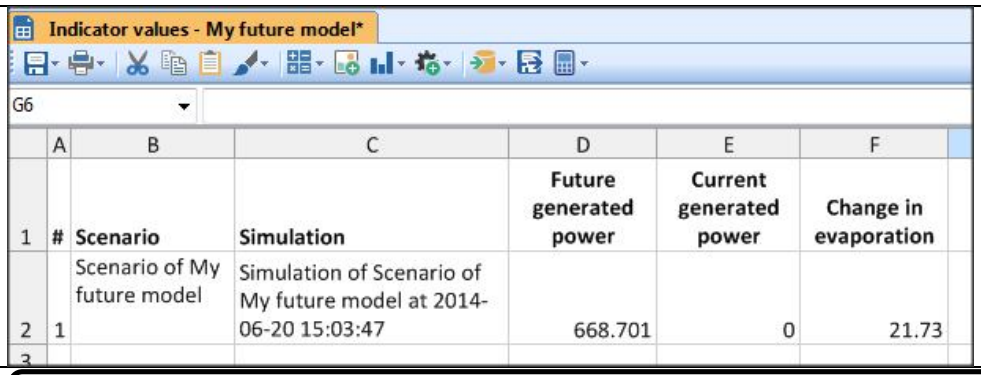
12- Once the definition of the indicator is completed, run a simulation for the 'Scenario of My future model' scenario. Indicator values can be viewed by double clicking 

after the simulation is done.



The indicators are calculated for all simulations that are carried out after they are defined.

13- As can be seen below, a spreadsheet is opened showing the scenario and simulation names followed by the indicator values. EC22 shows the future and the current annual generated power (an increase which is on the positive side). On the other hand, EC32 shows an increase in the evaporation which can be on the negative side.



	A	B	C	D	E	F
1	#	Scenario	Simulation	Future generated power	Current generated power	Change in evaporation
2	1	Scenario of My future model	Simulation of Scenario of My future model at 2014-06-20 15:03:47	668.701	0	21.73
3						

The indicators spreadsheet is created on the fly. If edited and saved without changing the name, edits are not overwritten.

Review Questions

1. List the result comparison methods in the DSS.
2. The comparison configuration can be used in an MCA
   - True
   - False
3. Indicators are defined at the scenario level.
   - True
   - False

Answers

1. Results comparison methods are: direct comparison, using the comparison configuration and using indicators.
2. False
3. False (at the model setup level)

2.6. Model setup changes

Introduction

This lesson introduces you to modifying model setups in DSS. If you are familiar with this process you may skip this lesson.

Topics covered:

- Opening model setups in native modeling tools
- Modifying model setups in native tools
- Saving and running model setup in native tools

Learning Objectives:

After completing this lesson, you will be familiar with the process of modifying, saving and running model setups in native tools.

Lesson pre-requisites

You have to be familiar with the model registration and scenario management, configuration and simulation to take this lesson.

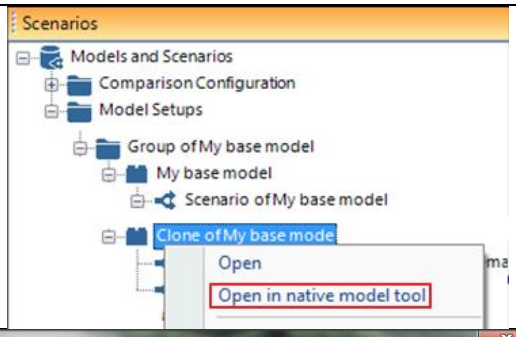
Modifying model setups (i.e. editing models in native tools)

A model setup that is registered and run in the DSS might need to be modified, for example, to assess the impacts of, for example, a new dam or a new irrigation development. This has to be done in the native tool (i.e. the modelling tool) that created the registered model setup. The DSS has the capacity to automatically open a model setup in a native by exporting all of its components in the native tool format. This is then opened in the native tool and you can modify the model schematic and/or data as needed. Following this, the modified model setup can be registered into the DSS. As mentioned previously, the modified model has to successfully run in the native tool prior to re-registration. These steps are presented in the exercises section below.

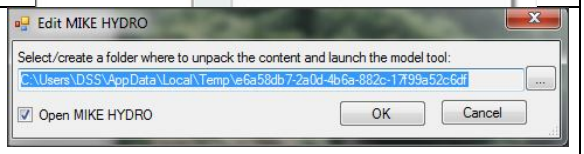
Exercises

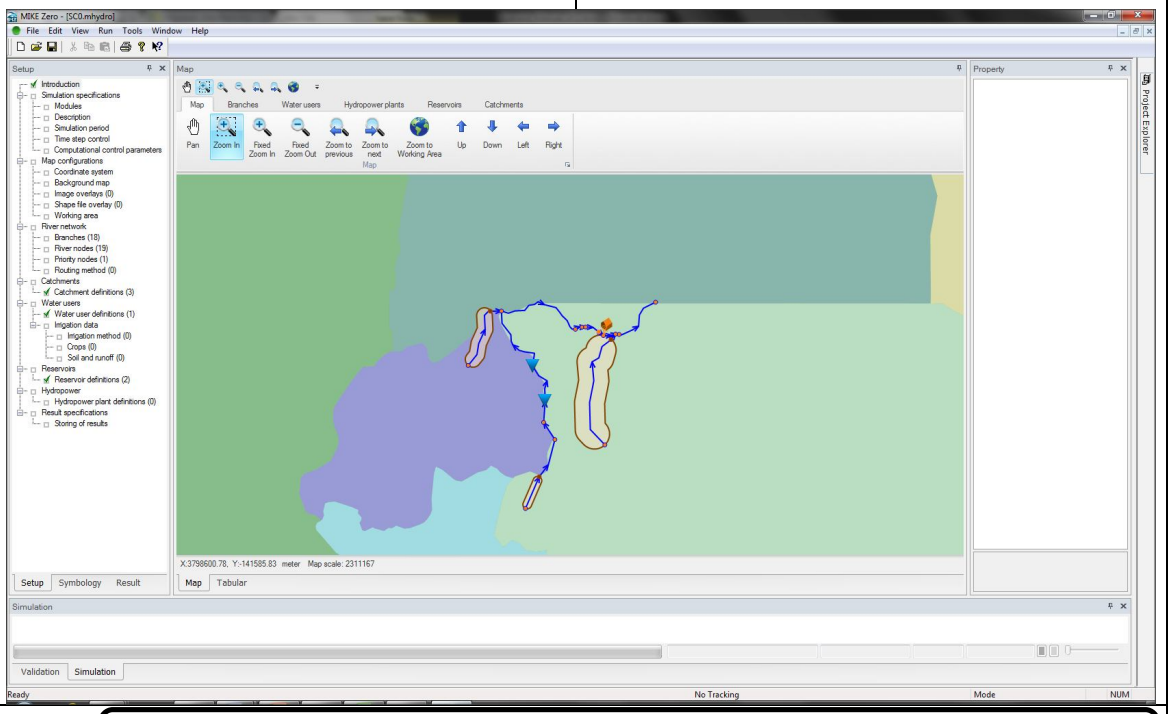
Modifying a model setup

1- Within the Scenario explorer, Select the model setup that you need to modify. Right click and select 'Open in native model tool'.



2- Keep “Open MIKE HYDRO” checked and select the folder to save the file using the ... button. Click 'OK' then the model opens directly in Mike Hydro. As shown below. It is advisable to save the model to an appropriate folder rather than using the suggested temporary location.

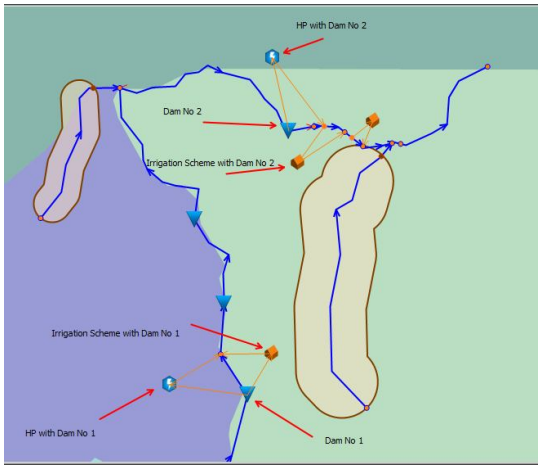




MIKE Hydro was selected here by the DSS as it is the ‘native’ modeling tool where the model setup was created. For model setups created by other modeling tools the choice would be different.

3- Make the changes described below. In those changes, two proposed dams are added. Each dam has a hydropower stations and irrigation scheme.

- Add Dam No 1 **(**Rusumo) and Dam No 2 **(**Kakono**)** , Irrgiation, and HP stations to the schematic as shown.
- Populate the data as given in the tables below.



Dams

	Dam No 1 (Rusumo)	**Dam No 2 (**Kakono**)**
Level Area Volume	Rusumo_LAV	Kakono_LAV
Initial Level	1322	1182
Losses	Mbarara_LossesGainsTS	Mbarara_LossesGainsTS
Characteristic Levels	Rusumo_Characteristic Levels	Kakono_CharacteristicLeve
Flood Control Level	Rusumo_FCL	Kakono_FCL
Minimum Release	Rusumo_Min_Release	10percent_of_average_flow
Minimum Operation Level	Rusumo_MinOpLevel	Kakono_MinOpLevel
Spillway	Rusumo_Spillway	Kakono_Spill
Users: Irrigation HP	Rusumo_Reduction Priority 2 Rusumo_Reduction Priority 1	 Kakono_Reduction Priority 1

Hydropower Plants

	Dam No 1 HP	**Dam No 2 HP**
Demand	Rusumo_Power	Kakono_Power
Efficiency	Hydropower Efficiency	Hydropower Efficiency
Tailwater level	Rusumo_Tailwater	

Water Users:

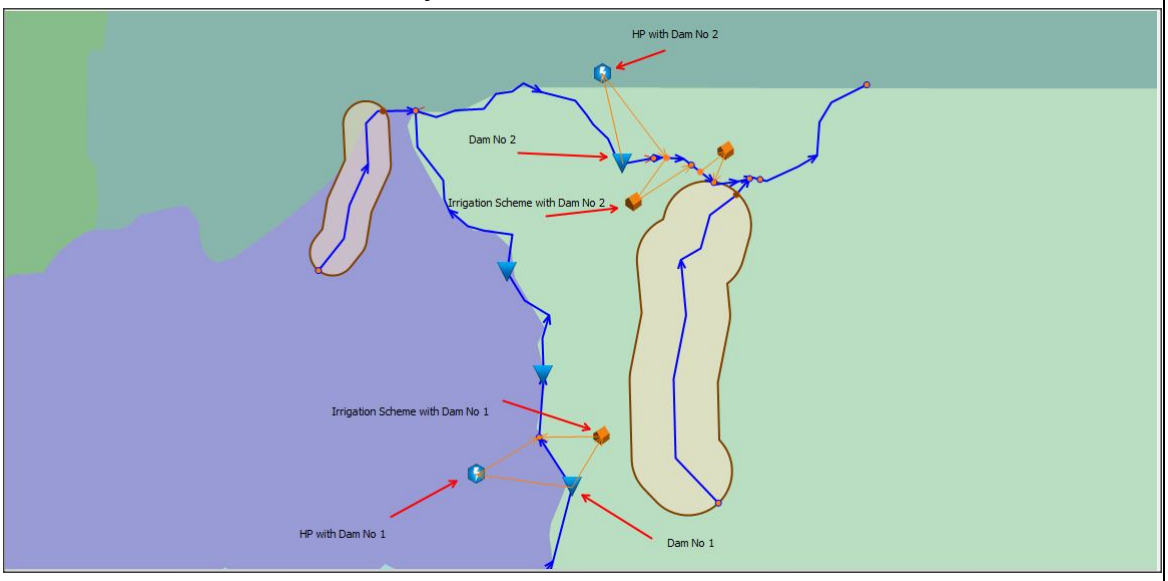
Water Use Time series:

Dam No 1Irrigation: Irrigation_Rusumo_WaterUseTS

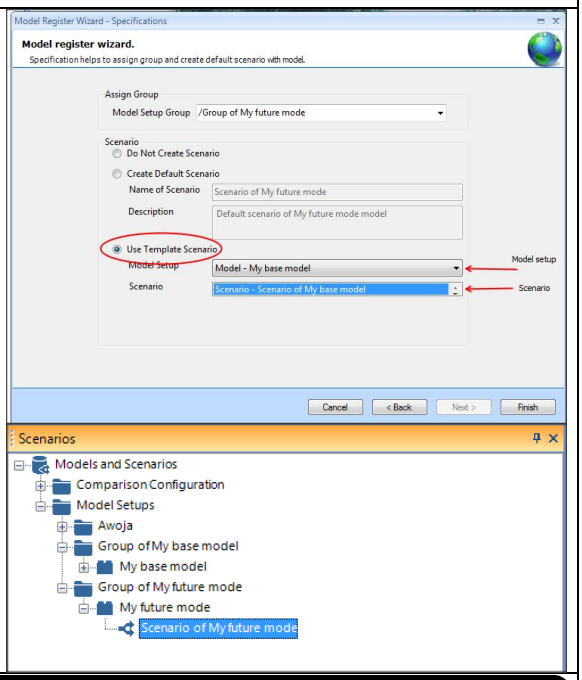
Dam No 2Irrigation: Irrigation_Kakono_WaterUseTS

Return Flow (same for all): 10 percent_return_flow

The model should look like the picture below after addition of the above model objects. Save the new model as 'SC1.mhydro' and run the new model then exit.



4- Register the new model as explained in the model registration section. Give it a suitable name (e.g. 'My future model'). At the last screen, instead of creating a default scenario, create a scenario that is based on the 'My base model' setup. To do this select the Use Template Scenario option and under 'Model Setup' select 'My base model'. This will populate the list of scenarios; select 'Scenario of My base model'.



Creating a scenario using a template saves time as the newly created scenario is populated with all the model objects that were added by the user. Therefore, there is no need to add them again. You need to rename to the new scenario to reflect the model setup

5- In addition to those time series that already exists in the created scenario, add the following outputs using the steps in configuring a scenario exercise:

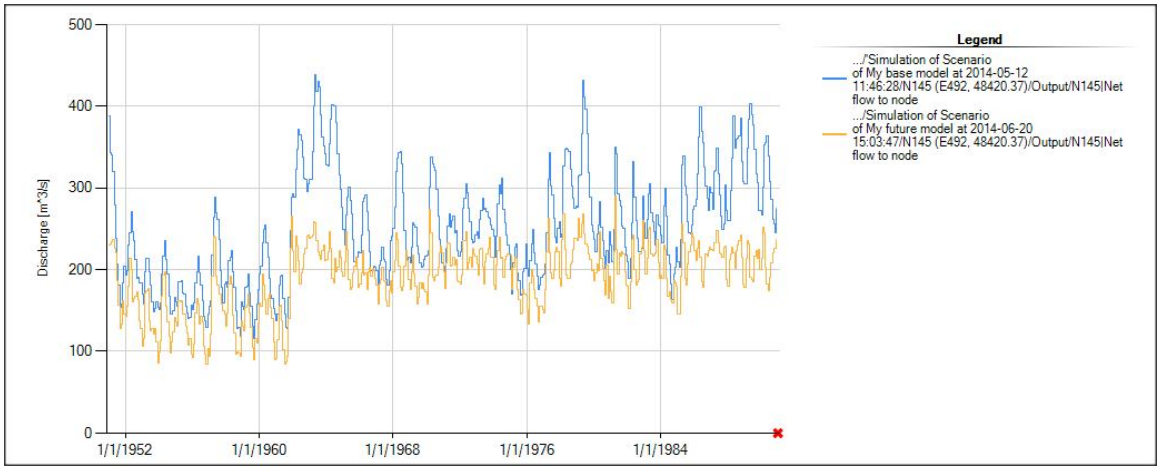
- Generated power for dams 1 and 2

- Evaporation from dams 1 and 2 reservoirs
6- Run a simulation and check the results

Review Questions

1. Modifying model setup can be done within the DSS user interface
   - True
   - False
2. User has to manually copy a registered model setup into the native modeling tool.
   - True
   - False
3. Plot the “net flow to node” at N145 from both the modified model and the original model to compare

Answers

1. False (in the native modelling tool)
2. False (Done using the DSS user interface)
3. 

2.7. Model linking

Introduction

This lesson introduces you to the concept and steps of linking models in the DSS. If you are familiar with those steps you may skip this lesson.

Topics covered:

- What is model linking?
- Why model linking is needed?
- Types of models that can be linked in the DSS
- Steps to link models in the DSS

Learning Objectives:

After completing this lesson, you will be familiar with the process of linking models in the DSS.

Lesson pre-requisites

You have to be familiar with the model registration and scenario management, configuration and simulation to take this lesson.

What is model linking?

In the DSS, it is possible to link two or more model setups and run scenarios based on them in sequence. This feature is useful when linking, for example, a detailed rainfall runoff model to a hydrological model or a hydrological model to a one-dimensional river model. As shown in the figure below, a rainfall-runoff (NAM model) and a MIKE hydro model are linked within the DSS and can be executed in sequence. The rainfall-runoff model is simulating a catchment and calculating its run off. This runoff then feeds into a reservoir which then releases water to a downstream user.

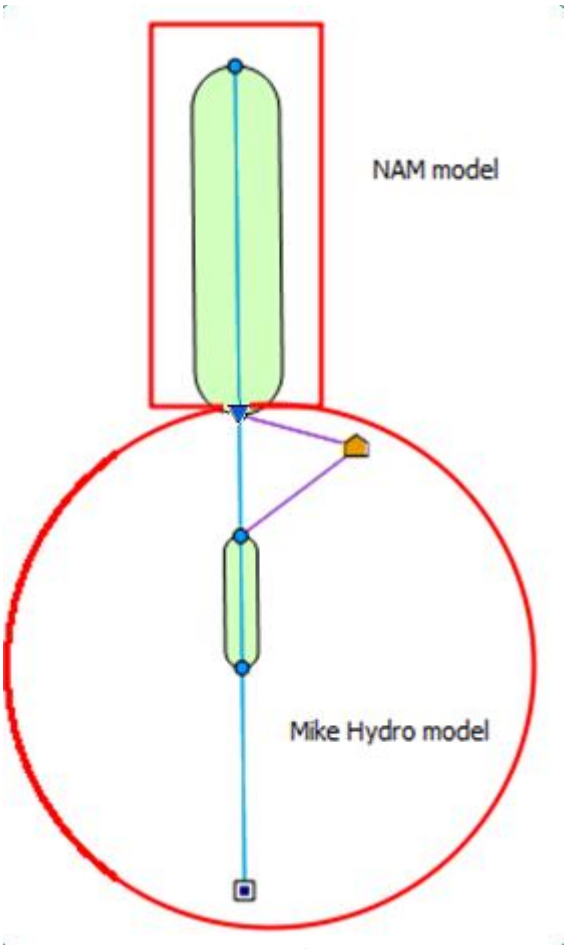


Figure 6: A schematic of two linked models.

Why model linking?

Model linking is another flexible and innovative tool that is included in the DSS. In various situation, Water resources studies might require modeling different parts of a basin using different approaches. For example, the lower reach of a catchment can modeled with a 1D hydraulics model that is fed by an output from a catchment rainfall-runoff model. Having those models linked in as one model is a big advantage as it reduces the efforts needed to move data from one to the other and reduce the possibility of making mistakes while moving the data. It also simplifies the creation of complex models for large systems (e.g. the whole Nile basin) as it can be subdivided into relatively smaller sub-catchment models that can then be linked together to a main-stem model. It also can facilitate the analysis of the impacts of making changes in one model on others that are run afterwards. Decision making is also made easier

as the model results can be taken as one in analysis tools such as the Multi Criteria Analysis (MCA) tool.

Types of models that can be linked in the DSS

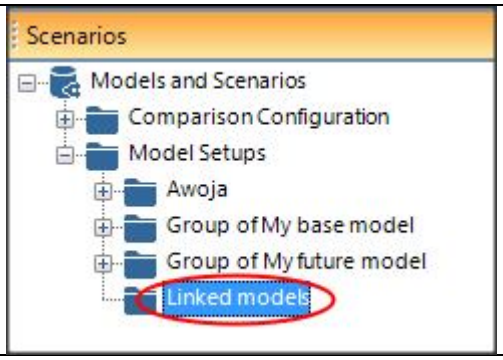
The general rule is that models that are registered in the DSS, can be linked to each other, provided that, it does make physical sense to link them.

In the next section, model linking is presented.

Exercises

Setting up a linked model

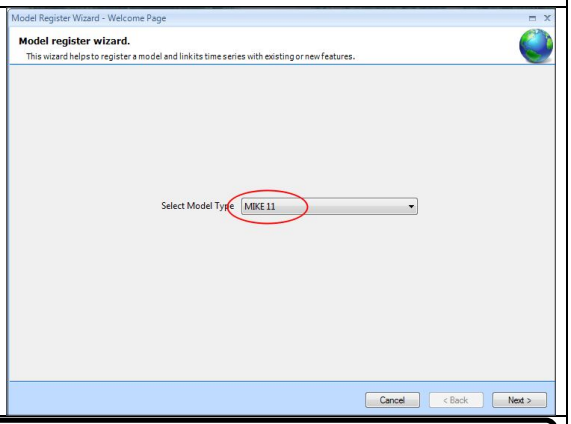
1- Create a new group under model setup and call it 'Linked models'.



2- Register the Mike Hydro model located at **..\ ScenarioExp\Data\Linking\Reservoir** under the 'Linked models' group. Call the model setup 'Reservoir model'. Refer to Exercise Registering a model into the DSS for additional information

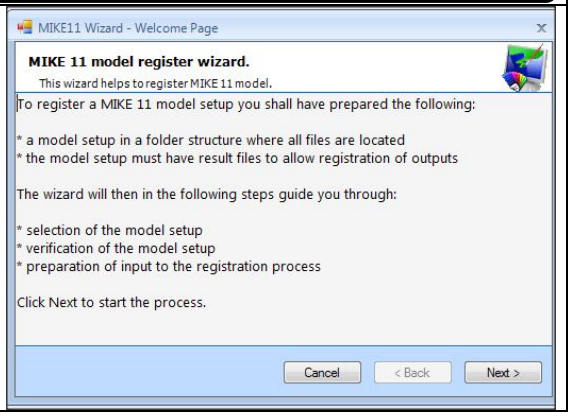
3- A NAM (rainfall-runoff) model needs to be also registered. This can done using Mike 11 DSS Adaptor.

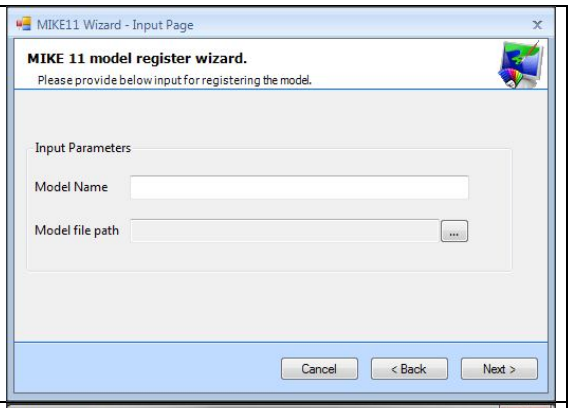
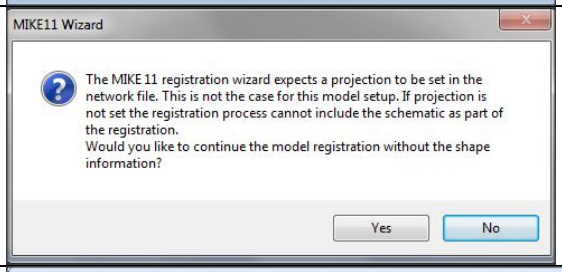
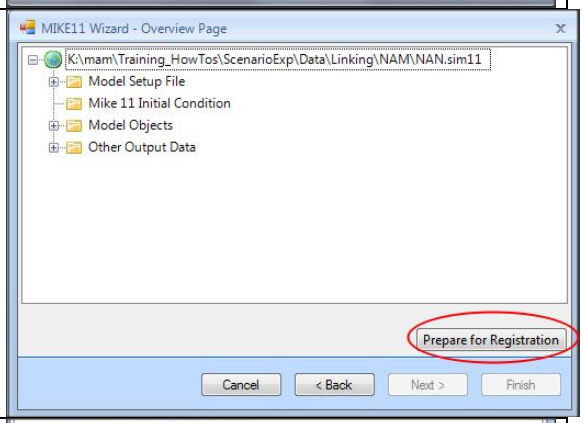
Select the 'Linked models' group and then 'Register model'. In the model registration wizard, select 'Mike 11' and click next.

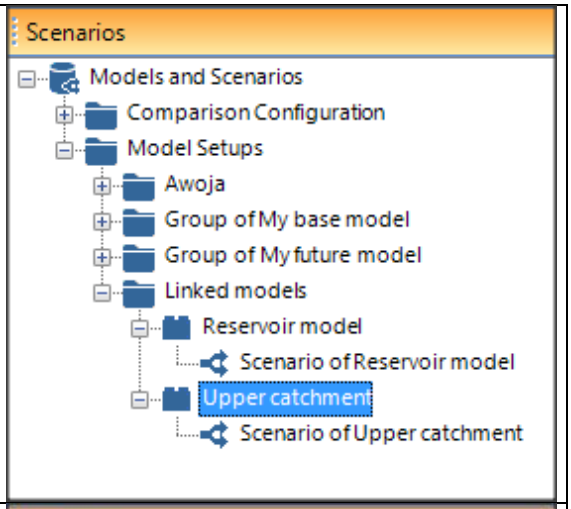
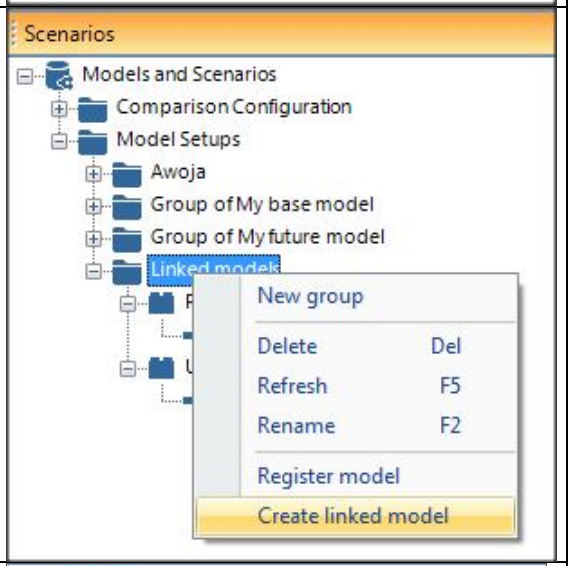
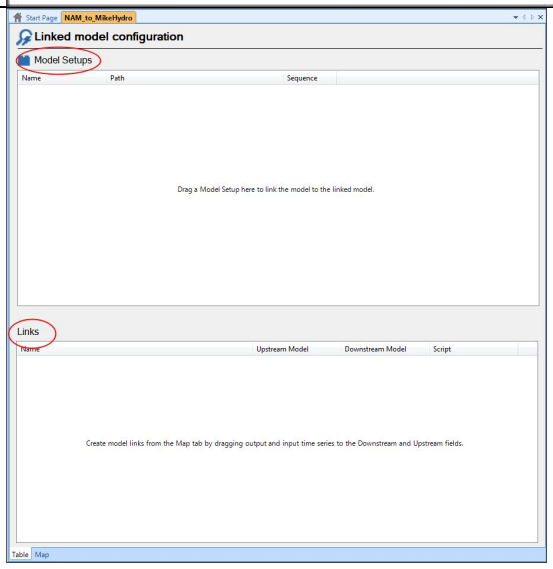


NAM model can also be created using MIKE HYDRO and in that case registered using the MIKE HYDRO adapter.

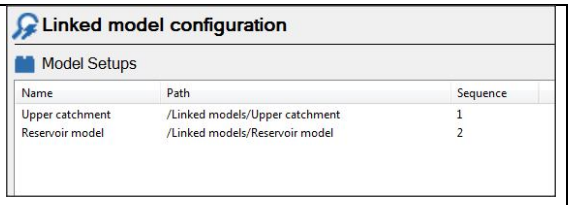
4- The Mike 11 model register wizard appears, Click next.



5- Call the model 'Upper catchment' and go to the **..\ ScenarioExp\Data\Linking\NAM** and select the NAN.sim11 file. Click next.	
6- A warning message appears since the model has no projection. Click yes.	
7- Click 'Prepare for Registration'.	
8- When preparation is completed. Click finish.	
9- Now you are back to the main registration wizard click next and then finish completing the registration.	

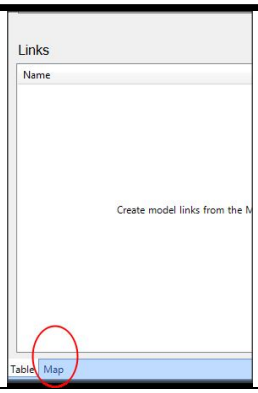
10- The Mike Hydro and NAM models have now been imported into the DSS.	
11- Right click the 'Linked models' group then select 'Create Linked model'. Call the linked model group 'NAM_to_MikeHydro '.	
12- Double click the 'NAM_to_MikeHydro ' group to open the 'Linked model configuration' window. The top pane of the window allows the user to add the model setups that will be linked. The bottom pane defines the links between the model setups.	

13- Drag and drop the Mike hydro model first into the 'Model Setups' Box and then the NAM model. Model setups should look like the window shown next with NAM model at the top (i.e. sequence 1) and the Mike Hydro at the bottom (i.e. sequence 2).

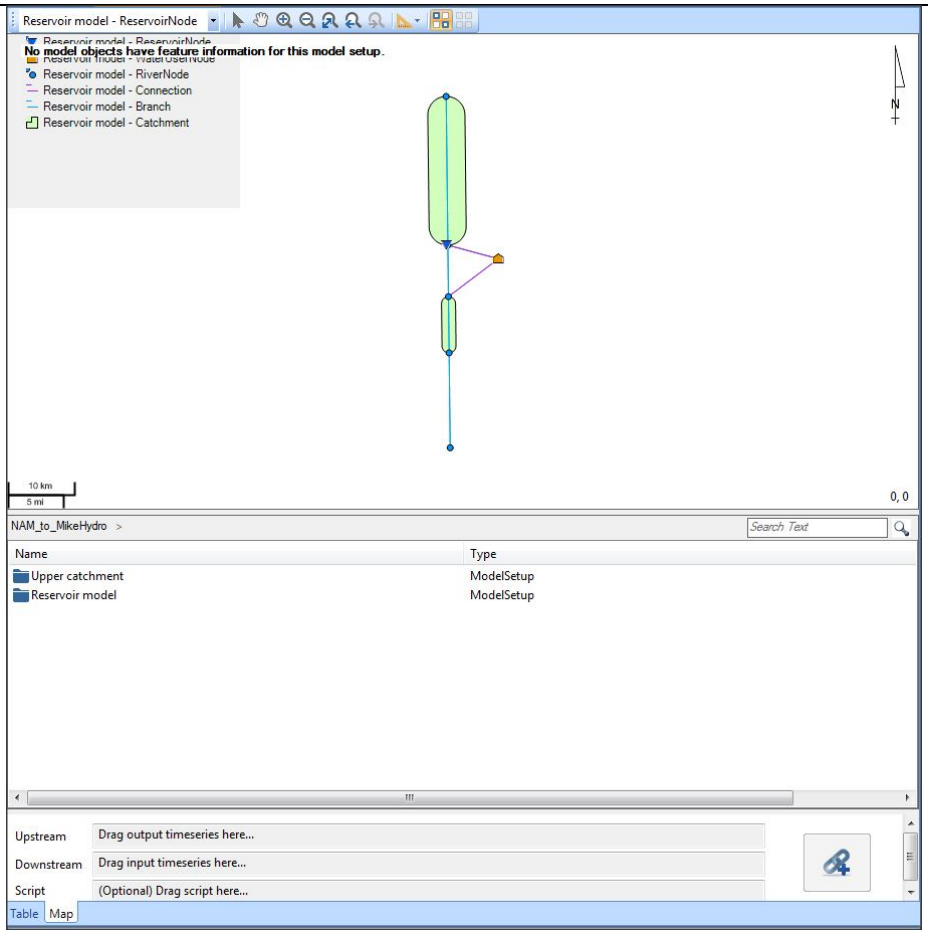


Model setup sequence can be changed by right clicking a model and moving it up or down from the popup menu. Model setups can also be deleted from the same menu.

14- To define the links you need to move to the 'Map' Tab of the Links box.

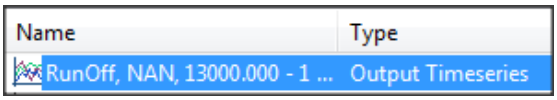


15- In the 'Map' tab, the models' map appears at the top them the model objects and at the bottom the link configuration box. This box has 3 items. The first two are mandatory as they define the upstream node of the first model that will be linked to a downstream point at the second model. The third item is a script that can be called when data is transferred from the first model to the second one in case any pre-processing is needed (e.g. unit conversion, time step change).

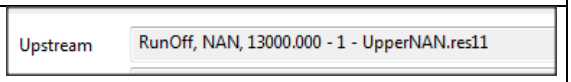


In this exercise, we will focus on the first two items.

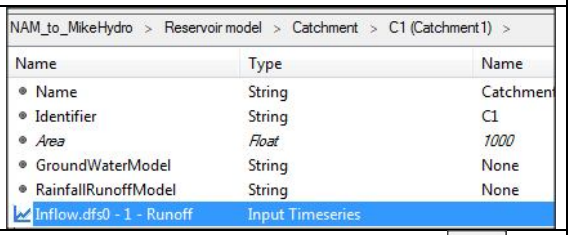
16- To create the link, double click 'Upper Catchment' model then 'Mike 11' twice and then select the runoff time series



17- Drag and drop the runoff time series in to the upstream box.



18- Similarly, double click Reservoir model' then 'Catchment' then 'C1 (catchment)' and then select the inflow time series.

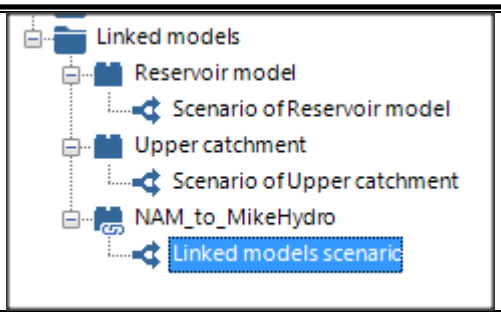


19- Drag and drop the inflow time series in to the downstream box then click the  button to add the link. Go back to the table box of the links window. The link have been added between the two models

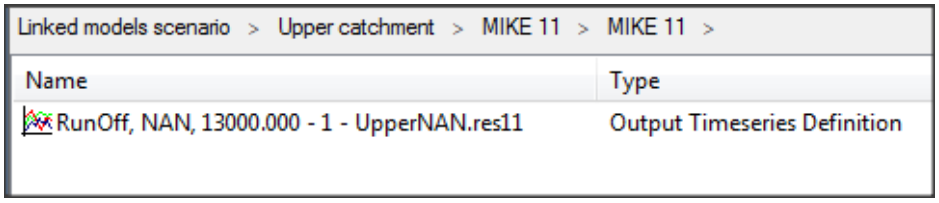
To remove a link, right click and select delete from the popup menu.

Note that the upstream time series is an output and the downstream time series is an input.

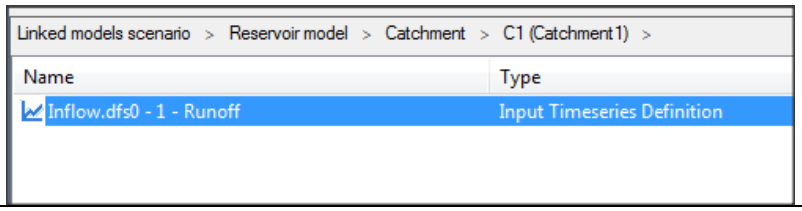
20- In order to run a scenario based on the linked model, a new scenario has to be created in same way it is created for a single model. So create a new scenario and call it 'Linked models scenario'



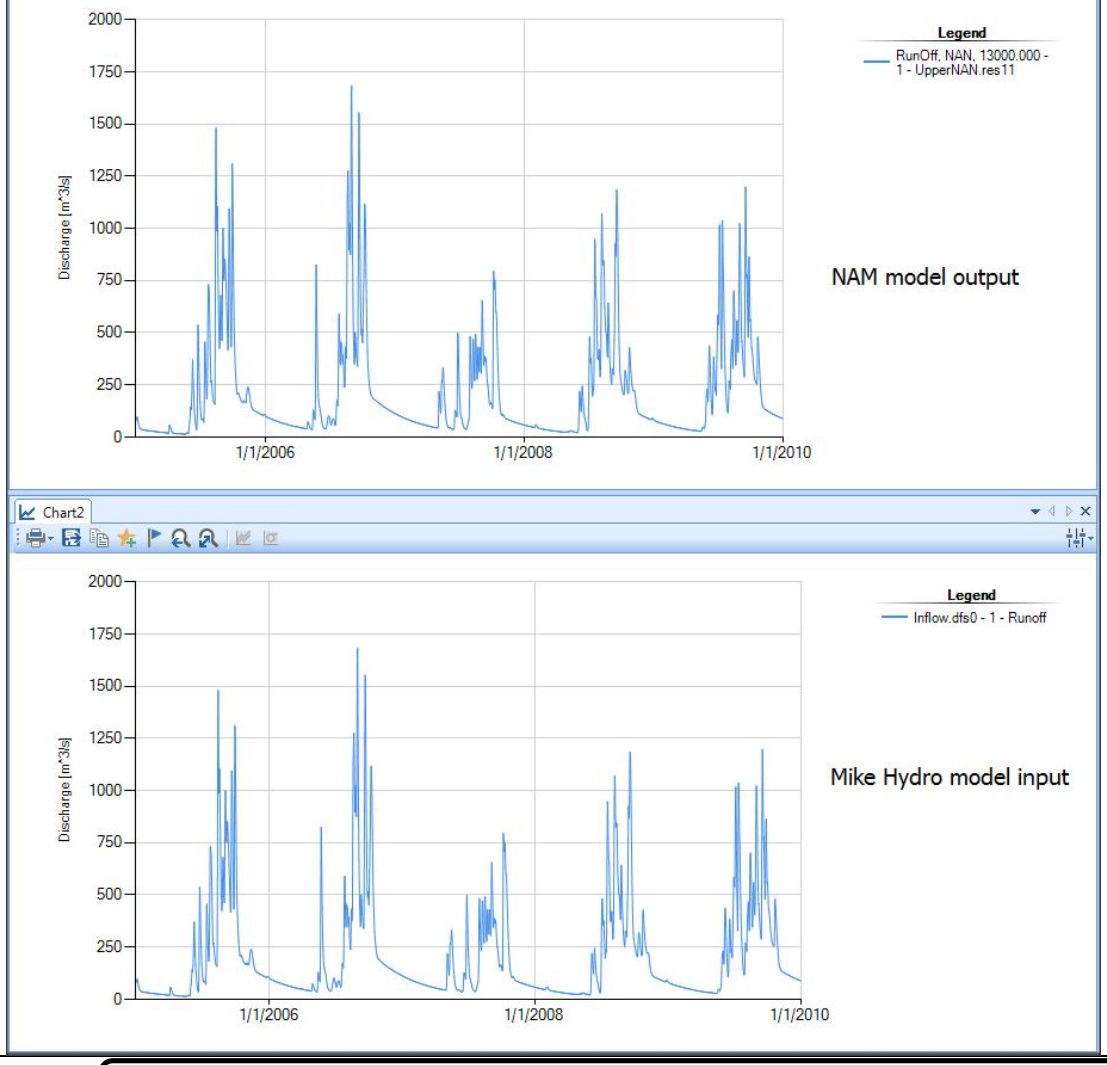
21- As done previously, add model objects to be included in this scenario from the model setup window map tab.



In this exercise, the runoff from the first model and the inflow to the second model can be added to check that they are identical.



22- Run the scenario and check the results. Runoff from the first model should be identical to the inflow of the second model as shown below.



Models that can be registered (i.e. imported) in the DSS can be linked irrespective of the native modeling tool.

Review Questions

1. Models developed by any modeling tools can be linked in the DSS.
   - True
   - False
2. Indicators can be defined for linked models.
   - True
   - False

Answers

1. False (registered models in the DSS can be linked to each other)
2. True

2.8. Running simulation with ensembles

Introduction

This lesson introduces you to running simulation for scenarios, which have ensemble time series inputs in the DSS. If you are familiar with this you may skip this lesson.

Topics covered:

- Introduction to Ensemble scenarios and simulations
- How are indicators are calculated for Ensemble runs?
- Steps to run Ensemble scenario in the DSS

Learning Objectives:

After completing this lesson, you will be familiar with the process of running Ensemble scenarios in the DSS.

Lesson pre-requisites

You have to be familiar with the model registration and scenario management, configuration and simulation to take this lesson. Details on Ensembles can be found in the 'Time Series' manager training module.

Ensemble scenarios and simulations in the DSS

In the DSS, ensemble time series can be assigned directly to the input variables of a scenario. As long as one variable has been associated with an ensemble time series, the scenario becomes an 'Ensemble scenario'. Typically the ensemble inputs are extracted from ensemble output of meteorological models, or by using DSS tools to generate an ensemble of equally likely realizations of weather data, based on historical data.

When an ensemble scenario is executed (i.e. a simulation is run), the DSS runs one simulation for each ensemble member, in the order that the members are defined in the ensemble time series. If two or more ensemble members have been associated to two or more different variables in the same ensemble scenario, a number of simulations corresponding to the ensemble with the lowest number of members will be executed.

Hence, if two ensembles with, say, 10 and 15 members have been associated to two different variables in the same ensemble scenario, the system will perform 10 model executions before returning. For the ensemble with 15 members, the DSS will use the first 10 ensemble members. The output ensemble time series will have 10 members.

When all simulations have been completed, a single simulation node is produced in the Scenario explorer (similar to 'regular' scenarios), but all simulation output time series will be in the form of ensemble time series. The ensemble outputs can be analyzed and their statistics (e.g. mean, quantiles, ranges, exceedance probabilities etc) can be calculated. If the ensemble scenario is run on a multi-core processer, the scenario manager will utilize the available cores to run the models in parallel.

How are indicators calculated for an Ensemble run?

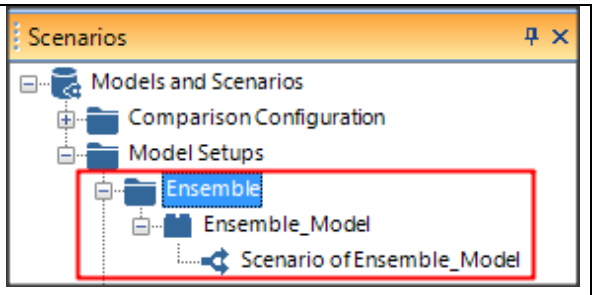
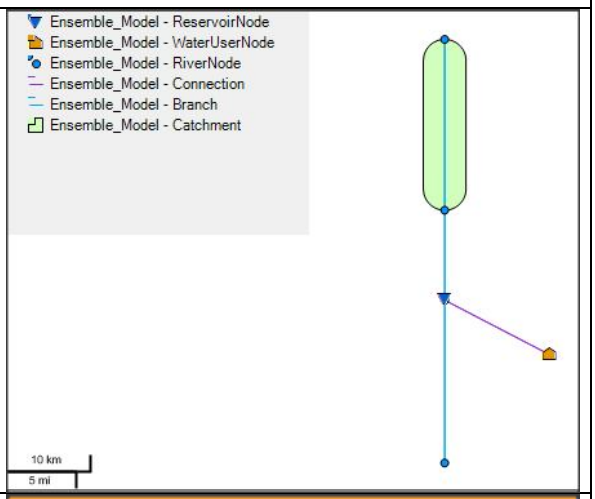
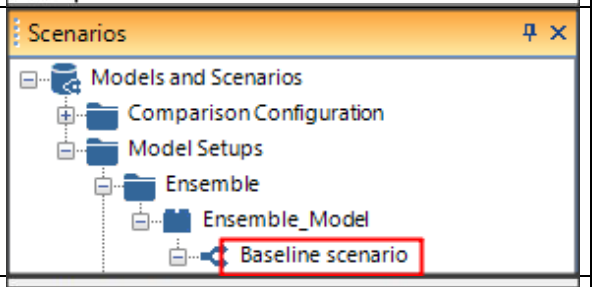
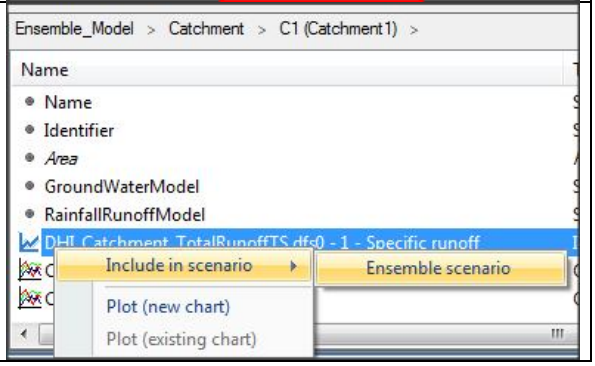
If a model setup has indicators defined, they will be calculated following a successful model run. If the scenario uses ensemble input the outputs become ensembles, hence an output time series used as argument for the indicator script will be an ensemble time series.

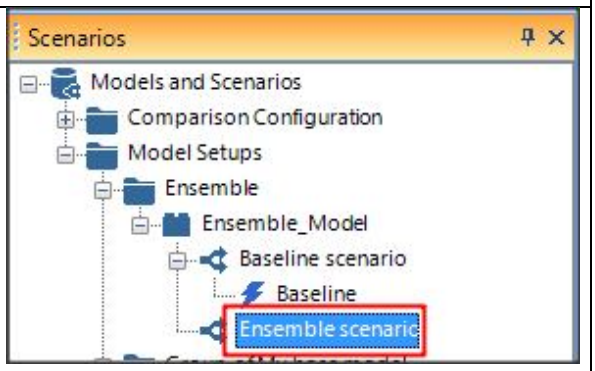
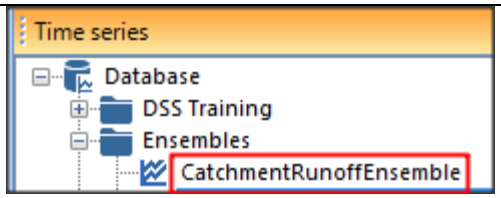
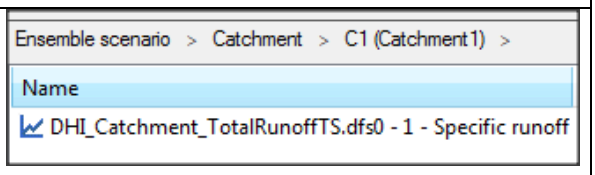
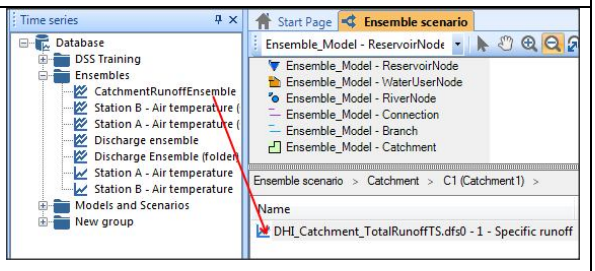
If the script assumes only a normal time series this will mean the output is calculated based upon ensemble member 0 (the first member). If the script is constructed to deal with ensemble time series then it will calculate the indicator value for the different members and then returning the average of that as the script must return ONE number.

In the next exercise, comparing scenarios using the above methods is presented.

Exercises

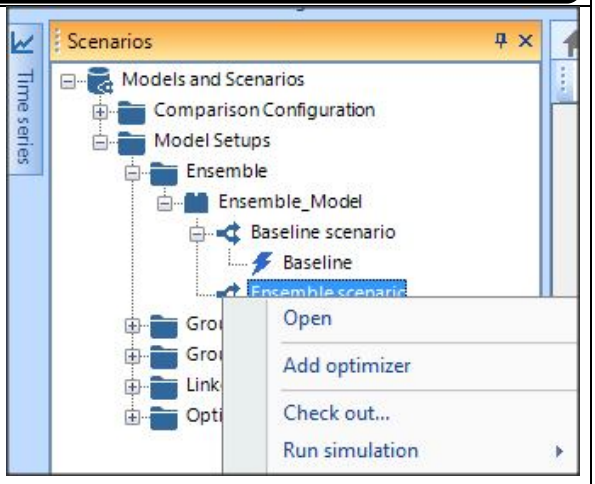
Running an ensemble scenario

1- Create a group under the Model Setups group and call it 'Ensemble'. Under the 'Ensemble' group, register the Mike Hydro model located at the **..\ScenarioExp\Data\Ensemble\Ensemble_model** folder (For details on registering a model see model registration section).	
2- Open the model data view. The model is a simple model consisting of a catchment, a reservoir and a water user that extracts water from the reservoir.	
3- Rename the Ensemble model scenario to 'Baseline scenario'.	
4- Add the following variables to the 'Baseline scenario': Catchment: *Specific runoff - input TS* Reservoir:	

Water level – output TS Run the 'Baseline scenario' and take a look at some of the results. Rename the simulation to *Baseline*	
5- Clone 'Baseline scenario' and Rename the clone to 'Ensemble scenario', and open the scenario view.	
5- Import the **'Runoff.dfs0'** file from the **..\ScenarioExp\Data\Ensemble** folder into the 'Time Series' manager as an ensemble (See 'Time Series' manager training module for details). Call the ensemble '***CatchmentRunoffEnsemble***' – Explore the data. This ensemble has 10 members	
6- Browse to the Specific runoff input time series in the model object explorer.	
7-Drag the '*CatchmentRunoffEnsemble' time series* from the time series explorer to the model object variable as shown. An ensemble time series has now been associated to the variable, and hence the scenario becomes an ensemble scenario.	

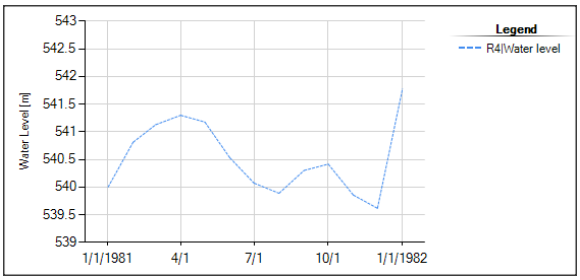
the drag and drop method describe above can be used to replace the scenario input with any other compatible TS (i.e. not limited to ensembles).

8- Run a simulation of the Ensemble scenario.

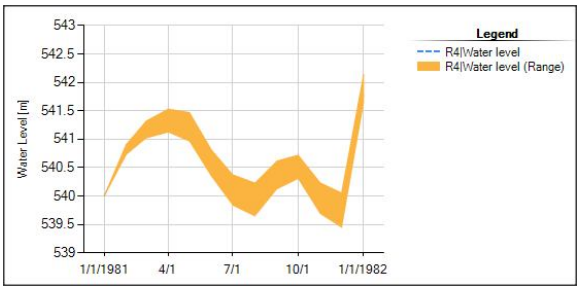


9- open the simulation view or the Time Series explorer

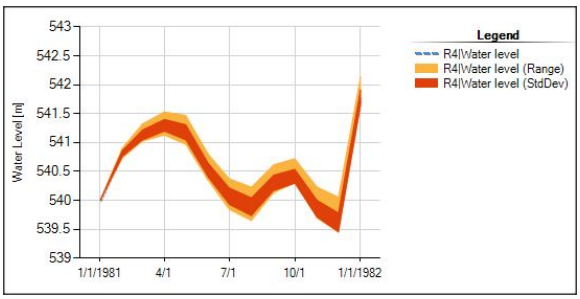
Browse to the Reservoir Water level variable, and double click it to create a plot.



Notice that the water level is now plotted as an ensemble (i.e. dashed line, showing the ensemble mean).



Select the series in the chart legend and click the button in the toolbar to get the range displayed.



Select the series in the chart legend and click the  button in the toolbar to get the standard deviation displayed.	

Review Questions

1. If two variables in a scenario have 5 and 7 ensemble members respectively. This scenario will run in the DSS
   - 5 times
   - 7 times
2. Explain how indicators are calculated for an Ensemble run?

Answers

1. 5 times
2. Mean indicator values are calculated for an Ensemble run.

2.9. Optimization

Introduction

This lesson introduces you to the concepts of optimization and describes using the optimizer that is included in the Scenario Manager. If you are familiar with those concepts and know how the DSS optimizer can be used you may skip this lesson.

Topics covered:

- Introduction to optimization including definition and problem types
- Steps to Setup and use the DSS optimizer

Learning Objectives:

After completing this lesson, you will be familiar with the concepts of optimization and the process of setting up and running the DSS optimizer.

Lesson pre-requisites

You have to be familiar with the model registration and scenario management, configuration and simulation to take this lesson.

What is optimization?

Optimization is an important tool in making decisions and in analyzing physical systems. In mathematical terms, an optimization problem is the problem of finding the best solution from among the set of all feasible solutions.

In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of this function. More generally, optimization includes finding 'best available' values of some objective function given a defined domain (or a set of constraints.

Optimization problem Types

An important step in the optimization process is classifying your optimization model (or problem), since a particular algorithm for solving optimization problems is tailored to a particular type of problem. The various optimization problem types are:

- Continuous Optimization versus Discrete Optimization

  Some models only make sense if the variables take on values from a discrete set, often a subset of integers, whereas other models contain variables that can take on any real value. Models with discrete variables are discrete optimization problems; models with continuous variables are continuous optimization problems. Continuous optimization problems tend to be easier to solve than discrete optimization problems; the smoothness of the functions means that the objective function and constraint function values at a point x can be used to deduce information about points in the neighborhood of x. However, improvements in algorithms coupled with advancements in computing technology have dramatically increased the size and complexity of discrete optimization problems that can be solved efficiently. Continuous optimization algorithms are important in discrete optimization because many discrete optimization algorithms generate a sequence of continuous sub-problems.
- Unconstrained Optimization versus Constrained Optimization

  Another important distinction is between problems in which there are no constraints on the variables and problems in which there are constraints on the variables. Unconstrained optimization problems arise directly in many practical applications; they also arise in the reformulation of constrained optimization problems in which the constraints are replaced by a penalty term in the objective function. Constrained optimization problems arise from applications in which there are explicit (e.g. physical) constraints on the variables. The constraints on the variables can vary widely from simple bounds to systems of equalities and inequalities that model complex relationships among the variables. Constrained optimization problems can be further classified according to the nature of the constraints (e.g., linear, nonlinear, convex) and the smoothness of the functions (e.g., differentiable or non-differentiable).
- None, One or Many Objectives

  Most optimization problems have a single objective function. There are interesting cases when optimization problems have no objective function or multiple objective functions. Feasibility problems are problems in which the goal is to find values for the variables that satisfy the constraints of a model with no

particular objective to optimize. Complementarity problems are pervasive in engineering and economics. The goal is to find a solution that satisfies the complementarity conditions. Multi-objective optimization problems arise in many fields, such as engineering, economics, and logistics, when optimal decisions need to be taken in the presence of trade-offs between two or more conflicting objectives. For example, developing a new component might involve minimizing weight while maximizing strength or choosing a portfolio might involve maximizing the expected return while minimizing the risk. In practice, problems with multiple objectives are often reformulated as single objective problems by either forming a weighted combination of the different objectives or by replacing some of the objectives by constraints.

- Deterministic Optimization versus Stochastic Optimization

  In deterministic optimization, it is assumed that the data for the given problem are known accurately. However, for many actual problems, the data cannot be known accurately for a variety of reasons. The first reason is due to simple measurement error. The second and more fundamental reason is that some data represent information about the future (e. g., product demand or price for a future time period) and simply cannot be known with certainty. In optimization under uncertainty, or stochastic optimization, the uncertainty is incorporated into the model. Robust optimization techniques can be used when the parameters are known only within certain bounds; the goal is to find a solution that is feasible for all data and optimal in some sense. Stochastic programming models take advantage of the fact that probability distributions governing the data are known or can be estimated; the goal is to find some policy that is feasible for all (or almost all) the possible data instances and optimizes the expected performance of the model.

Using the DSS optimizer

The Scenario Manager includes an optimizer. The optimizer can assist the user in optimizing, for example, reservoir operation. To illustrate the use of the optimizer in the DSS, A MIKE Hydro model that is relatively easy to understand and also quick to execute will be used but the concepts and methods presented here can be applied to more complex model setups.

As shown in the figure below, the model consists of a reach which is fed by a catchment. A reservoir is located downstream the catchment . One water user extracts water from the reservoir. The simulation period is one year, and all inputs and outputs are given on a monthly time step. The inflow to the reservoir varies over the year, from 100 m^3/s in the wet period to zero in the dry period. The initial water demand of the connected water user is small compared to the inflow, which means that the reservoir quickly fills up, and starts to spill. The goal of the optimization for this simple example is to maximize the demand of the water user, given that deficits shall not be allowed and given that the water demand must remain constant on a quarterly basis, and hence cannot vary freely from month to month. This is done to simplify the problem – but it can be left to vary freely.

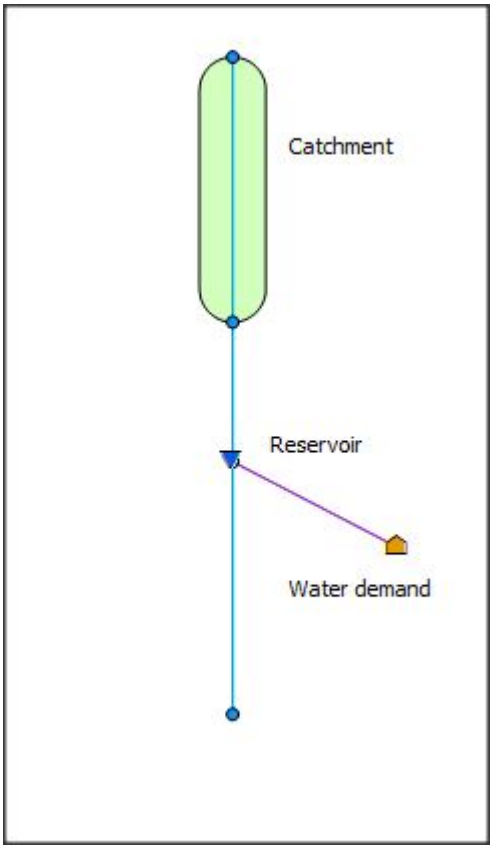


Figure 7: Mike hydro model

Optimization objectives

The first step in any optimization exercise is to identify the objectives. In this case, it is

an objective to maximize the water demand for the water user. At the same time, we want to minimize the water demand deficit. These are called competing objectives, but used together to ensure that the algorithm will search for the maximum demand that can actually be fulfilled.

Decision variables

Decision variables are those model input parameters that will be varied by the optimizer algorithm in the search for an optimum. In this example, the optimizer will need to vary the water demand, which is given as 12 monthly values in MIKE Hydro. However, due to the constraint that the demand must remain constant on a quarterly basis, we will only vary the value of the first month in each quarter, and then specify that this value shall be used in the following two months. For each decision variable, a valid range is specified, and the optimizer will only vary the variables inside this range. For the water demand, the lower bound is zero (no negative demands). For the upper limit the bound could be due to a physical limitation in the distribution network, but since such restrictions are often built into the model, it could also be a number sufficiently high not to interfere with the search.

Constraints

As explained above, optimization problems can be constrained or unconstrained. If the problem is constrained then solution of the optimization problem that be within those constrained. In the DSS, constraints can be defined for model object variables. For each constraint, upper and lower bounds need to be specified. The case that is described requires no constraints to be defined as it is constrained by the competing objectives functions as explained above.

Quantification of objectives – Model indicators

In the optimizer, objective functions are expressed through the use of so-called model indicators. Expressing the objectives described above in terms of indicators will be addressed in this exercise as well.

Optimization algorithms

The DSS Optimizer includes both single-objective algorithms and multi-objective algorithms. Multi-objective algorithms calculate a set of optimal solutions whereas single-objective algorithms calculate only one optimal solution.

In this example, we have two competing objectives (minimize demand deficit, maximize water demand). A single-objective algorithm will aggregate the value of the two objective functions into a single number:

$$obj_{agg} = w_1 * obj_1 + w_2 * obj_2$$

and the aggregated objective function is then subject to optimization. We have to choose the weights w_1 and w_2 before starting the optimization and the optimization algorithm will then narrow its search to minimize the aggregated objective function. Another choice of weights may lead to another solution.

In multi-objective algorithms no a priori choice of weights is made and the magnitude of the objective functions relative to each other does not affect the final set of optimal solutions. This gives us the possibility of choosing the weights after the execution of the optimization, and then selecting a point that has the lowest values of the aggregated objective function. This way the effect of choosing different weights can also be investigated. The downside of the multi-objective methods is that the search for the entire Pareto front is computationally more expensive than the “specialized” search carried out by single-objective algorithms.

Table 1 gives an overview of the optimization algorithms that has been implemented in the DSS. The Monte Carlo method has been coded so it points out the solution that has the lowest value of the aggregated objective function when all model simulations have been run. But as the values of the optimization variables are chosen at random (the value of the objective function is not used to “guide” the choice) it can be considered as a multi-objective algorithm, where the entire parameter space is investigated.

Table 1- Algorithms available in the DSS

Algorithms	*Single-objective*	*Multi-objective*
SCE	X	
Simplex	X	
DDS	X	
NSGA-II		X
Monte Carlo		(X)

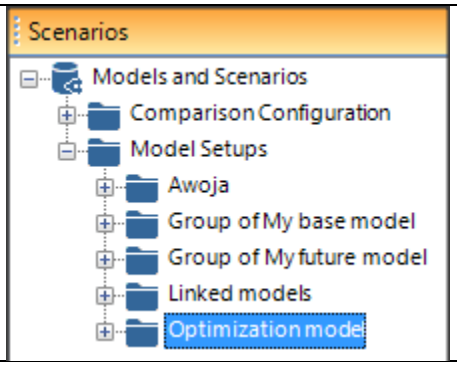
In the next exercise, using the optimizer is illustrated.

Exercises

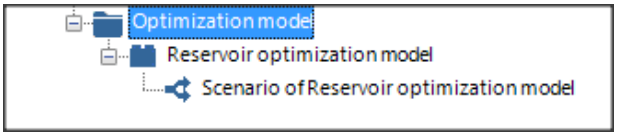
Setting up the optimizer

<objectives/brief description>

1- Create a new group under model setup and call it 'Optimization model'.



2- Register the Mike Hydro model located at **..\ScenarioExp\Data\Optimization\Optimization_model** under the 'Optimization model' group. Call the model setup 'Reservoir optimization model'.



3- Include all the model input variables that will be varied by the optimizer and the output variables that will be used to calculate the indicators used in the objective functions. This includes the following input:

- Water Demand for the water user node

and the following outputs:

- Water demand deficit for the water user node

- Used water for the water user Node

- Relative water level for the reservoir

4- The Optimizer uses model indicators to express the objective functions, and the value

of an objective function shall be calculated as the sum of one or more model indicators. Hence, the first step will be to define the scripts that shall be used as model indicators.
In this example we need two indicator scripts.
The first script shall return the average value of a time series. When provided with a time series of water demand deficit as input, this script will return the average water demand deficit. This value shall be minimized by the optimizer.
The second script shall be used to express the difference between a maximum allowed water use, and the actual water use. This value shall be minimized by the optimizer to maximize the amount of used water.
Open the script manager, and add the two scripts below (See 'Script' manager training module for details).

5- Create a script that calculates the average of an input time series, and return the result. An example is given to the right.
This script will be used for defining an indicator that expresses the Water demand deficit.

```
def TimeseriesAverage(ts):
    """
    <Script>
    <Author>admin</Author>
    <Description>Please enter script description here</Description>
    <Parameters>
    <Parameter name="ts" type="IDataSeries">Parameter of IDataSeries</Parameter>
    </Parameters>
    <ReturnValue type="double">Function returns the average of the ts</ReturnValue>
    </Script>
    """
    return ts.Statistics.Average
    pass;
```

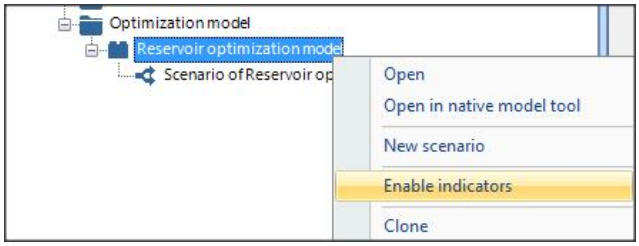
6- A general script that subtracts the average of an input time series from a constant and returns the result is given to the right.
This script will be used for defining an indicator that measures the difference between Used water and a target (the constant).

```
def ConstantMinusAverage(constant, ts):
    """
    <Script>
    <Author>admin</Author>
    <Description>Please enter script description here</Description>
    <Parameters>
    <Parameter name="constant" type="double">The constant</Parameter>
    <Parameter name="ts" type="IDataSeries">Parameter of type IDataSeries</Parameter>
    </Parameters>
    <ReturnValue type="double">Function returns the difference between the time series
    </Script>
    """
    return constant - ts.Statistics.Average
    pass;
```

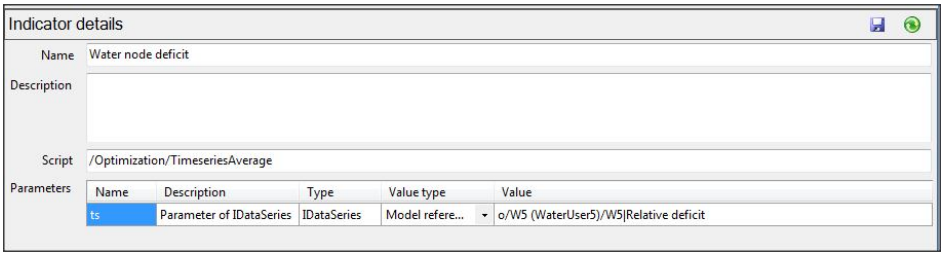
Next, the scripts has to be associated to model indicators, such that simulation outputs can be used as inputs and the result of the scripts can be reported back as model indicator values.

This will ensure that each time a simulation is executed, the simulation inputs and outputs will be used to calculate the necessary indicators (which can later be used in the calculation of objective functions).

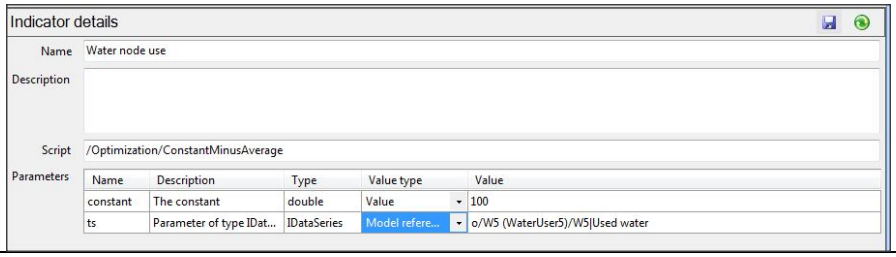
7- Enable the indicators for the 'Reservoir optimization model' and add the following two indicators:



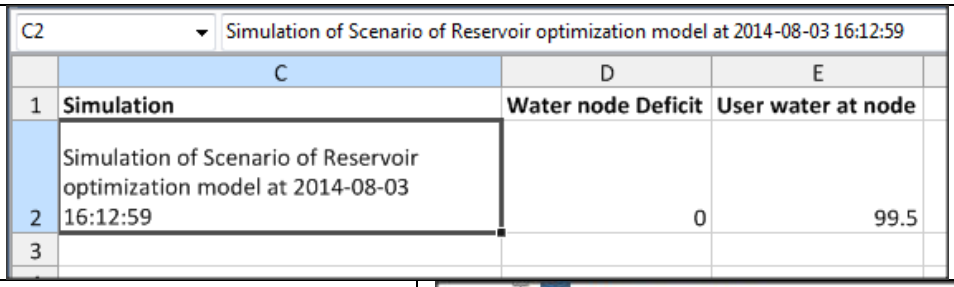
- A Model indicator that measures the demand deficit, by calculating the average over the simulation period. Note that the Value type of the input time series shall be defined as 'Model reference' and it should come from the model setup time series (See Indicator Manager training module for details).



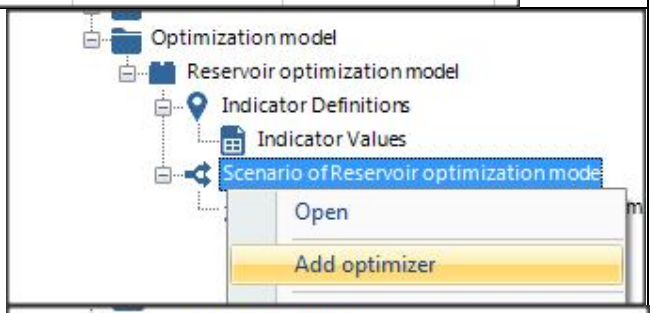
- A model indicator that indicates the amount of used water shall be added. It uses the 'ConstantMinusAverage' *script* in the Script Explorer. Note that the Value type of the input time series shall be defined as 'Model reference' and it should come from the model setup time series. Set the constant to 100.



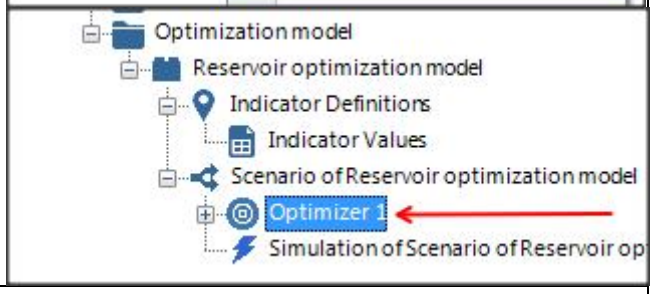
8- Run the scenario and check the indicator values with the values shown below.



9- To enable optimization functionality for a scenario, right click the scenario and select “Add optimizer”

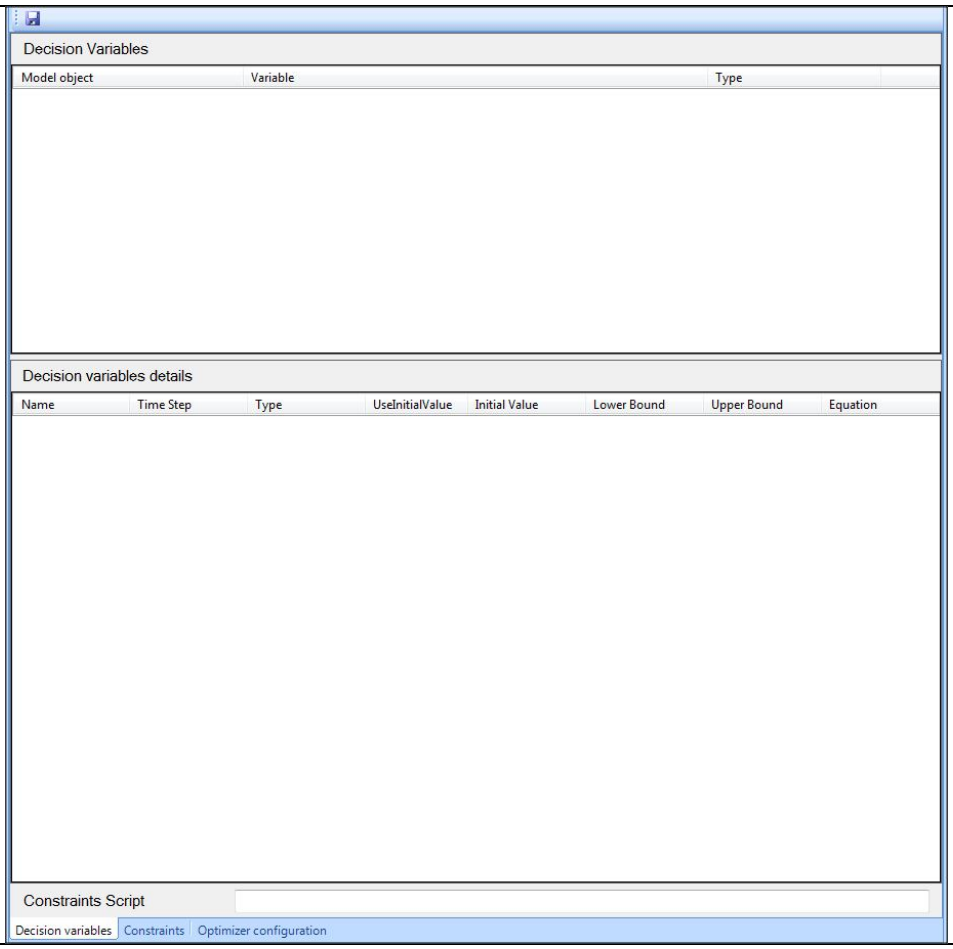


The optimizer gets added as a sub-node to the clicked scenario. Accept the default name for now.



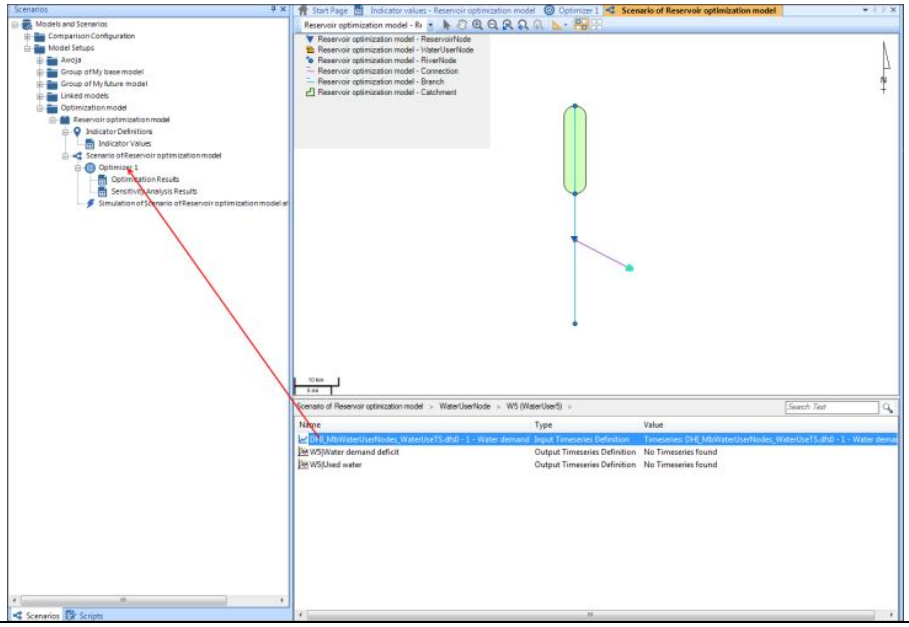
10- Double-click the optimizer node to open the optimizer configuration view.

Select the “Decision variables” tab (default when optimizer configuration is opened). Initially, the list of decision variables list is empty, and the first step will be to associate decision variables with the optimizer.

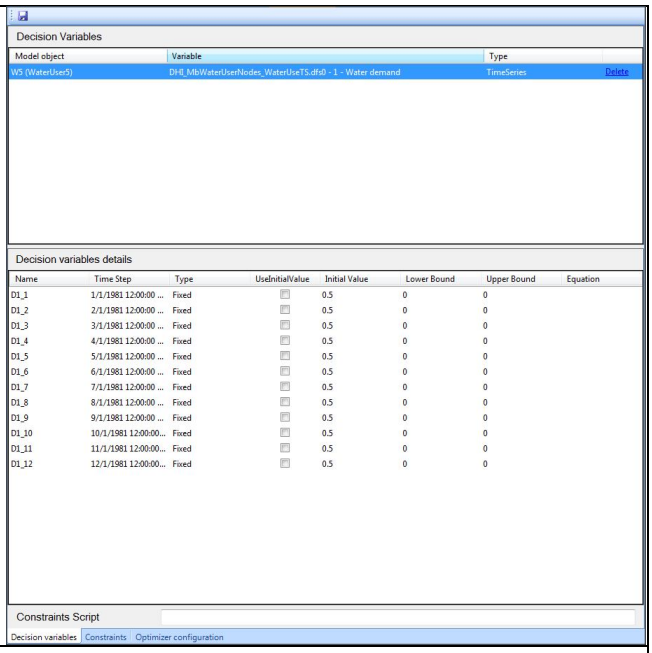


11- To associate decision variables with the optimizer, open the Scenario view by double-clicking on the ' Scenario of Reservoir optimization model' item.

Browse to the water demand and drag it onto the optimizer node.



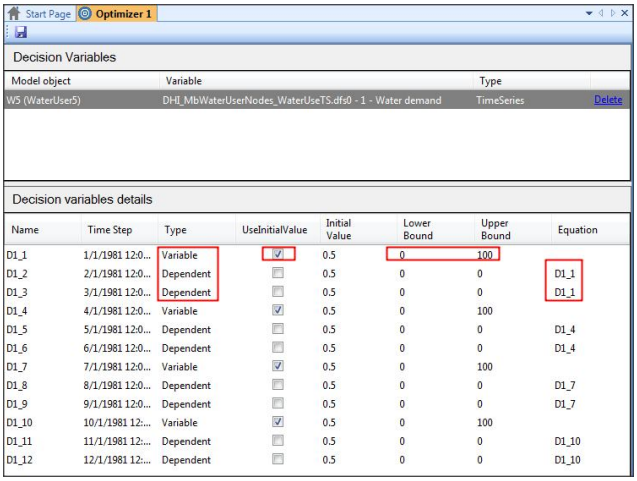
12- Go back to the optimizer configuration. The Water Demand variable is now shown in the Decision variables list. For time series the decision variable lists will be a list of time steps / values in the selected time series. The selected series contains 12 time steps, and the optimizer can access each of them during an optimization. Initially, they will however all be of Type Fixed. Fixed variables will not be adjusted by the optimizer



13- The next steps set up a quarterly variation of the water demand.

The steps are:

- Select the row named D1_1 in the decision variable details table (January).
- Set Type to “Variable” from drop-down menu.
- In the column UseInitialValue set the check-mark.
- In the column Upper Bound enter “100”. We will not allow demands higher than 100.
- Set the two month following January to Dependant to tie them to the variable month.
- Write D1_1 in the Equation field. This indicates that the value of D1_1 shall be used for D1_2 and D1_3.
- Repeat the steps above for D1_4 (April), D1_7 (July), D_10 (October)

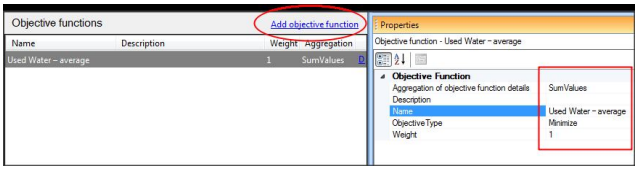


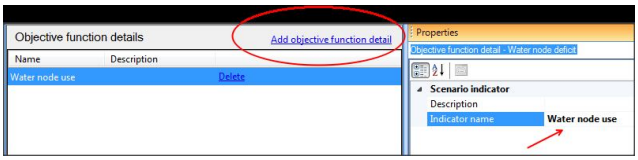
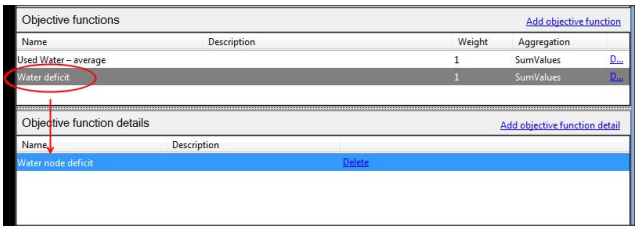
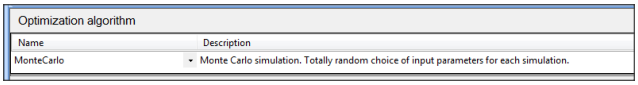
and change the two month following each one to dependant.
The Optimizer will only vary four variables between 0 and 100.

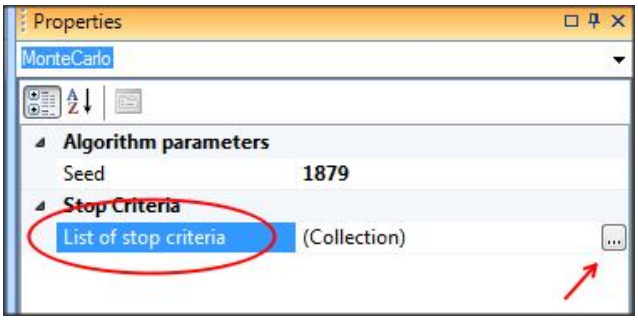
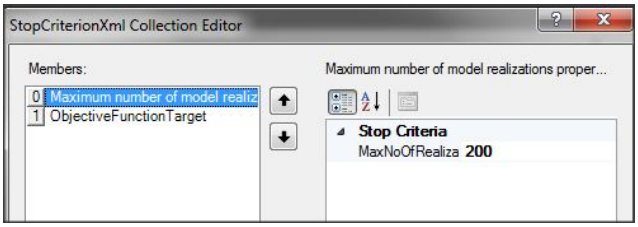
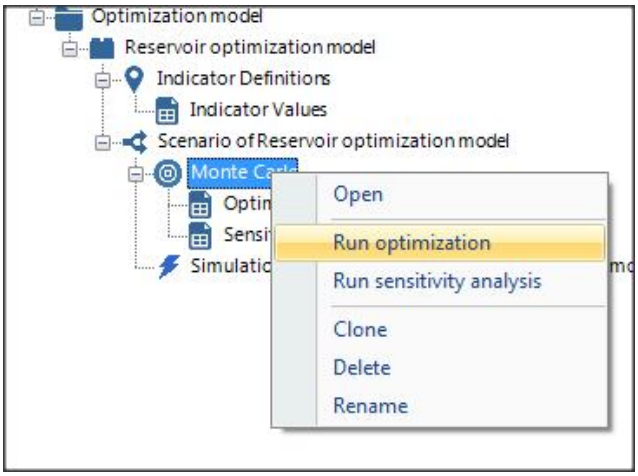
Do not forget to save the optimizer setup frequently by clicking the save button.

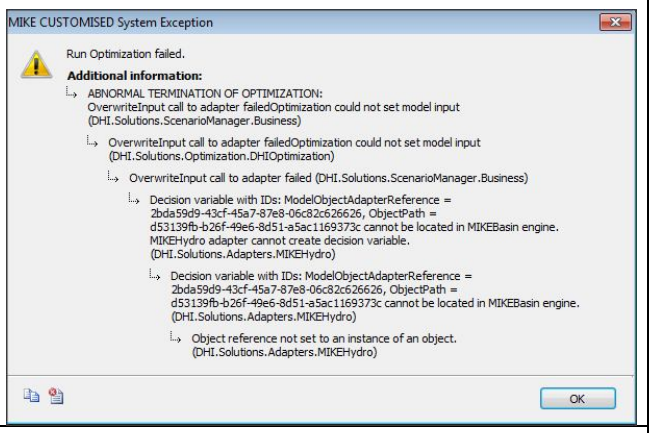
Now that the decision variables have been configured, the optimizer knows which parameters that shall be adjusted during an optimization.
Next step is to tell the optimizer how to evaluate the 'goodness' of a change. This is done by adding objective functions under the Optimizer configuration tab.

14- To add a new objective function, click the *Optimizer configuration* tab.
- Click “Add objective function”, and select the row in the objective functions list. The default properties of the new objective function are shown in the table.
- Select the objective function in the list. Its properties can now be configured in the property grid. Set the *Name* property to 'Used Water – average'
The *Objective type* property is to minimize and the*Weight* property shall remain unchanged at the default value (“1”)
Keep the default for the 'Aggregation' property as well ('SumValues')

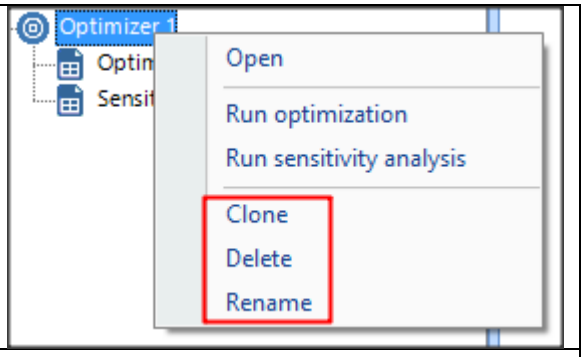


15- Since objective functions are basically expressed as a sum of indicators, next step is to associate one or more indicators to the objective function. Select the Used water – average objective function in the Objective functions table - Click Add objective function detail. A row is added to the Objective functions detail table - Select the new row. It can now be configured in the property grid. Choose the 'Water node use' indicator from the drop-down menu at the *Indicator name* property.	
16- Repeat the steps above to add a second objective function. The name of the objective function shall be 'Water deficit'. Associate the 'Water node deficit' model indicator with the new objective function. Now that the optimizer knows which variables that shall be adjusted, and knows how to evaluate the goodness of a change	
20- In the *Optimization algorithm* table choose “Monte Carlo” from the drop-down menu. The configuration parameters for the Monte Carlo method are shown in the property grid. The only available	

parameter is “Seed” (for the random number generator). Use the default value. Below the Algorithm parameters, the Stop criteria parameters are shown. Expand the list by clicking the  button. This will expand the list of stop criteria. Select a criterion to the left to configure its properties to the right. For now, leave the default values unchanged.	 
22- Finally, save the configuration by clicking the  button in the tools bar. The optimizer can now be executed.	
23- Before running the optimizer, rename it to 'Monte Carlo'. To run the optimizer, right-click on the 'Monte Carlo' item and select Run Optimization.	

24-	

Managing optimization setups

1- Management of optimization setups is done by selecting the setup and right click the mouse. This display the menu shown next.	
2- Optimization setups can be cloned, deleted or renamed. This is done in similar way to that explained for model setups (See the Model setup Management section for details)	

Review Questions

1. What are the available optimization algorithms in the DSS.
2. Only single objective function problems can be optimized in the DSS
   - True
   - False
3. Constraints cannot be defined as part of the DSS optimizer.
   - True
   - False

Answers

1. Optimization algorithms in the DSS are list below
    - *SCE*
    - Simplex
    - DDS
    - NSGA-II
    - Monte Carlo
2. False (both single and multi objective function problems can be optimized in the DSS.
3. False (Constraints can be defined as part of the DSS optimizer)

3. References

- Nile Basin Decision Support System help file (DSS Ver. 2.0)
- Nile Basin Decision Support training material (developed in 2013 and 2014)
- DHI training material for the Nile Basin Decision Support (developed in 2012)
- Wikipedia web site - http://en.wikipedia.org/wiki/Main_Page (last accessed on 8/5/2014)
- NEOS optimization guide - http://www.neos-guide.org/content/optimization-introduction (Last accessed on 1/8/2014).