CHES

Cumulative hydrological effects simulator user manual

NIWA Technical Report

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1 Introduction

1.1 What is CHES?

The number of fish have been decreasing for some of our rivers, and the number of permitted irrigation have been increasing at the same location (http://www.stuff.co.nz/environment/79762798/Sixty-per-cent-dip-in-Selwyn-River-flow-affecting-trout-population). Coincidence? How much can be attributed to abstraction, or overfishing, or pollution? By looking at individual drivers, one might get some answers. Hence one might want to look at surface and ground water abstraction only and the impact on surface water river flow. But is it a single abstraction or multiple abstractions? Questions, questions, questions.

So how about making a start by assessing the effects of each successive and cumulative groundwater and surface water take on river flows!? This could help resource managers to clarify the course of flow losses. A tool that shows how consented water abstractions has changed the rivers, and indicates how any additional abstraction would further affect the river's properties would have enabled better decisions making, which would also need to be transparent.

CHES (Cumulative Hydrological Effects Simulator) is an ArcGIS add-in application developed specifically to determine changes to in- and out-of-stream properties resulting from any or all existing abstractions, and to assess additional change e.g. further abstraction from the river, climate change, diversion,... Ah well, you hold a manual in your hands, which outlines exactly this CHES tool, which might help you to answer some of the questions.

This document is the user manual for CHES, and it is hoped that it contains all the information that you need so that you can run CHES and answer burning questions.

Any comments on CHES and the manual will be appreciated and used to improve both for future users. Feedback, comments and suggestions should be sent to Jan Diettrich at NIWA in Christchurch (CHES@niwa.co.nz).

Happy CHESing!!!

1.2 Introduction to using CHES

CHES is an ArcGIS add-in developed by NIWA (under the Sustainable Water and Allocation Programme (SWAP)) specifically to model changes to instream and out-of-stream attributes, such as, physical fish habitat availability/change and reliability of water supply. It simulates the surface water stream flows in a catchment that result from consented abstractions, operating under given abstraction rules. CHES can simulate the following abstractions:

- "take" (simple abstraction from the river),
- "off-line dam" (water is abstracted from a river via an external dam, which acts as buffer), and
- "dam" (an in-line dam, e.g., Clyde Dam).

CHES is catchment-based, and can generate surface water flows and dependent attributes as catchment averages, reach averages and reach time series. It requires the mean daily, natural flow time series to be supplied for each reach of the catchment that is to be examined. The CHES simulation routes the abstraction through the river network and determines the mean daily modified flow. With this approach, reliability of supply and changes in physical fish habitat can be determined. Further flow dependent attributes can be simulated using CHES, if a flow-attribute relationship is supplied to CHES.

The results from each CHES simulation can be visualised with in ArcGIS on three different levels:

- Reach level: time series of attribute of interest for each reach, e.g., reliability of supply in l/s or % allocated.
- Average reach: a single value for each reach can be derived (e.g., the mean value of an attribute time series), allowing the reaches to be colour-coded with respect to the derived value and mapped in colour.
- Average catchment: for a single attribute the overall average value can be determined, by averaging over the time and reaches.

CHES can be used to answer a variety of questions, which stakeholders, such as regional councils might need to know, such as (but not limited to):

- Investigating the effects of a proposed abstraction within a catchment on fish habitat.
- Investigating how downstream abstractors are affected by changes in abstraction upstream.
- Investigating if allocation rules are broken by currently consented abstractions.
- Comparing the effects of different allocation scenarios on reliability of supply and physical fish habitat availability.
- The effect of climate change on abstraction reliability and physical fish habitat availability.

1.3 Overview of CHES simulation

A brief outline of the steps that required to complete a CHES simulation is provided below, in chronological order. All required data sets are supplied with the full CHES installation or can be downloaded from the CHES webpage(ftp://ftp.niwa.co.nz/incoming/CHES/Install/), so after completing the installation of CHES (see Section 7), you are ready to go. The first step is to choose between the two comparison options:

A. Comparison of two scenarios (reference or natural and active or modified scenario):

1. Select (or create if not already created and then select) the reference scenario.
2. Select (or create if not already created and then select) the active scenario.
3. Move to the region of interest within the ArcGIS map and zoom in/out as required.
4. Check that existing abstraction symbols are on the map where you expect them.
5. Select the catchment of interest by selecting the most downstream reach of the catchment.
6. Run the simulation.
7. Investigate the results by looking at the time series plot and the map plot for the different attributes of interest

B. Comparison of two scenarios (reference and active) with the addition of a proposed abstraction in the active scenario:

1. Select (or create if not already created and then select) the reference scenario.
2. Select (or create if not already created and then select) the active scenario.
3. Move to the region of interest within the ArcGIS map and zoom in/out as required.
4. Check that existing abstraction symbols are on the map where you expect them.
5. Place the proposed abstraction on the desired reach.
6. Fill in the fields in the various windows that are presented to you for the proposed abstraction.
7. Select the catchment of interest by selecting the most downstream reach of the catchment.
8. Run the simulation.
9. Investigate the results by looking at the time series plot and the map plot for the different attributes of interest.

2 Creating and running scenarios

2.1 The main CHES window

The first window to appear when opening the CHES tool is the main CHES window. Use this window to create, select and run scenarios, access plotting functions, and add or remove proposed abstractions. The main CHES window appears as follows:

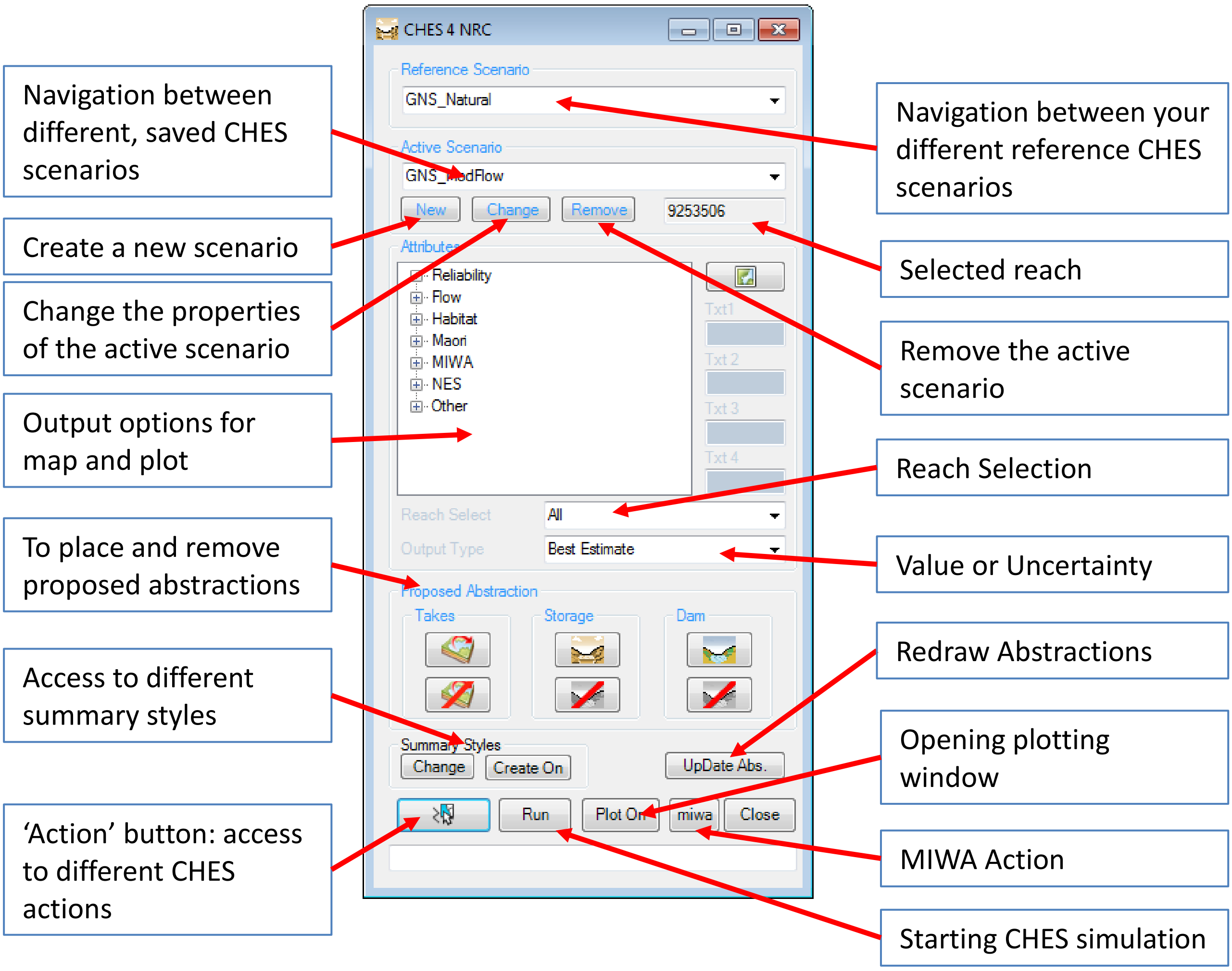


Figure 2-1: Guide to the main CHES window.

2.2 Creating a new scenario

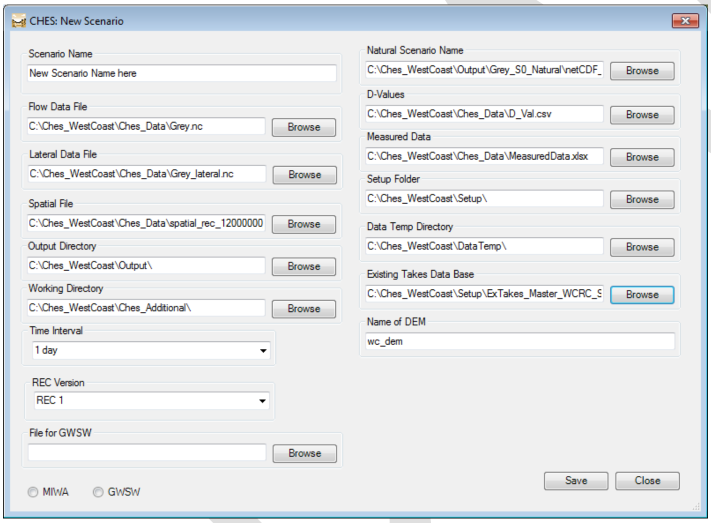
The first step when using CHES is to create at least one scenario. The user will need to create their own scenarios, as no scenarios are deployed with an initial CHES install. An active scenario (the scenario that the user is working on) may be created and run on its own to visualise statistical properties of the flow, e.g. mean flow or minimum flow. In addition any attribute that requires only a single flow time series, such as swim ability can also be simulated within a single scenario. When working with a single active scenario only, any setting under the reference scenario drop down menu in the main CHES menu will be ignored.

Most applications of CHES, however, involve comparisons of at least two scenarios: an **active scenario** and a **reference scenario**. These comparisons will show the likely changes in river attributes under the active (or modified) scenario to those under the reference scenario. For example, physical changes to fish habitat using the Jowett method (Jowett 2008) can only be simulated using the natural flow (reference scenario) and the modified flow (active scenario). Note, any active scenario can become a reference scenario, and vice versa.

A **reference scenario** is set up to compare with your active scenario. A reference scenario may be, for example, the catchment in its natural state (i.e., without any abstractions) or the catchment with all of its current abstractions (to be compared to the catchment with the addition of a proposed abstraction). Information required for any scenario includes the location of the natural flow data files, the location of the current takes data file, simulation start date and end date. As any reference scenario starts off as an active scenario, it is best to look at the process of creating an active scenario. This process is explained below.

To create a new scenario

In the main CHES window, under the Active Scenario drop down menu, click the “New” button, select the existing scenario that most closely resembles your new scenario (this is important as it ensures the correct reference scenario file is selected in the “New Scenario” window). The following window will appear:



Enter the name for the new scenario in the “Scenario Name” field. Note, using the same name as another scenario will cause the old scenario to be overwritten. All settings necessary to run a CHES simulation are stored in scenario files, stored in the "Scenario" folder. The file name of each scenario is also the scenario name itself. It is best remove spaces from the scenario name; use upper case letters at start of each word or use underscore characters between words, e.g., "HurunuiWinterScenario1" or "Hurunui_Winter_Scenario1".

Most fields should stay the same, as it was set up by NIWA. However, changes can be made for the following files that are needed within CHES (file names need to be supplied with full path name):

- Flow Data File: the file that contains the mean daily surface water flows.
- Lateral Data File: the netCDF file that contains additional time series information, such as lateral flow.

- Spatial File: the spatial netCDF file, containing spatial information containing REC spatial information such as a river network.
- Output Directory: the folder in which sub-folders are created, one for each scenario.
- Working Directory: this folder contains some of the ddl’s needed and other files, which will be supplied by NIWA.
- Time Interval: currently, the only time interval that can be selected is 1 day.
- REC Version: the REC version can be selected.
- File for GW2SW: specify the additional data needed that is required for the GW2SW conceptual TopNet module.
- Natural Scenario Name: the netCDF file is given for the CHES scenario, which contains no abstractions.
- D-Values: here a CSV file needs to be supplied for the reach-specific D-values.
- Measured Data: here an XLSX file needs to be supplied, which contains time series of the measured flow data, if applicable (see Section 9).
- Setup Folder: the path name of where the “Setup” folder can be found.
- Data Temp Directory: the path name of the folder that is being used for temporary data, and the content can be deleted by the user from time to time.
- Existing Takes Data Base: the file that contains all current abstractions, with information of their location, total allocation, time filters, etc. (see Section 12 for the generation of such a file).
- Name of DEM: the layer name from ArcGIS of the digital elevation model layer.

Click the “Save” button and then the “Close” button.

The “Scenario” window will appear, in which the more parameters for the new scenario must/may be specified. A sample window is give below:

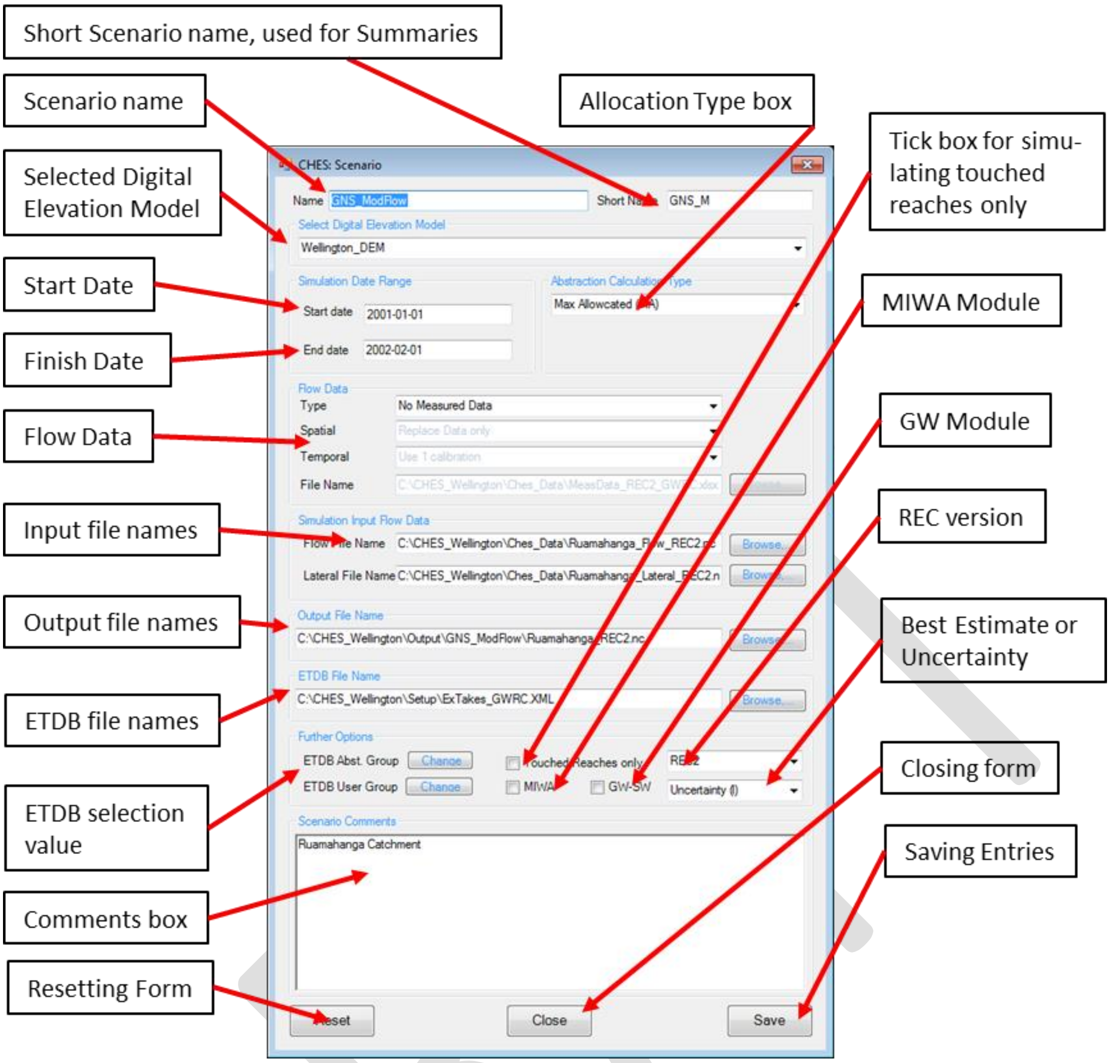


Figure 2-2. CHES scenario window.

The following parameters can be changed within the CHES Scenario window depending on the requirements of the user:

- **Short name**: please give a 3 character short version of the scenario name. It will be used as a label within CHES.
- **Selected Digital Elevation Model**: depending on the different Digital Elevation Models (DEM) that are loaded into your ArcGIS *.mxd file, different DEMs can be selected, with coarser ones speeding up the process of dam rating curve determination and other computational processes.
- **Simulation Date Range:** start date and end date for the scenario. The format of the date needs to be: yyyy-mm-dd. (Tip: to get the earliest start and latest end date from the supplied input data set, press the [Reset] button, which will reset the entire form).
- **Abstraction Calculation Type**: here the user can change between global scenario settings, which is explained in Section 2.2.1.

- **Flows Data**: in an upcoming version of CHES modelled natural time series information can be replaced with measured data and further alterations can be carried out to the time series of the upstream reaches. The information for this is given in these fields.
- **Simulation Input Flow Data file names**: the natural flow data which is being used as the input to CHES, given here as a file name. Data to be loaded into CHES will need to be located in the CHES folder "Ches_Data". The input data is supplied via two netCDF files that can be generated by TopDesk. They can be linked to this CHES project by pressing the "Browse,..." button, which will open a Windows Open File form in which the user can select a different input data set.
- **Output file name**: the name and the file name path where the generated output file will be written to. The output file type is netCDF.
- **ETDB file name**: the file name of the Existing Takes Data Base (ETDB) file name. This is an XML file which contains all existing abstractions in the catchments of interest. The same ETDB file can be used by several different scenarios.
- **ETDB Abst. Group:** abstraction types from the ETDB can be selected (see user manual "Generation of Existing takes file.docx").
- **ETDB User Group:** abstractions from the ETDB can be selected (see user manual "Generation of Existing takes file.docx").
- **Scenario Comments**: space where further information can be added, which will be saved to the scenario file, e.g., information on who supplied the data, who commissioned the investigation, origin of data supplied, etc.
- **Touched Reaches Only:** sub-select the reaches in the catchment can be selected so that only the reaches which have an abstraction on it or upstream of it have the flow calculated.
- **MIWA:** this button needs to be pressed when the user wants to have access to morphological data later on in the CHES simulation for this scenario. The simulation of the MIWA values is time and computer disk space intensive, hence this is optional.
- **GW-SW**: this button needs to be pressed when the user wants to use the conceptual surface water to ground water module from TopNet as part of CHES.
- **REC Selection:** REC version can be selected. Currently "REC1" and "REC2" are the options available.
- **Best Estimate or Uncertainty:** Here the user can specify if they want to simulate a single flow time series ("Best Estimate") only, which will be used for the attribute simulation. The other option is to simulate the some uncertainty associated with the attribute as well. For this the user needs to simulate a second flow time series ("Uncertainty (l)" or "Uncertainty (h)"), which will be used in the subsequent estimation of the attribute uncertainty. However to get an estimate of the uncertainty of the simulated attributes a second flow time series is being simulated within CHES, hence doubling the computational time.
  For a more in depth description of the steps undertaken within CHES for estimating an uncertainty of the attribute, please see Section 2.6.

Finally, for the CHES Scenario window:

- **Reset**: resets the CHES Scenario window fields. Simulation date ranges are extended to the largest range possible by extracting the information from the selected Simulation input flow data file. The Scenario Comments box will be cleared and the global settings will be set to 100% for both the Delta Q value and the QMin value. The Measured Flows drop-down will be set to "No Measured Data".
- **Save**: saves all relevant parameters to the scenario file of the same name as the scenario. All scenario files are stored in the CHES folder "Scenario".
- **Close**: closes the CHES Scenario window with any changes to the scenario settings since the last save not being saved.

2.2.1 Allocation types

Max allocated (MA)

In an initial simulation, we suggest running the Maximum Allocated (MA) allocation type. This allocation type runs with all abstractions set to their maximum consented volumes, even if, in reality, much of this water would be wasted. This allocation type is essentially the worst case abstraction scenario.

Percent of MA

Percent of MA (%MA) allows the user to specify by changes to any of four different properties:

- Delta Q: the amount to be taken.
- Q min: the minimum flow.
- Q Max: the maximum flow limit.
- Weekly: the maximum weekly amount able to be abstracted.

The default % MA values for all four properties are 100%. The user can reduce or increase any of the values, e.g., the amount taken (delta Q) could be doubled by setting the percent value to 200%, or halved by setting the value to 50%.

RAT

Here CHES uses specified metadata supplied by the user, e.g., the area of land to be irrigated, what kind of crop is to be grown, etc. If information for RAT is been supplied by the user for each abstraction, then the MA allocation type will be applied. See Appendix 3 for descriptions of methods and equations used for the modelling of this part.

Water use time series (WUTS)

Here the user can add the actual metered water usage or other supply information. Some councils require that water usage is being recorded, resulting in a water use time series (WUTS). Instead of assuming abstraction based on consented abstraction or through the RAT tool, the actual metered abstraction can be used within CHES through the WUTS option. Such time series information might be unavailable for some abstractors, in which case the MA approach will be used.

WUTS and RAT

These are very similar to each other, however if no water use time series (WUTS) is specified, then CHES defaults to using RAT instead. If neither WUTS nor RAT are available, then MA will be used.

WUTS, RAT and % MA

This is very similar to the above case, however in case that neither WUTS nor RAT options are applied for an abstraction, then the information from the user in respect of % MA will be used instead of MA.

Water take rules

Here the user can choose between pre-defined rules, which will must be specified in the file WaterTakeRules.xml. A brief description of the set-up is given in Appendix 4, where additional water take rules are added to the system (contact Jan Diettrich (NIWA) for full instruction on how to create or modify this file for a user specified rule).

2.2.2 Selecting scenarios

Reference scenarios are selected from the drop-down menu "Reference Scenario" in the main CHES window. Active scenarios for comparisons are selected in the "Active Scenario" drop-down menu. A reference scenario will need to have been created by the user, as no scenario came with the initial CHES install.

2.2.3 Editing existing scenarios

To edit an existing scenario, select the scenario within the "Active Scenario" drop-down menu. Click the "Change" button under this drop-down menu and the CHES "Scenario" form will open. Remember to save any changes before closing.

2.2.4 Removing existing scenarios

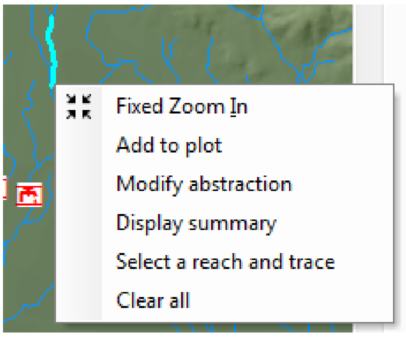
To remove a scenario and all of the associated files, select the scenario to delete with the "Active Scenario" drop-down menu. Click the "Delete" button under this drop-down menu. A warning message will appear, click "Yes" to continue with the delete or "No" to cancel. Note that the Base scenario supplied with CHES is not able to be deleted.

2.3 Selecting and deselecting a catchment

The catchment of interest for a simulation is chosen by selecting the most downstream reach. The steps for this process are:

Click the CHES "Action" button: 

Left click the reach of interest on the map, which will bring up the following options:



Select the option “Select a reach and trace” and all reaches upstream should change colour from blue to cyan:

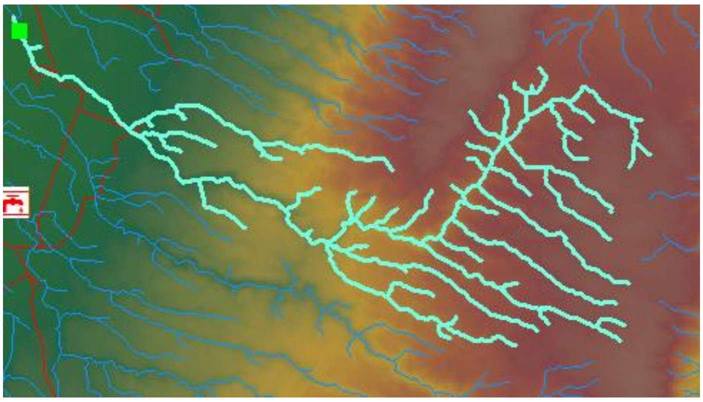


Figure 2-3. Catchment with selected reaches.

To clear the catchment selection, press the CHES “Action” button, move the cursor over the most downstream reach of the selected catchment, left click, and select “Clear all” from the menu.

2.4 Water abstractions

Water abstractions are among the key factors influencing river environments and, thus, are fundamental to CHES. The model includes options for three different types of abstraction: take, dam, and storage. A full list and description of meta-data for each abstraction can be found in section ??, whereas a brief description with some important meta-data is given below:

2.4.1 Take

A take is a simple removal of water directly from the river. In most cases, this water disappears from the river network (e.g., via irrigation, or to be bottled and removed from the catchment). Some of the main properties for a take are listed and described below:

- Allocation: how much water can be taken, in units of l/s, as a mean daily or mean hourly value (depending on which mode CHES is running in).
- Minimum flow: the minimum flow at the management site. The Management site is the site where the flow is measured and compared with the minimum flow value. This does not need to be the same location of abstraction, but could be anywhere. However, in most cases the management site is the same point where the water is being abstracted. If the flow at the management site is greater than the minimum flow plus the set allocation, then the entire allocation can be taken from the river. If the flow at the management site is greater than the minimum flow, BUT less than the minimum flow plus set allocation, then only part of the allocation may be taken to sustain at least the minimum flow.
- Diversion: a take can also be converted into a diversion, if the user specifies a reach number where the water will return to the river or a tributary. This reach cannot be upstream of the reach where the water was taken from the river.
- Minimum flow at take location: if the abstraction has a management site different to the abstraction reach that is downstream of the take reach, the user can also specify a minimum flow at the location of the take. CHES will only allow a take from the river if minimum flows area achieved at both the management site and the take location.

- CHES requires a user-specified time period for both the minimum flow and the allocation or take. This is currently only based on monthly selection, where only entire month periods can be selected or un-selected.

2.4.2 Storage

A storage is removal of water into a pond or reservoir constructed beyond the river's flow, with a connection from the river to the storage. The storage has user-specified dimensions for length, width and height (here the three parameters are used only to calculate the total volume of the storage, not any occurring visual effects). The portion of river flow that can be taken for the storage is set in the same as for a take, but additional rules govern the taking of water from the storage. Water from Storage can either be removed from the system (e.g., irrigation or bottled water exported from the catchment) or can be diverted back into the river catchment at a downstream reach. Below are some additional properties of a storage:

- Physical dimensions of the Storage: height, length and width, in units of metres.
- Operational properties: minimum and maximum water levels of the Storage. The minimum water level can't be smaller than zero or larger than the height of the Storage.
- Allocation: volume (mean hourly or daily l/s) of water that can be taken (depending on CHES selected).
- Minimum flow (at the management site): When flow at the management site is larger than the minimum flow, BUT smaller than the minimum flow plus set allocation, then CHES allocates only flows above the minimum in order to sustain the minimum flow.
- Minimum flow at take location: if the abstraction has a management reach that is not the same reach as where the water is being taken from, the user can also specify a minimum flow at the location of the take. Water is only allowed to be taken from the river if both conditions are satisfied: the Minimum flow at the management site and the Minimum flow at the take location.
- Rules regarding when and how much water shall be taken from the Storage: units are l/s, and rules can be set for individual months.

2.4.3 Dam

A dam is an in-stream wall across the river channel. CHES will generate a dam rating curve (water level or height versus water volume behind dam) using the supplied DEM and the location of the proposed dam. Some additional properties of a dam are:

- Physical dimensions: height of the dam crest. Additional dimensions can be supplied for the spill way (width, angle, depth and CD value (Khatsuria 2004)).
- Operational properties: minimum and maximum water levels of the dam. The water level cannot be lower than 0 or higher than the height of the dam crest.
- Allocation: the mean daily or mean hourly volume (depending on the CHES mode selected) of water take that the dam can hold.
- Minimum flow at the management site: CHES prioritises minimum flows, so that flows in excess of minimum flows only are available for allocation.

- Minimum flow at take location: if the abstraction has a management reach that is not the same reach as where the water is being taken from, the user can also specify a minimum flow at the location of the take. If this option is selected and a minimum flow is specified, CHES will only allow the take to happen if both conditions are satisfied. If flow at the dam intake is below the local minimum flow setting, then water from the dam will be used to top-up the flow below the dam. Water can be used to top up river flow only as long as the dam stays within its operational limits (minimum and maximum water level I dam).

- Rules for timing and volumes of water taken from the dam. Units are l/s, and rules can be set for individual months. The water can either be removed entirely from the river network, or can be fed back into the river network at the same location (just downstream of the dam) or at a different reach downstream of the dam's reach.

2.5 Reach selection

This option allows reaches to be pre-selected on the map, using the "Reach Select" drop-down menu under the "Attributes" section of the main CHES window. The user will need to first create a CSV file that contains lines of reach numbers and a value between 0 and 1, and save this file in the sub-folder "Reach Select". The files from that folder will automatically appear in the Reach Select drop-down menu (listed using the file name).

A sample file:

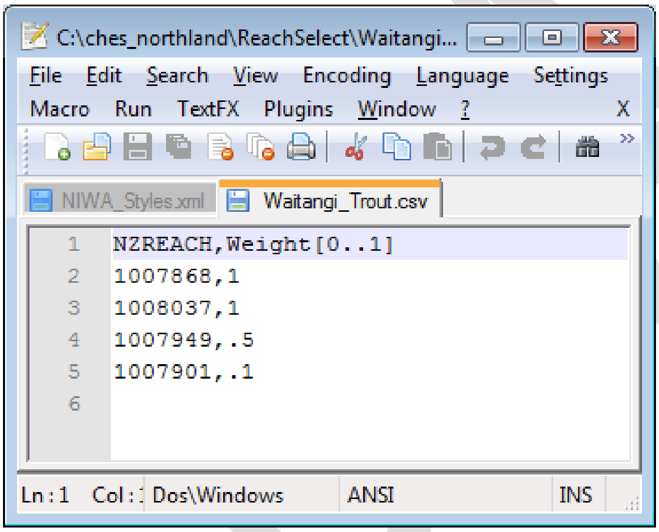


Figure 2-4: Sample file of reach selection and weighting

The name of the example file above is "Waitangi_Trout.csv", thus one of the drop-down options in the Reach Select dropdown will be "Waitangi_Trout" (the extension is omitted). The file must contain a header line, which is not read in. Every consecutive line has two numbers, a reach number and a number between 0 and 1, separated by a comma. Only reaches from with a value larger than 0 will be selected (coloured) or used for the overall summary

2.6 Value or Uncertainty

Here the user can select if they want to visualize the best estimate of the attribute or the uncertainty of the attribute selected. For this to work, the user needs to have selected "Uncertainty (l)" or "Uncertainty (h)" under the Scenario settings. Independed of which uncertainty was selected under the scenario selection, if the user selects either of the uncertainties in the CHES main menu, the plotted values, the values in the histogram, and the stats values will be the uncertainty of the requested attribute.

The uncertainty is determined by the following means:

- simulating the flow based on the best estimate (Q_{BE})
- simulate the attribute using the best estimate flow ($A(Q_{BE})$)
- simulate the flow using a worst case scenario, e.g. the lowest flow, or the flow relating to the 95% of certainty (Q_{UC})
- simulating the attribute using the worst case scenario ($A(Q_{UC})$)
- Forming the difference between those two attribute simulations. ($abs(A(Q_{BE}) - A(Q_{UC}))$)

As one can see, any uncertainty in the attribute is only attributed to the uncertainty in the flow, and any uncertainty due to attribute values is being ignore. This is currently simulated in such a way, as the contributing uncertainty from the attribute simulations are not knows, or the interplay of flow uncertainty and attribute uncertainty is un-know. However it is assumed that the flow uncertainty is the larger of the two, hence it is most important to simulate the uncertainty based on the flow.

2.7 Running the simulation

To run the current simulation, press the “Run” button on the main CHES window. The CHES application saves the current scenario and executes the underlying CHES simulation to estimate the flow for the selected scenario. The progress of this process can be seen at the bottom of the ArcGIS application window, with percentage indicating the completeness of the simulation. The progress bar is cleared at the finish of each successful simulation.

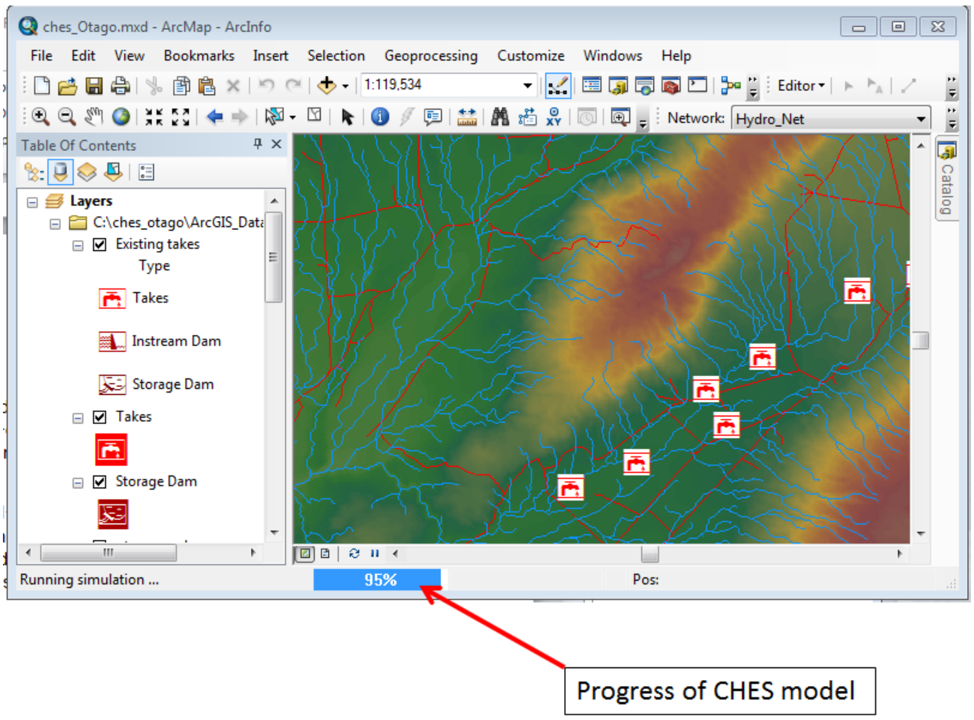


Figure 2-5. ArcGIS window with progress bar showing completeness of the CHES simulation.

3 Incorporating proposed water takes/dams/storage

A key feature of CHES is the scoping of new abstractions within a catchment. Hence the user has the option of placing a take, dam, or storage anywhere in the catchment of interest and supplying CHES with the required meta-data for the abstraction. Subsequently, the scenarios can be rerun with the proposed abstraction in place, to investigate the impacts of the proposed abstraction.

This section describes how to place and remove abstractions, and what information is needed for each type of abstraction.

3.1 Placing a new proposed abstraction (or take)

Under the “Proposed Abstraction” GUI section in the GUI of the main CHES window, there are buttons to place and remove proposed abstractions.

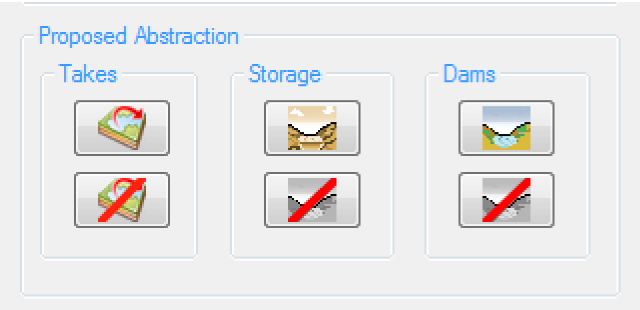


Figure 3-1. The buttons that control placing and removing different types of abstractions.

This GUI section is divided into the three different blocks, one for each of the three different abstraction types ("Take", "Storage" and "Dam"). Each block contains a create and a remove button.

Note that the “Takes” and “OffDam” layers must be ticked under the ArcGIS Layers list for the placed symbols to be visible on the map.

The following section describes how to place abstractions, and the meta-data required for each of them.

A new proposed abstraction can be placed anywhere on the ArcGIS map (provided any previously placed proposed abstraction has been removed, see Section 3.2). When a proposed abstraction is placed, further CHES windows will open for the user to define options. These options are described below.

3.1.1 Adding a proposed water take

Select the add take functionality from the CHES main form by clicking this button:  .

This will activate the ability to place a take into the ArcGIS map. Move the cursor over the reach to which the Take is to be added, and press the left mouse button. A new window will appear, which looks as follows:

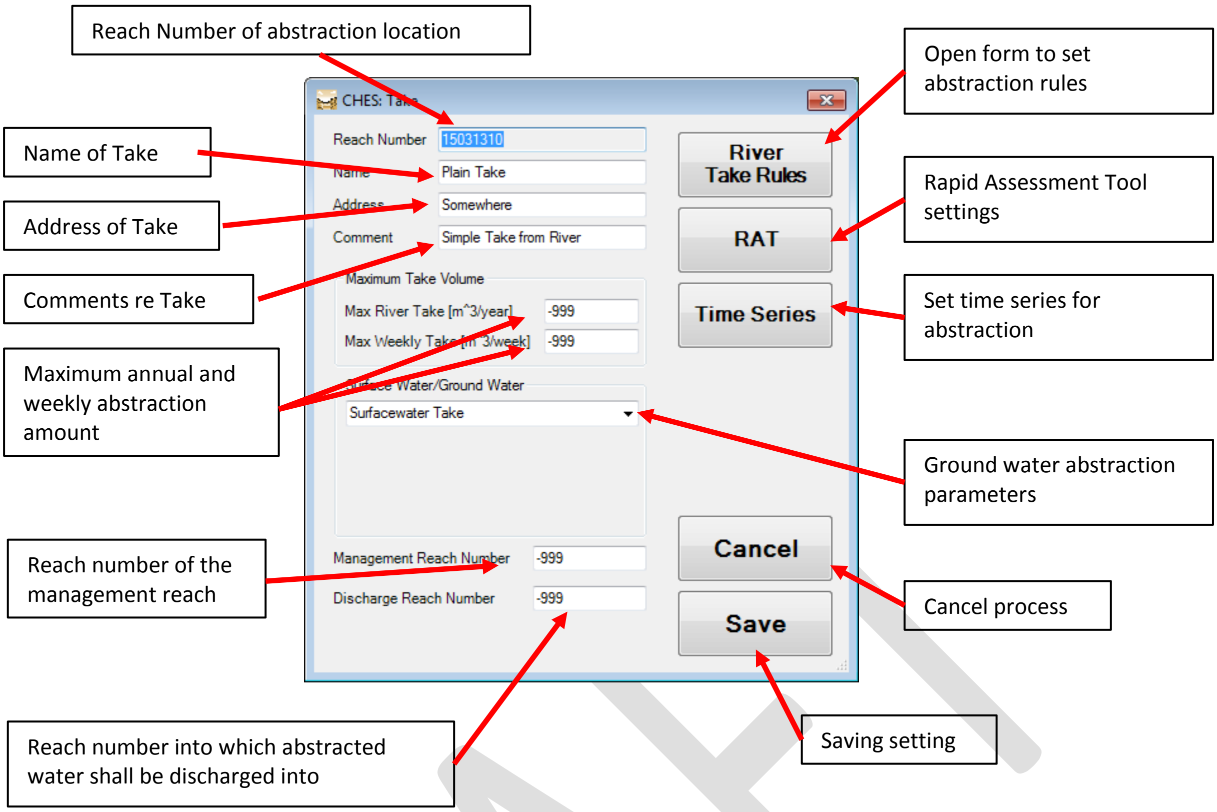


Figure 3-1. Take window.

The reach number field is populated automatically. The user can modify all white edit fields in the form with the following information:

- **Name**: a name associated with the proposed Take.
- **Address**: the address that is associated with the proposed Take.
- **Comment**: any comments or additional information regarding the proposed Take.
- **Max River Take**: the maximum annual take volume. The number needs to larger than zero if a maximum value is being supplied. A value of "-999" can be used to indicate an unlimited take. The weekly maximum allowed take can also be specified. This information will be written to the takes setup file.
- **Management Reach Number**: the REC reach number for a management can be specified. This is the reach that will be used to determine if the flow is above the minimum flow or not. In most cases, the management reach is equal to the reach where the water is taken from. Where the management reach is downstream of the take's reach, the management reach number must be entered prior to placing the proposed take.
- **Discharge Reach Number**: the REC reach number to which the take is diverted, hence converting the take into a diversion. This means that the water taken during a specific time step will be added back to the river network at the supplied discharge reach number at the same time step. IMPORTANT: It is not possible to discharge the water upstream of the take.

River takes rules

This window is where the rules for the abstraction are set. The “River Takes Rules” button opens the "River Take" window:

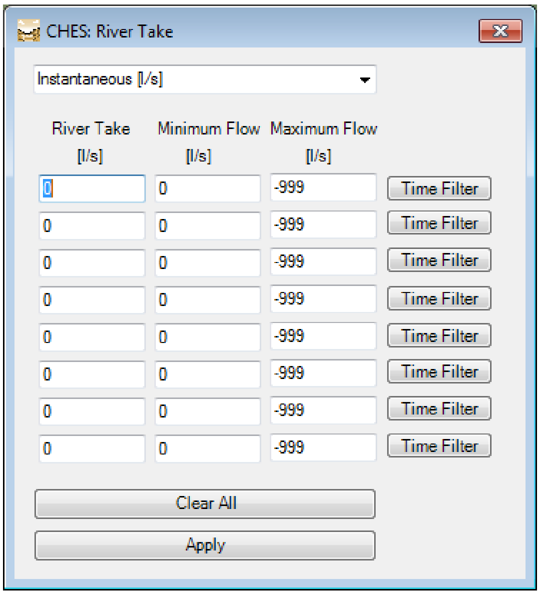


Figure 3-2. River take window

Data units can be changed between:

- Instantaneous, in l/s
- Mean Daily, in m^3/day
- Mean Monthly, in m^3/month

The form will update with the units selected.

The amount of water that will be abstracted is set in the first column, under River Take l/s. The minimum river flow is set in the second column, under Minimum Flow, in l/s. In addition, the abstraction can be set to cease when river flow exceed a specified maximum (e.g., flood waters containing a high sediment loading would require the take to cease). Using “-999” means no upper limit is set.

For each combination of River Take and Minimum Flow, the months for the take must be specified. This is done by clicking the corresponding “Time Filter” button, which opens the following window:

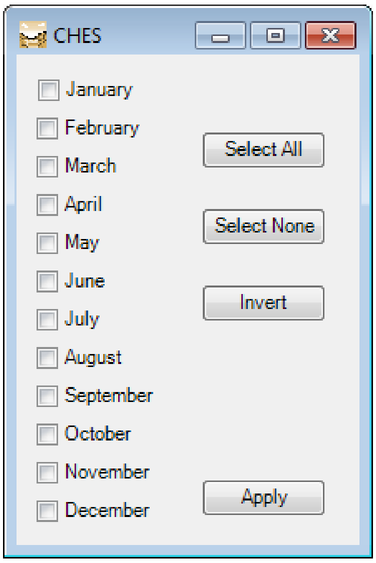


Figure 3-3. Time filter window.

Use the tick boxes to select the month(s) the take is valid for, or use the “Select All” button to tick all months, and press the “Apply” button.

This process can be repeated for further river takes by supplying further pairs of River Take and Minimum Flow values in the River Take form, and specifying the corresponding time period using the Time Filter button.

After adding all the takes required, press the “Apply” button.

Save takes

Click the “Save” button in the Takes window to complete the process. A message box will open, indicating that the take has been saved.

3.1.2 Adding a proposed storage

Select the add Storage functionality from the CHES main form by clicking this button: 

This will activate the ability to place a Storage into the ArcGIS map. Move the cursor over the reach within which the Storage will be added, and press the left mouse button. A new window will appear:

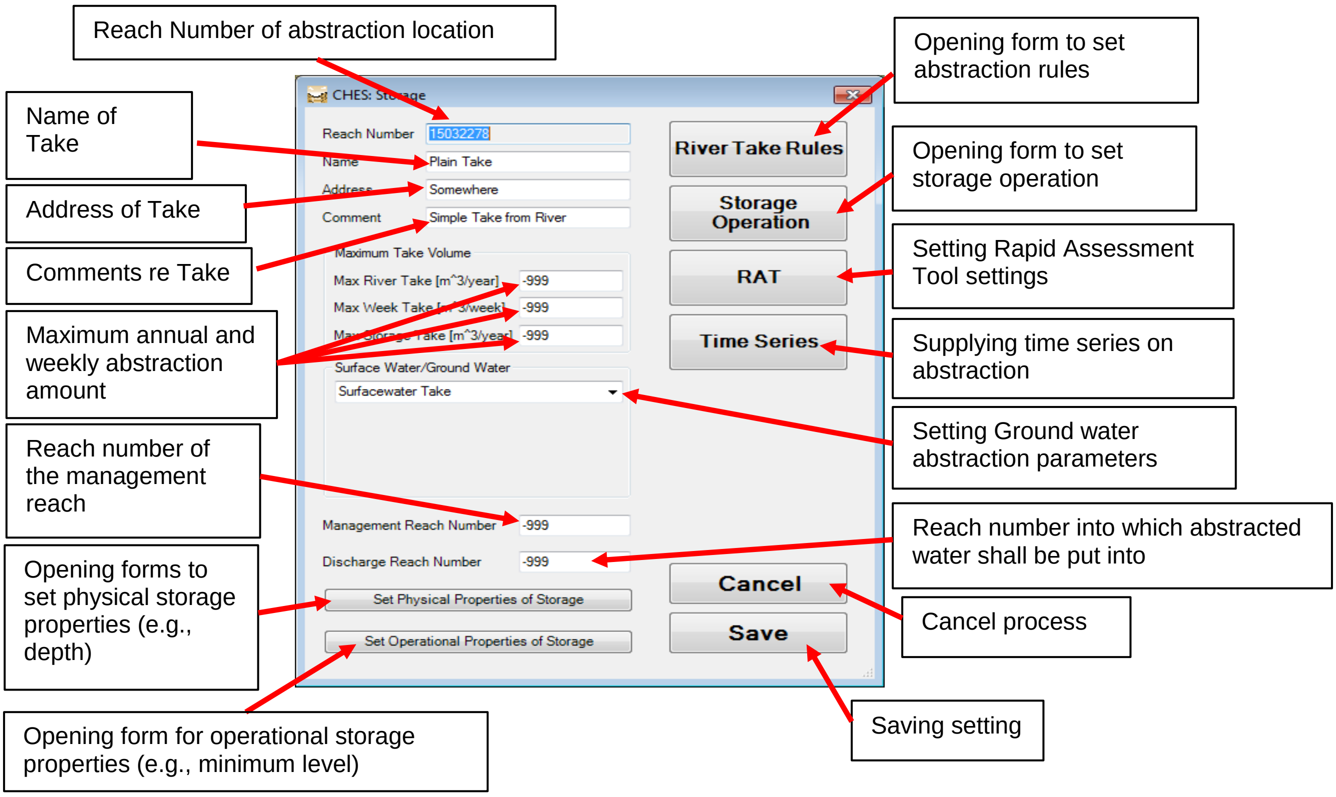


Figure 3-4. Storage window.

The Storage window is the same as the Take window, with a few additional options. The user will need to change the following parameters where required:

- **Name**: a name to identify the proposed Storage. This is meta-data that will not be used throughout the simulation process.
- **Address**: the address associated with the proposed. This can be the address as given in the resource consent. This is meta-data that will not be used throughout the simulation process.
- **Comment**: any comments or additional information on the proposed Storage. This is meta-data that will not be used throughout the simulation process.
- **Max River Take**: the maximum annual take from the river into the Storage, in m^3/year. The value needs to be larger than zero, or can be left at "-999" if there is no set limit.
- **Max Week Take**: the maximum weekly cumulative abstraction, in m^3/week. The value needs to be larger than zero, or "-999" if there is no set limit.
- **Maximum Storage Take**: the maximum annual take from the storage, in m^3/year. The value needs to be larger than zero, or no set limit if left at "-999".

The buttons will open additional forms. The forms accessed by the buttons “River Take Rules”, “RAT” and “Time Series” are the same as for a Take (see Section 3.1.1). The functions of the additional buttons are described below.

Set physical properties of storage

The “Set Physical Properties of Storage” button will open a window for setting the dimensions of the pond or lake above a dam. These values determine how much water can be stored in the pond, which may affect the reliability of water supply. The Set Physical Properties of Storage window appears as follows:

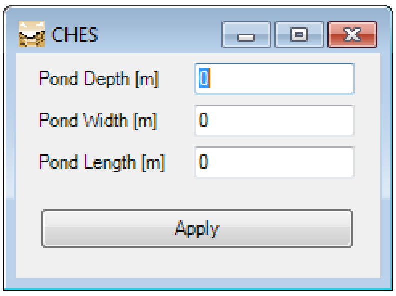


Figure 3-5. Physical Properties of Storage window.

After setting the physical dimensions of the Storage, click the “Apply” button to save the values and close the window.

Set operational properties of storage

The “Set Operational Properties of Storage” button opens another window that allows the user to set how much water can be stored, what the minimum water level is and the water level at the start of the simulation in the pond. The Set Operational Properties of Storage window is:

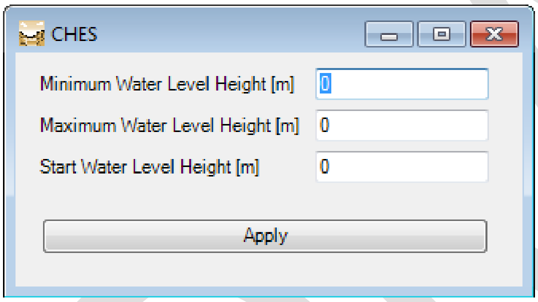


Figure 3-6. Operational properties of storage window.

After setting the operational properties of the Storage, press the “Apply” button to save the values and close the window.

Storage operation

The “Storage Operation” button on the Storage form opens the following window:

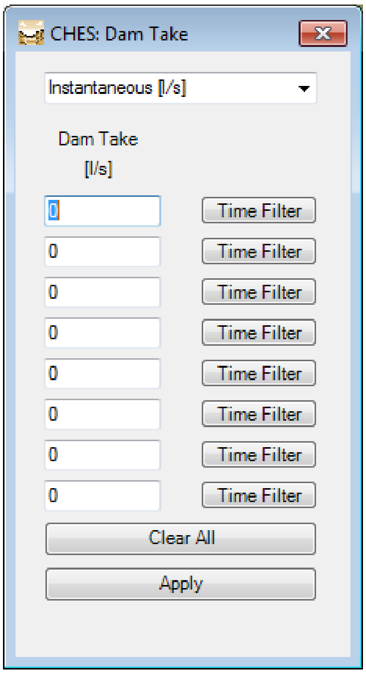


Figure 3-7. Storage operation window.

To set up when and how much water will be taken from the Storage unit, enter a value in the Dam Take field, and tick the applicable month(s) in the window opened with the "Time Filter" button. Note that these rules will apply only when the minimum water level set in the Operation Rules is not broken. The units can be set from the top drop-down menu.

Save storage

Click the "Save" button in the Storage window to complete the process. A message box will open indicating that the take has been saved.

3.1.3 Adding a proposed Dam

Prior to placing a proposed Dam, ensure that all other proposed abstractions are removed from the catchment of interest (see Section 3.2).

Select the add Dam functionality from the CHES main form by clicking this button: 

This will activate the ability to place a Dam into the ArcGIS map. Move the cursor over the reach to which the Dam is to be added, and press the left mouse button. A new window will appear, which looks as follows:

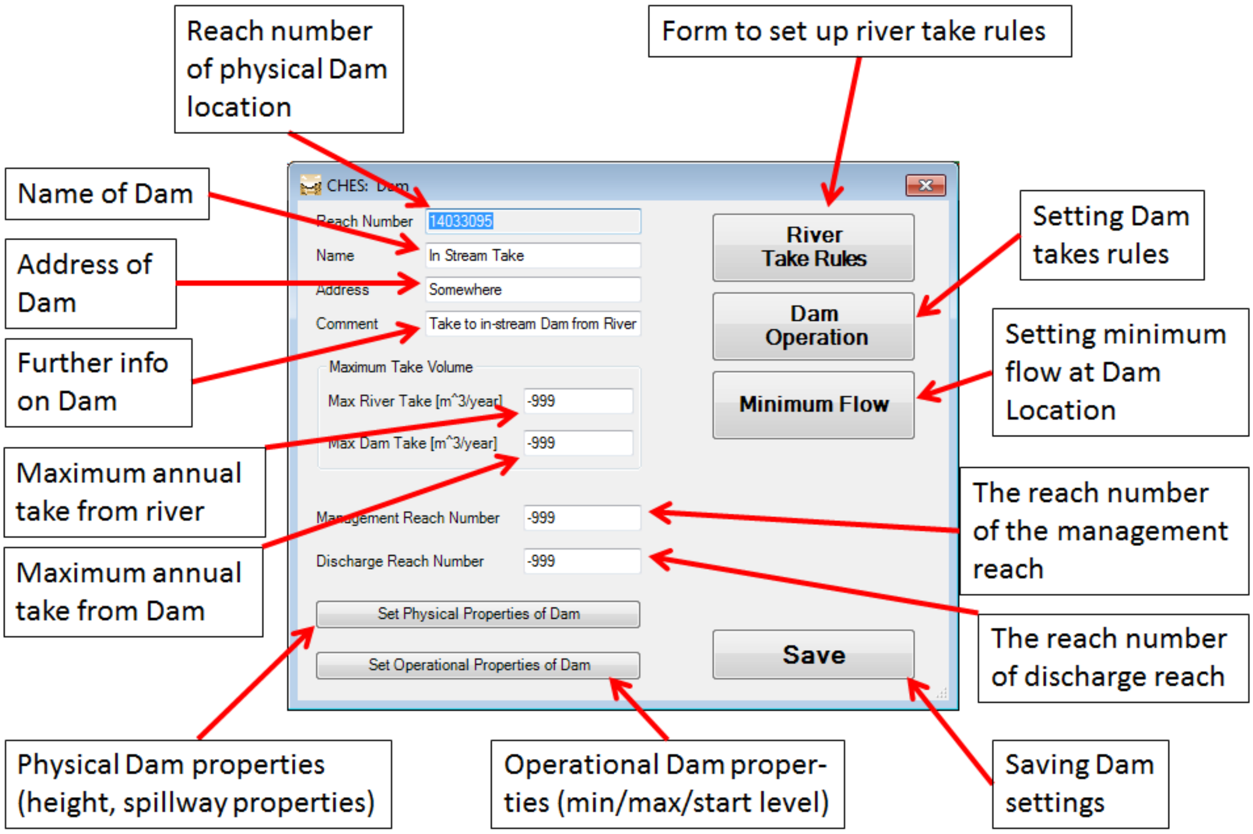


Figure 3-8. Dam window.

The Dam window is the same as the Take window, with a few additional options. The user may change the following parameters where required:

- **Name**: a name associated with the proposed Dam.
- **Address**: an address associated with the proposed Dam.
- **Comment**: any comments or additional information about the proposed Dam.
- **Max River Take**: the maximum annual take from the river into the Dam, in m^3/year. The value must be larger than zero, or left at "-999" if there is no set limit.
- **Max Week Take**: the maximum weekly take from the river into the dam, in units of m^3/week. The value must be larger than zero, or left at "-999" if there is no set limit.
- **Maximum Storage Take**: the maximum annual take from the Dam, in units of m^3/year. The value must be larger than zero, or left at "-999" if there is no limit set.

Each button opens an additional form. The forms accessed by the buttons "River Take Rules", "RAT" and "Time Series" are the same as for a Take (see Section 3.1.1). The functions of the additional buttons are described below.

Set physical properties of storage

The physical properties of the in-line dam (spill-way properties and crest height) are accessed with the "Set Physical Properties of Storage" button. These properties will be used to determine how much water can be stored in the Dam, using the digital elevation model. The Set Physical Properties of Storage window appears as follows:

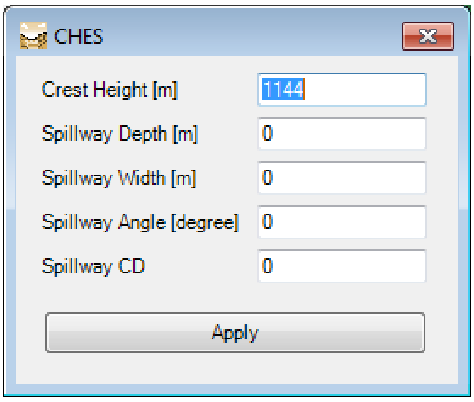


Figure 3-9. Dam physical properties window.

The user needs to specify physical properties of the Dam:

- **Crest Height**: the physical height of the Dam in metres. This value must be larger than zero, and cannot exceed the supplied value.
- **Spillway Depth**: the distance between the Dam crest and the lowest point of the spill way, in metres.
- **Spillway Width**: the maximum width (metres) of the spillway at the top of the spill way (at crest height).
- **Spillway Angle**: the angle between the spillway crest and the side walls (i.e., extent to which the spillway widens). Sidewalls are vertical when the angle is 90 degrees, and sidewall angles cannot exceed 180 degrees.
- **Spillway CD**: the discharge coefficient needs to be determined experimentally.

The following equations have been used following Cengel et al. (2006):

- Rectangular weir (180 degree)
  SpillFlow = 0.666 * SpillwayCD * SpillwayWidth * SQRT(2 * 9.81) * (DeltaHeight * 0.001) ^ 1.5
- Triangular /V-notch Weir
  SpillFlow = 0.533 * SpillwayCD * (2 * 9.81) ^2 * Tan(Angle * 0.5) * (DeltaHeight * 0.001) ^ 2.5
  where DeltaHeight = ThisDamWaterHeight - (CrestHeight - SpillWayDepth)

Set operational properties of dam

The minimum and maximum water level in the dam, and the starting water level for the simulation can be set in the window accessed with the “Set Operational Properties of Dam” button. The window appears as follows:

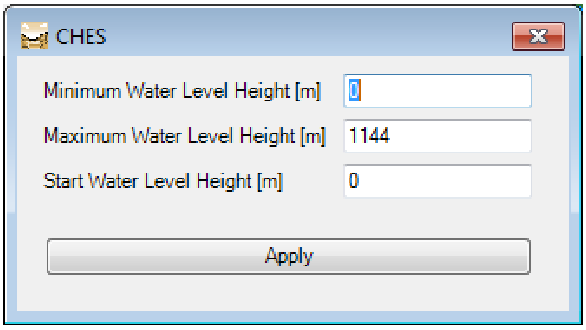


Figure 3-10. Dam operational properties window.

The minimum and maximum dam operation water levels need to be specified (in units of m), with smallest minimum water level not to be smaller than 0 m, and largest maximum water level not to be larger than supplied values (in this case 1144 m). The Start Water Level Height value needs to be larger than or equal to zero (empty) and cannot be larger than the default maximum water level height.

Dam operation

The “Dam Operation” button opens the Dam Operation rules:

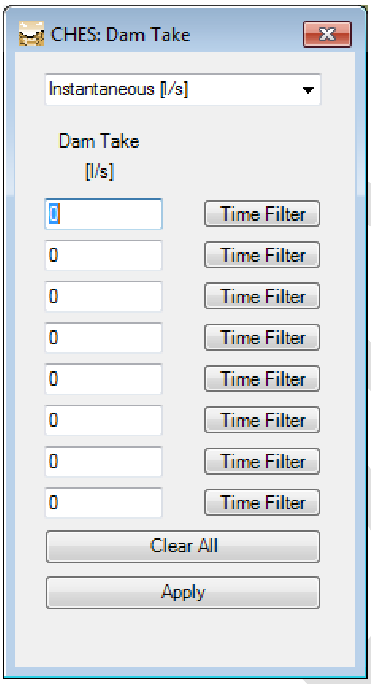


Figure 3-11. Dam operation window.

To set up when and how much water will be taken from the Dam unit, enter a value in the Dam Take field, and tick the applicable month(s) in the window opened with the “Time Filter” button. Note that these rules will apply only as long as the minimum water level set in the Operation Rules is not broken. The units can be set from the top drop-down menu.

Minimum flow

For an inline Dam, the user can specify how much water is to flow into the river downstream of the dam (i.e., water from the Dam). The rules can also be set so that water has to be released from the Dam even if no water is flowing into the Dam, so long as there is water in the Dam from previous time periods. The minimum flows are a constant flow that can be set on a monthly level. The "Minimum flow" button will open the following window:

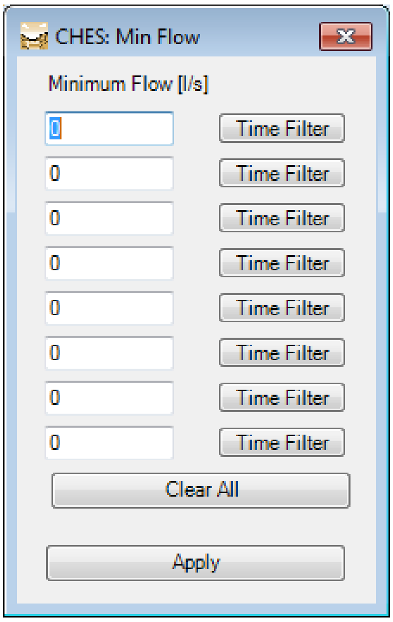


Figure 3-12. Dam minimum flow window.

To set the minimum flow, place a value larger than zero into the first edit field, and specify the month by opening the "Time Select" window with the "Time Filter" button. Any further minimum flow values can be set by entering values in the subsequent fields and specifying the month accordingly.

Save dam

Click the "Save" button in the Dam window to complete the process. A message box will open indicating that the take has been saved.

3.2 Removing proposed abstractions

Removing a proposed take

A proposed take is indicated on the map by the symbol: 

To remove the proposed take press the "Delete Take" button: 

Hover the cursor over the proposed take symbol on the ArcGIS map, and left click. The symbol of the proposed take will disappear from the ArcGIS map. Only proposed abstractions (abstractions added through the process described above) can be deleted.

Removing a proposed storage

A proposed Storage location is identified by: .

To remove the proposed storage press the “Delete Storage” button: 

Hover the cursor over the proposed storage symbol on the ArcGIS map, and left click. The symbol of the proposed storage will disappear from the ArcGIS map.

Removing of a proposed dam

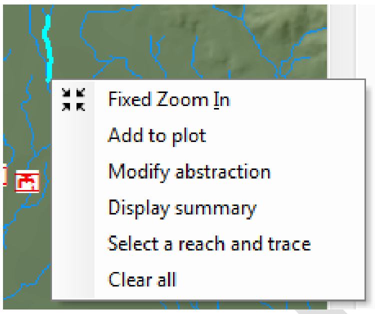
A proposed dam location is identified by a blue shape approximating the lake area over the submerged land.

To remove the proposed dam press the “Delete Dam” button: 

Hover the cursor over the proposed dam symbol on the ArcGIS map, and left click. The symbol of the proposed dam will disappear from the ArcGIS map.

3.3 Editing a proposed abstraction

The settings for any abstraction can be changed by hovering the cursor over the location (reach) of the abstraction that is to be changed and clicking the left mouse button. The following menu will appear:



Select “Modify abstraction”. If there is more than one abstraction in the catchment, the following form will appear:

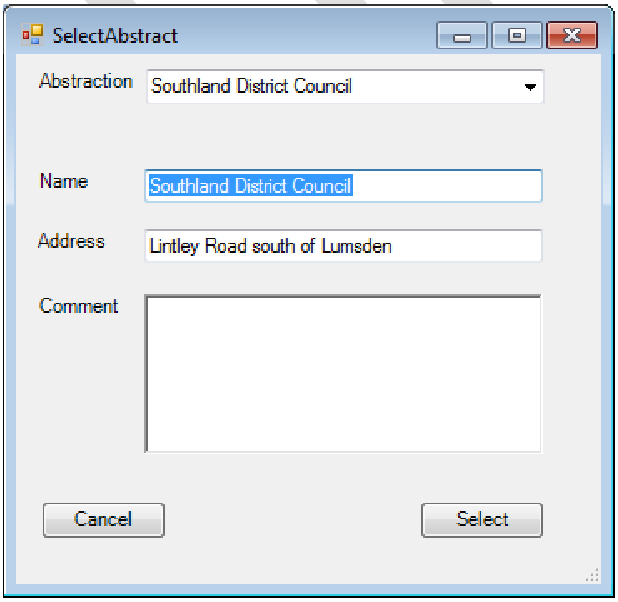


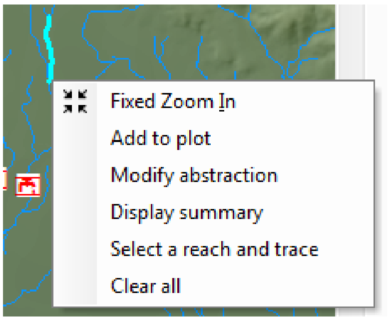
Figure 3-13. Window from which to select an abstraction if several abstractions are located on the same reach.

The abstraction that is to be changed needs to be selected from the drop-down menu. The other fields will update accordingly. Once the abstraction is selected, press the “Select” button, and the Takes/Dam/Storage form will appear.

On the Takes/Dam/Storage form make the changes and then press the “Save” button and the altered information will be updated.

4 Plotting time series

The plotting form is part of the main CHES window. The plotting window is opened by hovering the cursor over the reach of interest, left clicking and selecting “Add to plot” from the drop-down menu:



The main CHES window with additional plotting fields:

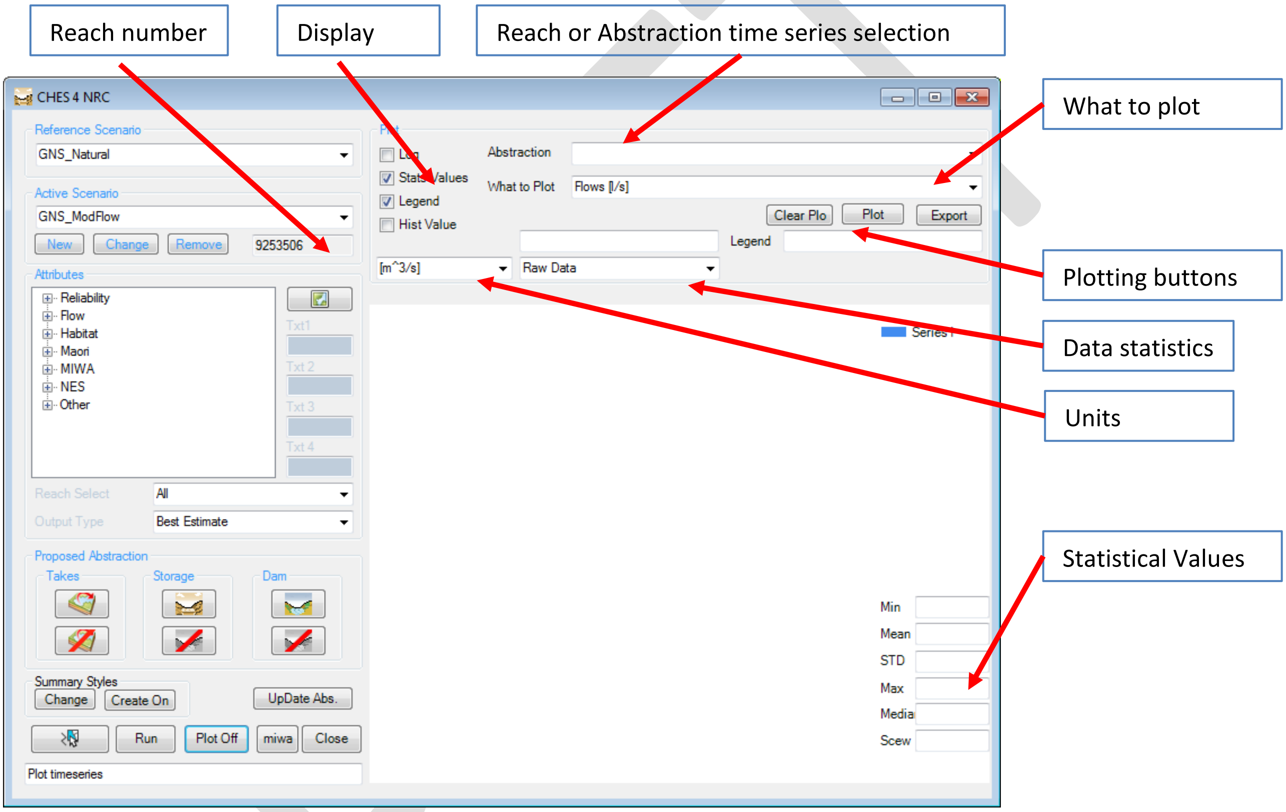


Figure 4-1. Main CHES window with plotting extension.

To remove the plotting fields in this window click the “Plot Off” button.

4.1 Selecting the location

CHES automatically fills the reach number field in the main CHES window for the selected reach. The “Abstraction” drop-down menu in the plotting window will be populated with the names of all the different abstractions that can be used for time series plots. If the reach of interest does not contain any abstraction, then “Reach Only” will be the only option in this field. When the abstraction of interest is selected from the Abstraction drop-down menu, the selected reach will be highlighted on the ArcGIS map.

4.2 Selecting the plot type

The following options can be selected from the "What to plot" drop-down menu:

- **Flows [l/s]**: the flow from the selected scenario for the selected reach, with all selected existing abstractions and the proposed abstraction (if present). Existing abstractions were read in from a database, and the proposed abstraction was entered by the user.
- **WUA [m^2/m]**: displays the WUA time series derived from the active scenario for the selected reach.
- **Flows [l/s] (ref)**: displays the flow from the reference scenario for the selected reach.
- **WUA [m^2/m] (ref)**: displays the WUA time series derived from the reference scenario for the selected reach.
- **Flow Change [l/s]**: displays the change in flow (in units of litres per second) for the selected reach. The flow change is calculated on a daily basis by subtracting the flow time series from the reference scenario from the selected scenario flow time series.
- **Flow Change [%]**: same as Flow Change [l/s] however is given in percent of the reference flow of that day.
- **delta H [%]:** the physical habitat change between the reference scenario and the active scenario using the generalised physical habitat models will be displayed. For this to work, a species from the "Attributes" tree needs to be selected under the "Habitat" branch. A list of habitat can be found in Section 5.1.
- **Supply [l/s]:** if an abstraction was selected from the reach list, this time series contains when and how much water was taken from the river for an abstraction. This property can only be supplied for an abstraction, and not for a reach without an abstraction.
- **Reliability [%]:** displays a time series for the selected abstraction of the reliability of water. This is ratio of abstracted over demanded/consented. This can be a better attribute to look at as demand/consented can vary from day to day.

4.3 Additional features

Additional features for plotting the data are:

- **Log**: the time plots will be in logarithmic scale.
- **Stats Values**: turns on/off the calculation and presentation of the statistical values in the "Statistical Values" section.
- **Legend**: turns on/off the plot legend.
- **Hist Value**: turns on/off the histogram value plotting.

4.4 Unit selection

The units of the time series to be plotted can also be set by selecting the following options from the drop-down menu below the "Hist Value" radio button:

- [m^3/s]: cubic metres per second.

- [l/s]: litres per second.
- [0..1]: all time series are scaled between zero and one, so that time series of different nature and units can be compared, e.g., river flow and reliability.

4.5 Data statistics

The drop-down menu to the right of the Unit Selection drop-down menu allows different averaging of raw data to be selected, which gives different annual/monthly summaries. The result will be a new and shorter time series, depending on the statistics applied to the raw data. The options are:

- **Raw Data**: the raw daily time stepped data.
- **Mean of Year (365 values)**: an average year calculated and displayed from a multi-year data set, where all values from the 1st of January are averaged, then all the values from the 2nd of January, and so on, leading to 365 values.
- **Mean of Weekly (52 values)**: an average year with weekly values calculated and displayed from a multi-year data set (also possible from a single year data set), where all values for the first week are averaged, then all values for the second week, and so on. Gives 52 values.
- **Mean of Monthly (12 values)**: an average year with monthly values calculated and displayed from a multi-year data set (also possible from a single year data set), where all values for January are averaged, then all values for the February, and so on. Gives 12 values.
- **Annual Mean (40 values)**: an average value for each supplied year of time series data is generated. As TopNet data for up to 40 years is supplied, up to 40 values can be expected.
- **Weekly Mean (40*52 values)**: an average value for each supplied week of time series data is generated. As TopNet data for up to 40 years is supplied, up to 40*52 values can be expected.
- **Monthly Mean (40*12 values)**: an average value for each supplied month of time series data is generated. As TopNet data for up to 40 years is supplied, up to 40*12 values can be expected.
- **Mean of Year (365 values) & STD**: the same as Mean of Year (365 values), however with additional lines at (value + STD) and (value – STD).
- **Mean of Weekly (52 values) & STD**: the same as Mean of Week (52 values), however with additional lines at (value + STD) and (value – STD).
- **Mean of Monthly (12 values) & STD**: the same as Mean of Monthly (12 values), however with additional lines at (value + STD) and (value – STD).
- **Annual Mean (40 values) & STD**: the same as Annual Mean (40 values), however with additional lines at (value + STD) and (value – STD).
- **Weekly Mean (40*52 values) & STD**: the same as Weekly Mean (40*52 values), however with additional lines at (value + STD) and (value – STD).

- **Monthly Mean (40*12 values) & STD**: the same as Month Mean (40*12 values), however with additional lines at (value + STD) and (value – STD).

4.6 Plotting buttons

The Plotting window has buttons for plotting the selected time series, clearing the plot field and exporting the selected time series.

4.6.1 Plotting data

After having selected the reach and the time series type, click the “Plot” button to add selected time series to the plotting window.

4.6.2 Clearing plot window

To clear any plotted time series from the plotting window, click the “Clear Plot” button.

4.6.3 Exporting data

Plotted data can be exported into a CSV file by pressing the “Export” button, which will open a new window:

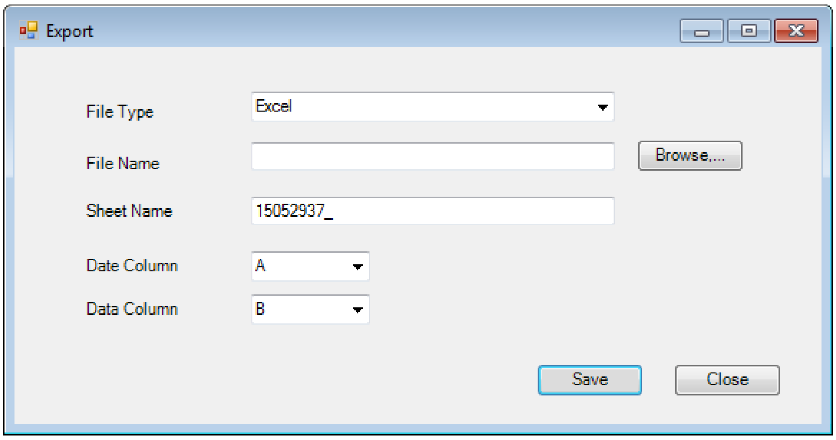


Figure 4-2. Exporting data form.

The exported file type can be selected from the “File Type” drop-down menu. Currently Excel is the only option programed into CHES, even though Tideda is listed as an option.

To enter the file name, click the “Browse,…” button to open a Microsoft window file select form, in which the file to have the data written to needs to be specified.

In the “Sheet Name” field, a name (based on reach number) has been auto filled, followed by an underscore (“_”). In addition to this, if required, further characters can be added after the underscore to specify the type of data, e.g., “natural” or “R1”.

Under the “Date Column” and “Data Column” drop-down menus, specify the columns into which the data will be written.

Press the “Save” button to write the data into the specified Excel file.

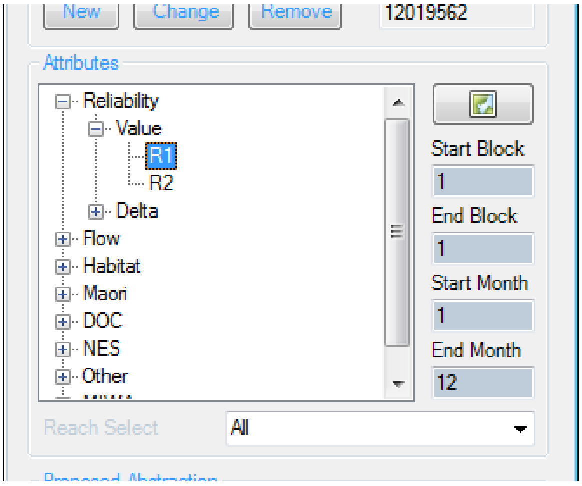
4.6.4 Closing the plotting form

The plotting form can only be closed by pressing the “Plot Off” button next to the “Run” button in the main CHES window.

5 Plotting maps

CHES can be used to display the spatial variation of attribute values by colouring each reach based on derived value. These values are determined using the modified flow time series and/or attribute time series. If the user wants to visualise time series information for an individual reach, then please see Section 4.

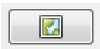
Different indices (model results) can be used to colour reaches. The index is selected from the "Attributes" tree in the main CHES window by expanding the attribute by clicking on the "+" symbols and then clicking on the desired attribute. For example, the R1 and R2 reliability value is selected below:



See Section 5.1 for description of the attributes.

Reaches to be coloured can be 'pre-selected' with a user-supplied file, which needs to be located in the subfolder "ReachSelect". These files can be selected from the "Reach Select" drop-down menu below the "Attributes" section of the main CHES window. Only the reaches specified in the file will be coloured, (see Section 2.5 for file setup).

To colour code reaches on the map based on the selected index click the "Index Plot" button:



This will colour code the catchment of the active scenario. In addition, a histogram for the selected index will be plotted in the plot window (open with the "Plot On" button on the main CHES window).

5.1 Available attributes

The "Attributes" tree has the following eight main branches. Each branch is listed below, with a brief description of the attribute that can be found within this branch:

- **Reliability**: out-of-stream attribute reliability of water supply.
- **Flow**: attributes and statistical properties of the flow, such as minimum flow, maximum flow, etc.
- **Habitat**: instream physical fish habitat attributes.
- **Maori**: Maori values attributes.
- **DOC**: Department of Conservation attributes.

- **NES**: proposed National Environmental Standards properties.
- **Other**: additional attributes, e.g., including CLUES (water quality) attributes.
- **MIWA**: Morphological Impacts of Water Allocation Model.

Each of the main branches has one or more of the following sub-branches. Here the user can select if they want to see actual values or compare values of the active scenario with the reference scenario:

- **Value**: the attributes for the active scenario will be used for visualisation within the map.
- **Delta%**: the attribute change between the active scenario and the reference scenario are being visualizes on the map by presenting the percentage change from reference scenario to active scenario. In equations this means as an example of maximum flow (ΔQ_{max}):
- ΔQ_{max} = (Q_{max} (reference scenario) – Q_{max} (active scenario))/Q_{max} (reference scenario)*100
- **Delta**: the attribute change between the active scenario and the reference scenario are used for visualisation within the map. This means that actual attribute values are subtracted from the two different scenarios, such as change in reliability R_1:
- $\Delta R_1 = R_1$ (active scenario) – R_1 (reference scenario)

The attributes that are available under each main branch (as listed above) are listed below:

Reliability

- **R1 River Takes**: the percent of time (total) that the user can extract the water as required. For all presentations of the reliability, only those reaches with an abstraction will have the reached coloured, whereas reaches with no abstraction will not have the reaches coloured. For a normal abstraction (take), reliability R1 is the reliability of abstracting water. For an instream Dam or Storage unit, the reliability is not the reliability of abstracting water from the river into the dams, but is the reliability the water can be abstracted from the dam.
- **R2 River Takes**: the percent of time (total) that the user can abstract all or part of the allocated amount. The amount of time that the user cannot abstract any water is 100 – R2. The difference between the definition for takes, instream Dams and Storage units are the same as for R1.

Flow

- **Min(Q)**: the overall minimum flow for each reach.
- **Max(Q)**: the overall maximum flow for each reach.
- **Mean(Q)**: the overall mean flow for each reach.
- **Median(Q)**: the overall median flow for each reach.
- **MALF**: the overall 7-day MALF for each reach.
- **Days less MALF**: the amount of time (in percent) that a reach had a flow lower than the 7-day MALF (natural flow).
- **FRE3**: gives the flood frequency FRE3.

- **Touched Reach**: colour codes for if the flow of a reach has been changed or not.
- **Mean(\DeltaQ)**: shows by how much the mean flow changed between the natural flow condition and the active scenario.
- **Max(\DeltaQ)**: shows by how much the mean flow changed between the natural flow condition and the active scenario.

Habitat

When habitat change is being simulated within CHES, a time series of habitat change is generated using daily data for each reach. Hence the information that those time series contain is rather large. One could look at mean habitat change or maximum habitat change to name just a few. The "Habitat" branch has been divided further into different calculation methods, which are given below:

- **Daily average net habitat change**:
  This describes the mean daily difference in habitat availability between two scenarios. It is a measure of the magnitude of change in habitat availability and is described by **Error! Reference source not found.**:
  $$Daily\ average\ net\ habitat\ change = \sum \Delta H_t / N$$
  where ΔH_t is the difference in habitat between the two scenarios on day *t*, and *N* is the number of days in the time series over which the comparison is being made. ΔH_t will be negative if habitat is reduced, and positive if habitat is increased. This is calculated at a reach scale, but can also be summarised as a catchment average.
- **Daily average habitat reduction**:
  This describes the mean daily difference in habitat availability between two scenarios only for days when habitat change is negative. It is a measure of the magnitude of change in habitat availability and is described by the following equation:
  $$Daily\ average\ habitat\ reduction = \sum \Delta H_t / N_R \ \text{ for: } t \in \Delta H_t < 0$$
  where N_R is the number of days in the time series over which the comparison is being made where habitat is reduced. This descriptor takes account of the fact that in the calculation of mean daily habitat change, multiple days of habitat reduction may be 'cancelled out' by multiple days of habitat increase, therefore giving a false sense of the overall consequences of water use for instream values.
- **Daily average habitat increase**:
  This describes the mean daily difference in habitat availability between two scenarios only for days when habitat change is positive. It is a measure of the magnitude of change in habitat availability and is described by the following equation:
  $$Daily\ average\ habitat\ increase = \sum \Delta H_t / N_I \ \text{ for: } t \in \Delta H_t > 0$$
  where N_I is the number of days in the time series over which the comparison is being made where habitat is increased. This descriptor takes account of the fact that in the calculation of mean daily habitat change, multiple days of habitat increase may be 'cancelled out' by multiple days of habitat decrease, therefore giving a false sense of the overall consequences of water use for instream values.

- **Time habitat reduced**:
  This is a measure of the duration of habitat change. It describes the proportion of days in the time series over which a comparison is being made where the difference in habitat between two scenarios is negative (i.e., habitat is reduced). It is described by the following equation:
  $$Time\ habitat\ reduced = N_R / N * 100$$
- **Time habitat increased**:
  This is a measure of the duration of habitat change. It describes the proportion of days in the time series over which a comparison is being made where the difference in habitat between two scenarios is positive (i.e., habitat is increased). It is described by the following equation:
  $$Time\ habitat\ increased = N_I / N * 100$$
- **Max duration reduced habitat events**:
  This describes the maximum number of consecutive days that habitat is reduced compared to the reference scenario. This is another measure of the duration of habitat change and is an indicator of prolonged stress due to reduced flows. It is not weighted to reflect the magnitude of habitat change.
- **Max duration increased habitat events**:
  This describes the maximum number of consecutive days that habitat is increased compared to the reference scenario. This is another measure of the duration of habitat change. It is not weighted to reflect the magnitude of habitat change.
- **Daily average habitat reduction over reduced habitat events**:
  This describes the average habitat decrease compared to the reference scenario. This is another measure of the decrease in habitat change. It is weighted to reflect only those days on which habitat decreased.
- **Daily average habitat increase over increased habitat events**:
  This describes the average habitat increase compared to the reference scenario. This is another measure of the increase in habitat change. It is weighted to reflect only those days on which habitat increased.

The above listed habitat change values can be simulated for the following fish/non-fish species, using the Jowett method (Jowett et al.):

- Aoteapsyche
- Banded Kokopu (juvenile)
- Bluegill Bully
- Brown Trout adult
- Brown Trout spawning
- Brown Trout yearling
- Coloburiscus humeralis
- Common Bully
- Crans Bully
- Deleatidium
- Flathead Galaxias
- Food producing habitat
- Galaxias vulgaris
- Inanga
- Longfin Eel (0-30cm)
- Lowland Longjaw Galaxias
- Nesameletus
- Periphyton
- Rainbow Trout feeding (30-40 cm)

- Rainbow Trout spawning
- Redfin Bully
- Roundhead Galaxias
- Shortfin Eel (0-30cm)
- Shortjaw Bully
- Torrentfish
- Trout Fry
- Upland Bully
- Zelandoperla

In addition, the following fish species can be simulated using Booker method (Booker et al.):

- Bluegill Bully
- Brown Trout small
- Brown Trout spawning
- Common Bully
- Crans Bully
- Giant Kokopu
- Inanga Feeding
- Koaro
- Longfin Eel (large)
- Longfin Eel (small)
- Redfin Bully
- Shortfin Eel (large)
- Shortfin Eel (small)
- Shortjaw Bully
- Smelt
- Torrentfish
- Upland Bully

Maori

Currently CHES contains a couple of examples of Maori values: “Swim Hole” and “Food Gathering”. However those values are site specific. The relationship between one of those attributes and the flow needs to be supplied to CHES and is currently not being used in a spatially generalised form. This means that those values can only be simulated for those sites, where this relationship has been determined. However CHES allows any site specific attribute, which can be related to flow, to be visualised on the map.

NES

The proposed National Environmental Standard for ecological flows and water levels (proposed NES; MfE 2008) made recommendations for default water allocation and minimum flow limits designed to provide a basic level of protection for instream values, while also providing for out-of-stream water use. For river reaches where mean flow is ≥ 5 m^3/s, the proposed minimum flow limit was 80% of MALF and the allocation limit 50% of MALF. For river reaches where mean flow is < 5 m^3/s, the proposed minimum flow was 90% of MALF and the allocation limit 30% of MALF. The following attributes can be selected:

- **Maximum take relative to NES take**: This is the determination of the maximum abstraction/flow change occurring in respect to the NES abstraction. E.g., if NES “allowed” for 50 l/s to be abstracted, but for a given reach the maximum abstraction/change in flow due to abstraction upstream is 70 l/s. then Maximum take relative to NES take would be 140 %.
- **Time not compliant with NES take**: describes the total number of days on which the abstracted amount of water was not compliant with the proposed NES rules.
- **Take not compliant with NES take**: describes the amount of water, in respect of NES proposed amount, taken from the river that is not compliant with the proposed NES rules.

- **Take not compliant with Policy 7.3.1**: a West Coast Regional Council (WCRC) specific rule:
  A-block: ΔQ = 20% of MALF, Q_{min} = 0 l/s
  B-block: ΔQ = infinity, Q_{min} = 75% of MALF
  and the amount of water that is not compliant with the rules is given in the map.

Other

Under this branch, pre-calculated values, independent of flow can be selected and visualised on the map. These are water quality values, derived using the CLUES model. A list is given below:

- **Clues N**: the N load in units of tonnes per year.
- **Clues P**: the P load in units of tonnes per year.
- **Clues Sedi**: the sediment load in kilo tonnes per year.
- **Clues Ecoli**: the Ecoli load in peta Ecoli per year.
- **NES \DeltaQ**: shows in the map what the abstraction limit should be based on the proposed NES rules.

In addition, please see Section 5.3 for further detail on CLUES.

MIWA

Please see Section 5.2 for further detail on MIWA.

5.2 MIWA for CHES

The Morphological Impact of Water Allocation Model (MIWA) functionality has been incorporated into CHES. MIWA has been developed by Dr Ude Shankar. For further information see Hicks et al. (Hicks 2009) or contact:

Dr. Ude Shankar
(03) 343 7892
u.shankar@niwa.co.nz

The following MIWA attributes can be visualised within CHES:

- Existing morphology:
  - Q2
  - Channel forming discharge
  - Channel type(alluvial/bedrock reach)
  - Slope
  - Bed-material
  - Bed material size
  - Sediment supply
- Dimensionless indices:
  - Q* (Discharge)

- T* (Shear stress)
- Qs* (Sediment supply)
- W* (Width)
- S* (Planform)

- Morphological changes:
  - Aggradation or degradation
  - Bed incision potential
  - Bankfull width
  - Bankfull depth
  - Sinuosity
  - Braiding indicator

5.3 CLUES for CHES

CLUES is a GIS-based modelling system which assesses the effects of land use change on water quality and socio-economic indicators. It was developed by NIWA for MAF and is an amalgamation of existing modelling and mapping procedures contributed by various research organisations, including MfE, AgResearch, Landcare Research, Plant and Food Research and Harris Consulting.

By assuming current land use, all CLUES output values have been generated and saved into a static file that can be visualised with CHES. The values are:

- N-load, in t/y
- P-load, in t/y
- Sediment load, in kt/y
- Ecoli load, in p Ecoli/y

As these values are static, and no effects of a change in flow have been incorporated, they are purely of informative value. The same values could be visualised with the CLUES software itself, which is another add-in available for ArcGIS, and can be obtained from NIWA.

See https://www.niwa.co.nz/freshwater/our-services/clues-%E2%80%93-catchment-land-use-for-environmental-sustainability-model for further information on CLUES. If you wish to install the CLUES add-in into ArcGIS, please contact:

Dr. Sandy Elliot
(07) 859 1839
s.elliott@niwa.co.nz

The software can be found under the following link: ftp://ftp.niwa.co.nz/clues/

6 Plotting summaries

The focus of CHES is determining values and attributes, and it was originally designed to determine in- and out-of-stream values for different abstraction settings/scenarios. Reliability is an example of an out-of-stream value. There are several reliability attributes that describe overall reliability value. For the CHES value “Reliability” we have the two attributes “R1” and “R2”. R1 represents the percentage of time all allocated water can be abstracted and R2 represents the percentage of time that all or part of the allocated amount can be abstracted. In a similar way, the value “Habitat” could include several different habitat attributes for different species. In other words, CHES values are groups of attributes.

This section covers the plotting of summary sheets for different active scenarios, with the intended outcome that different scenarios can be quickly compared. A summary plot gives a single value for each requested attribute (e.g., percent of time the physical habitat of the banded kokopu decreases, or the overall reliability of all abstractions, etc.).

An example of a summary sheet:

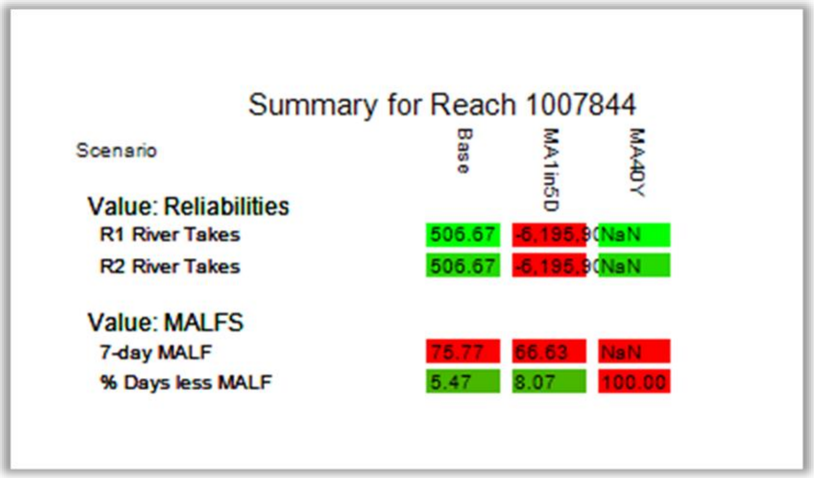


Figure 6-1. Summary sheet for three difference scenarios.

An example where plotting summaries would be useful is comparing different scenarios for different time periods, where different time periods are different flow return periods (1 in 5 year drought, 1 in 10 year drought, 1 in 20 year drought). For this, scenarios would need to be created, each with a different time period that corresponds to the drought conditions. Another example is the comparison of different allocation periods, e.g., 100% of paper allocation, 60% of paper allocation, 50% of paper allocation, etc. For this, scenarios would need to be created where the time period was the same, but allocation amounts were different.

The steps to create a summary page:

- Create and run all required scenarios to generate the data.
- Set up a summary page template, called a “summary style”. Many different summary styles can be set up.

- Select the most downstream reach, or the reach of interest, for which the summary will be generated.

For attributes where a reference time series is needed, CHES will use the data from the reference scenario.

6.1 Setting up a summary style

To set up the summary style, click the “Change” button in the “Summary Styles” section at the bottom of the main CHES window. The Style window:

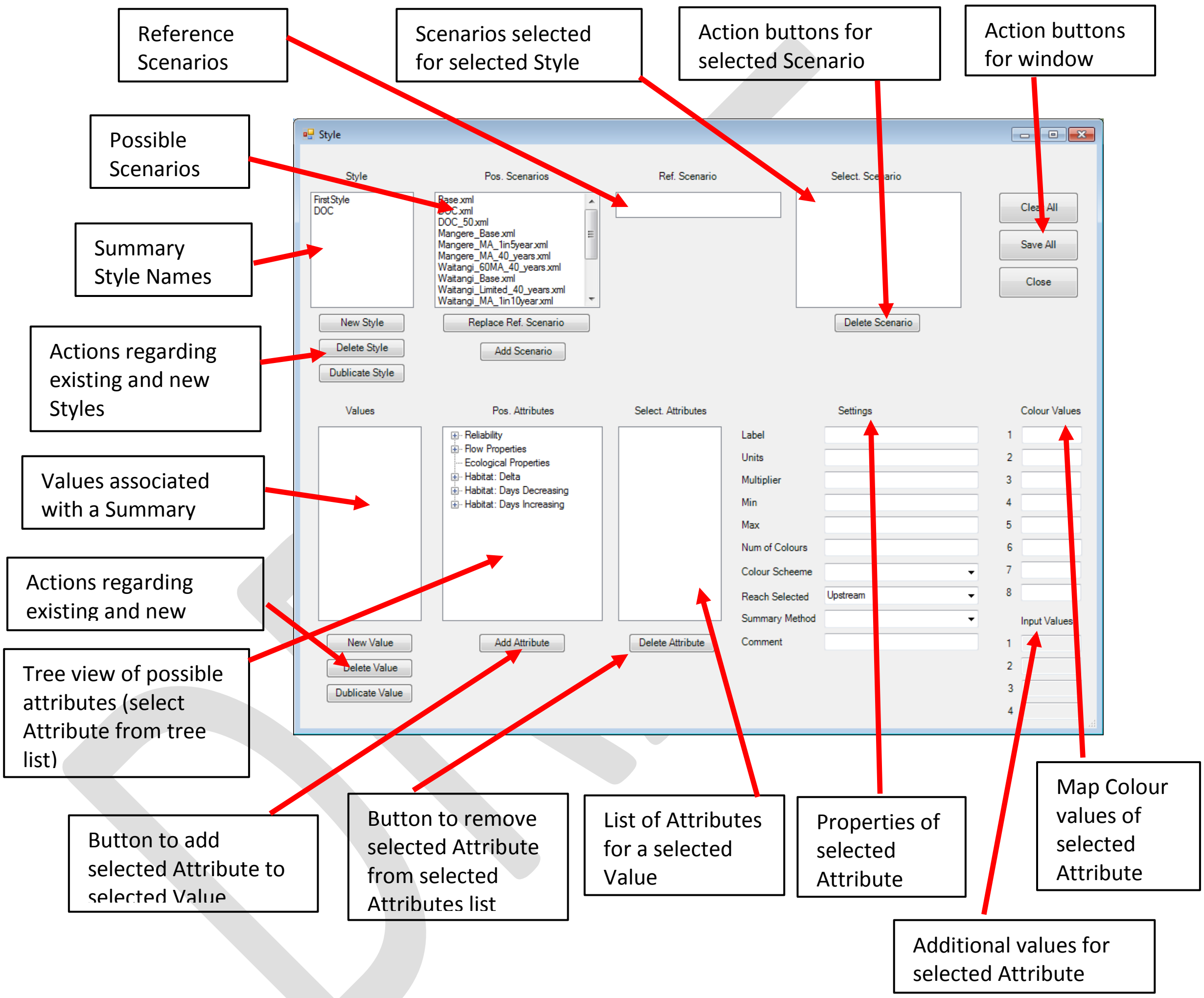


Figure 6-2. Summary style window.

Setting up a summary style involves selecting different scenarios and attaching different attributes to the style. The properties of the attributes can be changed for each style.

Steps to create a style:

- Create and run all required scenarios, including the reference scenario.
- Open the Style window.
- Click the “New Style” button under the “Style” box of the window and enter the name of the new style.

- Select the newly created style in the style box by clicking on it (it will become highlighted).
- Add the reference scenario to the “Ref. Scenario” box by clicking on it in the “Pos. Scenarios” box and clicking the “Replace Ref. Scenario” button.
- Add the required non-reference scenarios to the “Select. Scenario” box by selecting each one and clicking the “Add” button.
- Create new value by clicking the “New Value” button under the “Values” box and giving the new value a name. A value is an attribute or group of attributes, such as out-of-stream or in-stream values (e.g., reliabilities “R1” and “R2” could be an out-of-stream value and a number of different habitat values could be the in-stream value).
- To add attributes to a value, first select the value in the values box (e.g., “out-of-stream”) to which the first attribute shall be added. Attributes are added using the “Pos. Attributes” box, which contains all the possible attributes found on the main CHES window. For example, add the attribute “R1” by expanding the branch “Reliability” (click the “+” symbol next to the word “Reliability”) to reveal “Value” and “Delta”, and then expand “Value” to reveal “R1”. Left mouse click on “R1”, and then click the “Add Attribute” button below the box. “R1” will appear in the “Select. Attributes” box.
- A summary style has now been set up, which contains default settings.

The following section describes how to change the default settings.
The Settings section of the Style window:

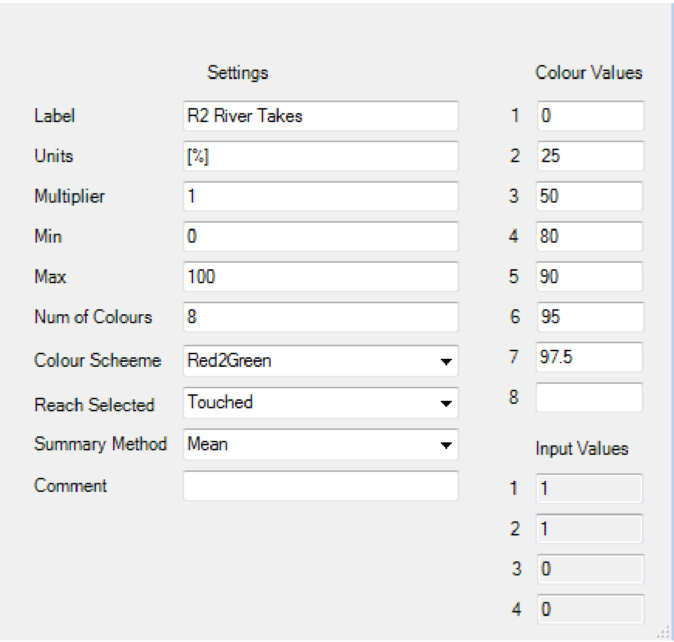


Figure 6-3. The settings section of the summary style window (bottom right corner).

The following values can be changed:

- **Label**: a string of the label that will be used on the summary form. A short one is preferable as there is not much space.

- **Units**: the units of the attribute, with the default units supplied. If the units are changed, then the "Multiplier" will also need to be changed (see below).
- **Multiplier**: a number (floating) that will be multiplied with the output attribute values. If a value other than "1" is selected, then the "Units" string may also need to be changed.
- **Min**: a number (float) that is the smallest number allowed for the attributes. Any attribute value smaller than the "Min" value will be ignored. This number is also important for the "Colour Values" (see below).
- **Max**: a number (float) that is the largest allowed number for the attribute. Any attribute value larger than the "Max" value will be ignored. This number is also important for the "Colour Values" as well (see below).
- **Num of colours**: the number of different colours that will be used in the summary style. This number needs to be one larger than the numbers supplied in the "Colour Values" fields. (see below).
- **Colour scheme**:
  Options are:
  - **Green2Red**: green to read
  - **Red2Green**: red to green
  - **Green2Blue**: green to blue
  - **Blue2Green**: blue to green
  - **Red2Blue**: red to blue
  - **Blue2Red**: blue to red
  - **Hotter**: orange to red
- **Reach selected**: the selection of reaches which are being used for the summary value of this attribute. For each attribute the user can choose between different options of which reach to select. For examples, the attribute for a specific reach, or the attribute for all reaches upstream of a particular reach. The options are:
  - **Upstream**: uses all reaches upstream of the reach for which the summary style was requested.
  - **Touched**: all touched reaches in the catchment
  - **Reach single**: uses the data only from the current selected reach.
- **Summary Method**: Because the summary provides a single value per attribute from a number of reaches, the mathematical process to derive the single value for each attribute needs to be specified. The options are:
  - **Min**: the smallest value from all selected reaches.
  - **Perc 1%**: the 1% percentile from all selected reaches.

- **Perc 5%**: the 5% percentile from all selected reaches.
- **Perc 25%**: the 25% percentile from all selected reaches.
- **Mean**: the average from all selected reaches.
- **Median**: the median value from all selected reaches.
- **Perc 75%**: the 75% percentile from all selected reaches.
- **Perc 95%**: the 95% percentile from all selected reaches.
- **Perc 99%%**: the 99% percentile from all selected reaches.
- **Max**: the maximum value from all selected reaches.
- **Mean (reach length)**: here a weighting has taken place in respect of the reach length for all selected reaches, in respect of the length of each reach.
- **Mean (reach area)**: here a weighting has taken place in respect of the reach length for all selected reaches in respect of the land surface area of each reach.
- **Colour values** 1–8: the ranges which correspond to each colour need to be supplied. The first colour represents the value between “Min” and the value entered for “1”. The second colour represents the value between the entered value of “1” and “2”, and so on. The last colour represents the value between the entry of the last “Colour Values” and the “Max” value. Overall with “Min”, the “Colour Values” and “Max”, there are (*x+1*)-number of different colours, where *x* is the number of values within “Colour Values”. As there is only space for 8 values within the “Colour Values” overall there can only be a maximum of 9 different colours.

7 Installing CHES

By installing and/or using CHES 1.0, you acknowledge that you have read the terms and conditions set out in the appended CHES software licensing agreement (Appendix 17), and agree to be bound, and abide, by the terms of that licence.

7.1 System requirements

You will need the following to install and use CHES:

- PC with Windows 7 operating system
- ESRI ArcMap v. 10.X (ArcInfo)
- 4 GB RAM
- About up to 15 GB of storage space on your hard disk
- Administrative rights

7.2 Licence requirements

To run CHES in the ArcGIS environment, the following ArcGIS licences are required:

- ArcInfo Desktop
- Spatial Analyst

7.3 Data requirement

To run CHES in the ArcGIS environment a large number of data sets are needed, all of which should be included on the install DVD. The required data can be divided into the following four groups:

- ArcGIS layer: data needed for the visualization within the ArcGIS software.
- CHES data: data needed to run the CHES simulation.
- CHES additional data: additional metadata needed to run the CHES simulation.
- Model data: metadata needed to estimate the desired indices from the supplied models.

7.4 ArcGIS layer

Within the ArcGIS environment, the following layers need to exist:

- **Existing Takes**: layer will be supplied.
- **Takes**: layer will be supplied.
- **Storage Dam**: layer will be supplied.
- **Stream**: layer will be supplied and is used to display estimated indices values, which have been derived from the three different flow time series for each reach.
- **HydroEdge**: a layer that can be supplied by NIWA, otherwise needs to be a Geodatabase Feature Class, with a Feature Class name "HydroEdge".

- **Digital Elevation Model (DEM)**: a layer that can be supplied by NIWA. Otherwise this layer needs to be a Geodatabase Raster Dataset. There can be several DEM layers of different coarseness. The finer the grid of the raster DEM data set, the better the relationship that can be derived for dams (height versus dam water volume). However, the finer the grid of the DEM, the longer the process will take. It is suggested that the 100 m DEM (or coarser) should be used to cut down on the time it takes to place a dam.

All layers need to be of the same projection. Currently, the projection for CHES within ArcGIS is GD_1949_New_Zealand_Map_Grid.

7.5 CHES data

For the projection of CHES within ArcGIS and running the CHES simulation, the following data sets are needed:

- **Flow data**: currently supplied by NIWA as TopNet model runs, in the file format of netCDF files.
- **Spatial data**: currently supplied by NIWA as TopNet spatial files, in the file format of netCDF files.
- **ReachID data**: currently supplied by NIWA as a netCDF file.
- **D-Values**: currently supplied by NIWA as a CSV file that contains four columns: 1) reach number, 2) D0 value, 3) D1 value, and 4) D2 value. The values are used to determine the wetted width for each reach, which is used to derive indices of interest, e.g., habitat change for a selected species.
- **Slope data**: the estimated slope for each reach, currently supplied by NIWA. It is contained in a file named "NZ_preds.csv", with a column called "SEGSLOPE" as the seventh column, and with the reach number listed in column one. The slope values are used to determine the Manning's N value.
- **REC metadata**: currently supplied by NIWA that contains reach specific metadata, which is being used through the simulation process of CHES.

7.6 CHES additional data

Additional data, which is needed to carry out the CHES simulation, is stored in the CHES folder "CHES_Additional". This entire folder will be supplied by NIWA and is required to ensure that CHES simulations run successfully.

7.7 Model data

For good housekeeping practice, all data that is connected and only used by additional model index calculation is stored in the CHES folder "Model_Data". This folder might be empty during the initial install but will contain files once models are run.

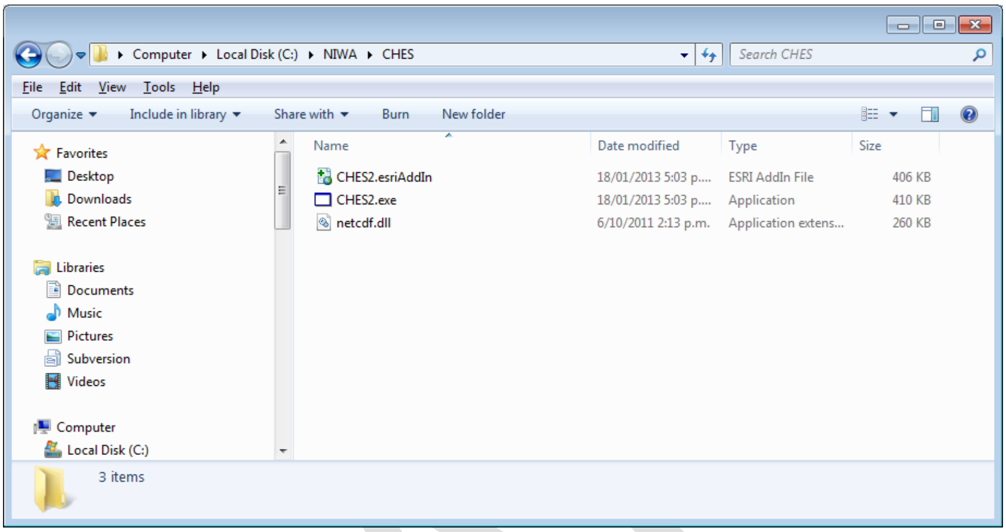
7.8 Installation process

1. Close ArcMap.

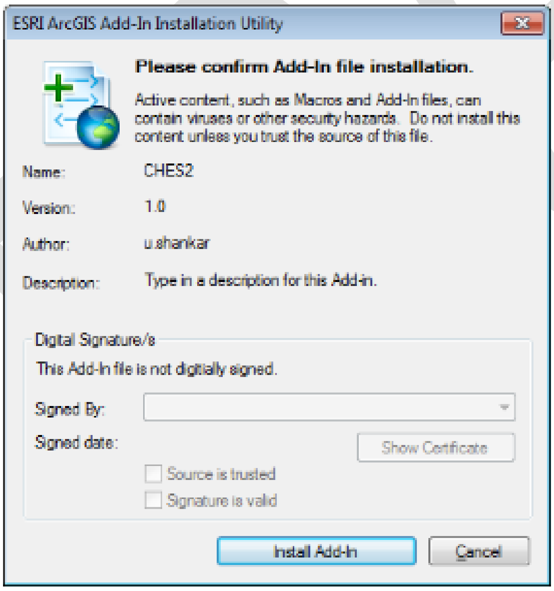
2. If you are running an earlier version of CHES, remove it by following the instructions in Section 8.

3. Copy files from the supplied DVDs into your local (C) drive, suggested location: "C:\NIWA\CHES\".

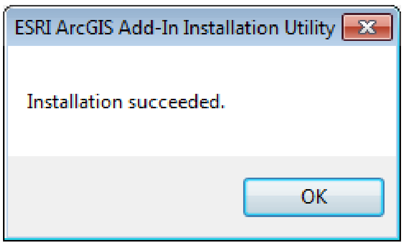
4. Open the extracted "CHES_Install" folder. You should see the following three files as shown in the figure blow:



5. Double click on the "CHESx.exriAddIn.exe", this will open the ESRI-add-in window:

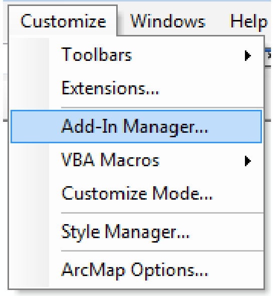


6. Click "Install Add-in". You will be notified when CHES has been installed. Click "OK"

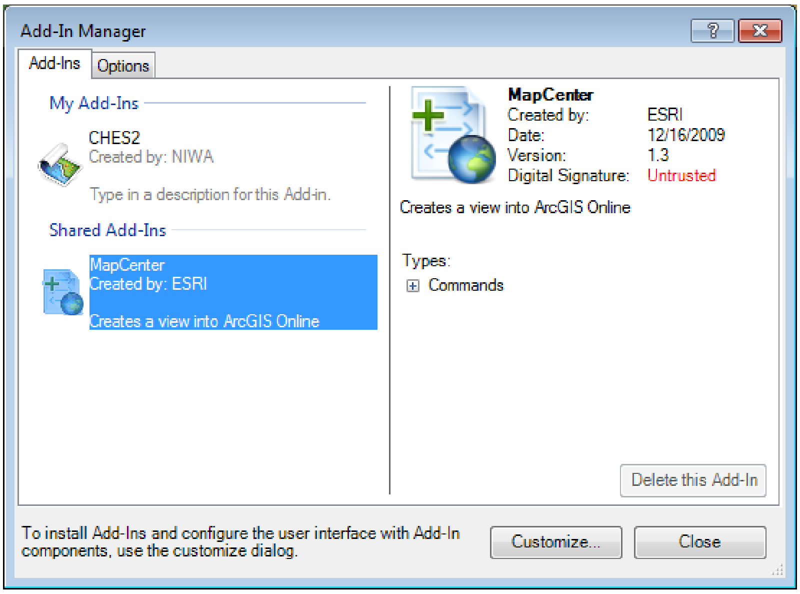


7. Open ArcMap 10.X with a black document.

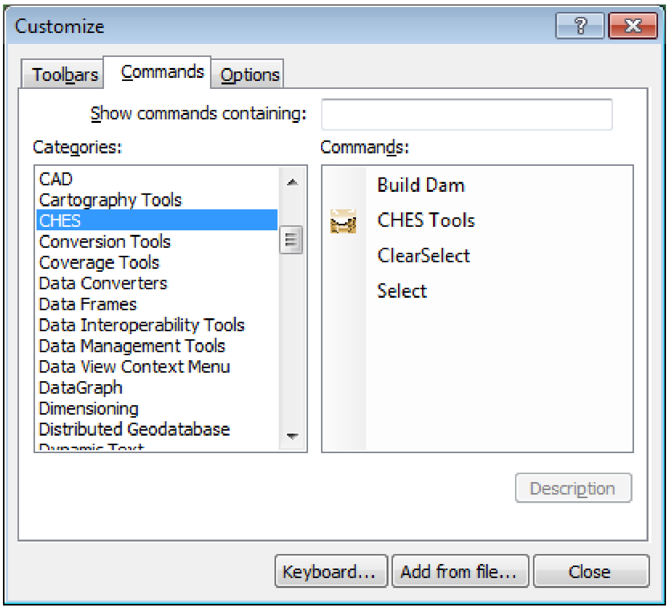
8. Under the "Customize" menu, click the "Add-In Manager"



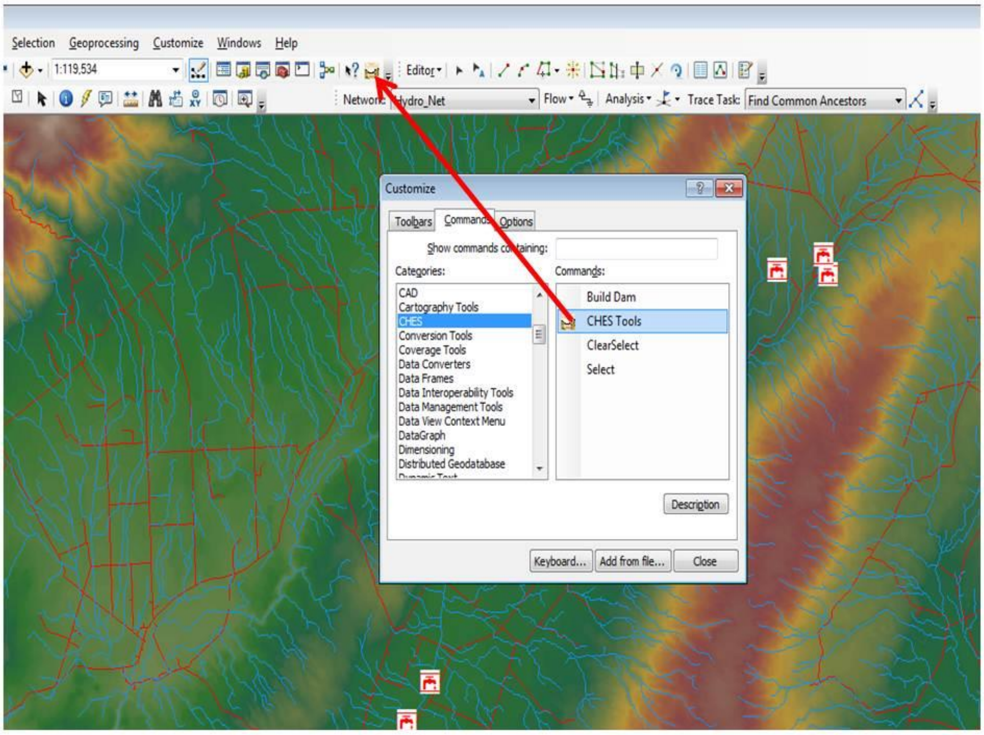
This will open the following window with CHES listed as an add-in:



9. Click "Customize", and in this window click on the "Commands" tab. Select "CHES" from the Categories pull down menu. It can take a few moments for CHES to be displayed.

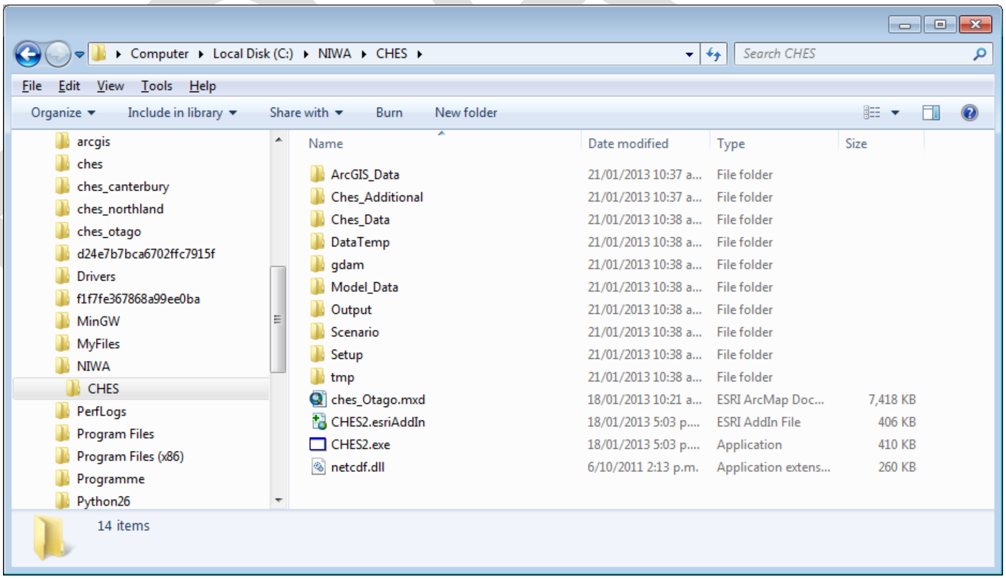


10. Click and drag the "CHES Tools" button to the tool bar.



11. Close the "Customize" window.

12. Copy the additional folders from the DVD to end up with the following directory and file structure:

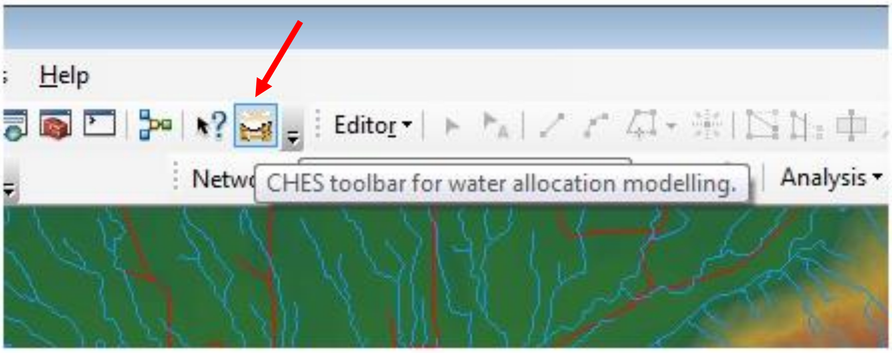


13. If you have installed your files at a different location, you will need to do the following changes in the setup files:

   1. ..\Setup\Setup_Models.xml:
   Any entry for <FileName>, which will be "C:\NIWA\CHES\Model_Data\..." needs to be changed to your file path name.

2. ..\Scenario\Base.txt:
   All occurrences of "C:\NIWA\CHES\" will need to be replaced with the directory path you have chosen. There will be at least 17 changes you will have to do.

14. Now you can start CHES from within ArcMap, by clicking on the CHES add-in symbol:



15. For improved speed rename file “ArcGISConnection.exe” in folder C:\Program Files (x86)\Common Files\ArcGIS\bin to a different name.

7.9 CHES update

From time to time a newer version of CHES will be made available, which can be found at the following web-link:
ftp://ftp.niwa.co.nz/incoming/CHES/UpDates/

Please select the latest update and download the files from the most recent folder to your computer. At least the following files should have been downloaded:

Name	Date modified	Type	Size
CHES2.application	21/09/2016 1:06 p....	ClickOnce Applica...	2 KB
CHES2.esriAddIn	21/09/2016 1:06 p....	Esri AddIn File	1,813 KB
CHES2.exe	21/09/2016 1:06 p....	Application	849 KB
CHES2.exe.manifest	21/09/2016 1:06 p....	MANIFEST File	20 KB
CHES2.pdb	21/09/2016 1:06 p....	Program Debug D...	1,040 KB
CHES2.xml	21/09/2016 1:06 p....	XML File	6 KB
CHES2.exe.config	9/10/2013 11:54 a....	XML Configuratio...	2 KB
netcdf.dll	6/10/2011 2:13 p.m.	Application extens...	260 KB
Microsoft.Office.Interop.Excel.xml	18/01/2011 9:08 p....	XML File	3,488 KB
office.xml	18/01/2011 9:08 p....	XML File	1,085 KB
Microsoft.Office.Interop.Excel.dll	18/01/2011 6:27 p....	Application extens...	1,514 KB
Microsoft.Vbe.Interop.dll	18/01/2011 6:27 p....	Application extens...	62 KB
office.dll	18/01/2011 6:27 p....	Application extens...	438 KB
ESRI.ArcGIS.3DAnalystUI.dll	19/05/2010 2:15 p....	Application extens...	14 KB
ESRI.ArcGIS.3DAnalyst.dll	19/05/2010 1:01 p....	Application extens...	232 KB
ESRI.ArcGIS.GeoAnalyst.dll	19/05/2010 12:35 ...	Application extens...	76 KB

You then will need to carry out the following steps:

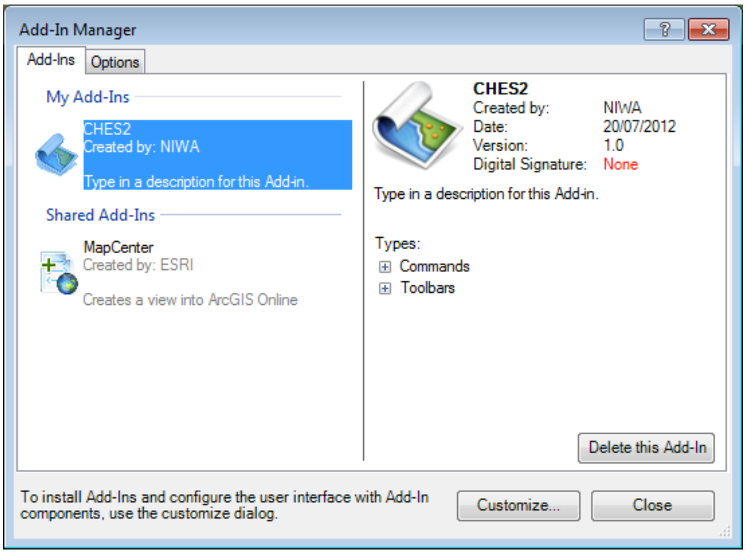
- Close CHES and ArcGIS
- Copy above files into folder (replace double ups)
  C:\NIWA\YOUR_CHES \Ches_AddIn\
- Execute: CHES2.esriAddIn
- Restart ArcGIS
- Start CHES

From time to time additional setup files might have changed their content/structure. These will also need to be downloaded. The ReadMe.txt file on the same FTP site will indicate which files need to be copied to which location, overwriting existing files on your computer under CHES.

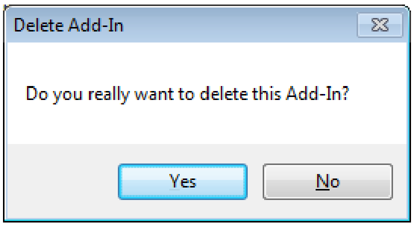
8 Removing CHES

The steps to remove CHES from ArcGIS are as follows:

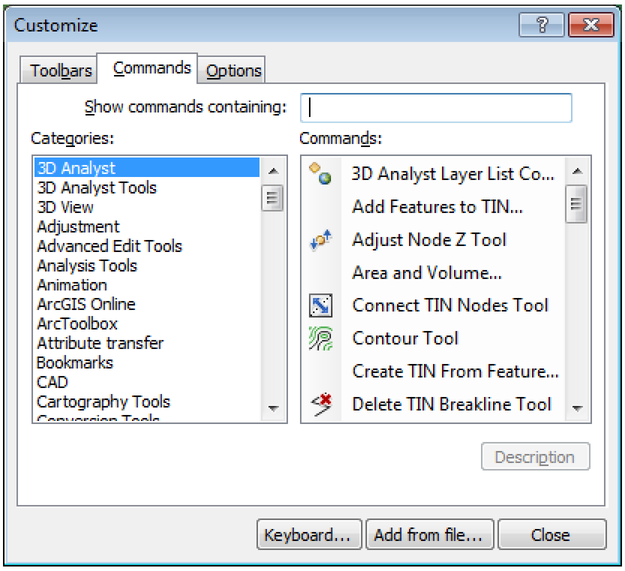
1. Open the "Add-In Manager..." window under the "Customize" menu. Click on CHES (or CHES2).



2. Click "Delete this Add-In" and then "Yes" at the prompt:



3. To remove the CHES button from the ArcMap toolbar, click on the "Customize" button in the Add-In Manager form, and select the "Commands" tab:



4. Drag the CHES button from the toolbar onto the map display. Close the "Add-In Manager" by pressing the "Close" button.

9 Importing measured data

CHES has the capability to incorporate measured data into the simulation process. The measured data needs to be supplied in a pre-defined format, and the required action for the data specified via the “Flow Data” drop-down menu on the CHES Scenario form.

9.1 Setting up measured data

The measured data needs to be supplied in an Excel workbook. This file should be located in the CHES folder "Ches_Data", with the file name "MeasuredData.xlsx". In the workbook, each measured data set for each reach needs to be in a separate sheet with the associated reach number as the sheet name. The Excel sheets need to have one heading line/information. Each sheet needs to have the following two columns:

- **Date time**: the date and time value for each given flow value. Each date/time value should correspond to the end of the time interval for the given flow value, e.g., if data is supplied as mean daily values, with a date/time stamp of 2-02-1999 21:00, then the time period starts on the 01-02-1999 21:00:01 and finishes on 2-02-1999 21:00 (same as it is currently for Tideda). The format of the date/time stamp needs to be: dd-mm-yyyy HH:MM.

- **Flow value**: the flow, in units of l/s.

A sample data file containing measured data:

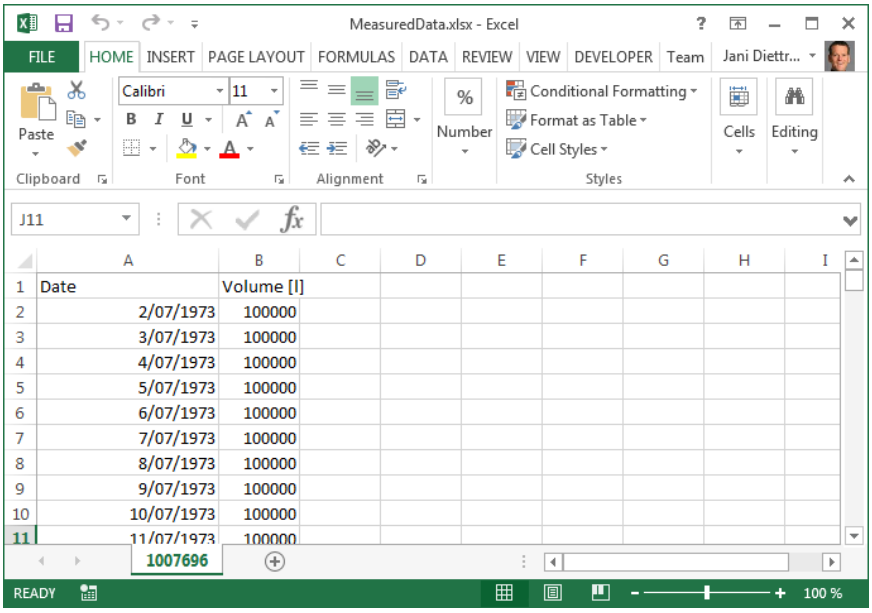


Figure 9-1 Measured data input Excel file

9.2 Selecting different measured data input options

Once a file containing measured data has been selected in the CHES Scenario form, the user can select what to do with the measured data. There are several options, as described below:

- **No measured data**: any measured data will be ignored.

- **Replace**: the flow values from the modelled input data will be replaced with the measured data, where measured data has been supplied. This will affect the reach for which the measured data was provided, and all reaches downstream of this reach.

10 Setup models

This section describes the files “Setup_Models_Base.xml” and “Setup_Models_Small.xml”. These two files are read in whenever CHES is started, and CHES populates the attributes table and defines a large range of metadata for each attribute, so that it can be plotted and summarised accordingly. For example, if the user wants to change the colours for a specific attribute, the changes will need to be made within those files.

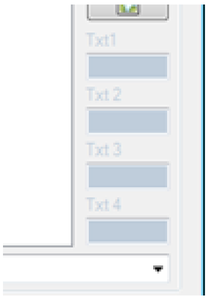
10.1 Element description

The following settings are possible for each attribute:

- **TreeGroup**: a setting (string), identifying under which Main-tree branch the attribute shall appear.
- **Name_Unique**: a string for a unique name, which is given to a single attribute.
- **SelectReach**: a setting (string), identifying the reaches on which this simulation shall be applied to. Options are:
  - **Touched:** only for the touched reaches the attribute shall be simulated and visualised.
  - **Upstream**: only for the upstream reaches the attribute shall be simulated and visualised.
  - **Single**: only for the single selected reach the value will be displayed/simulated.
- **ToolTip**: a string that will appear as a tool-tip when the cursor is hovered over the attribute in the attribute tree.
- **Name**: the name that will appear in the attribute tree.
- **Comment**: a comment that will only be in the xml file and not visible to the user from within CHES.
- **Units**: a string containing the unit of the attribute.
- **Multiplier**: a value by which the attribute value is multiplied before the visualization process.
- **Min**: the minimum value that is acceptable. Any reach with a value smaller than the min value will not be colour coded.
- **Max**: the maximum value that is acceptable. Any reach that has a value larger than the max value will not be colour coded.
- **Colour_Num**: a number that indicates how many colour values will be used for colour coding the map.
- **Colour_Scheme**: a string that indicates the colour scheme to be used. Names should be self-explanatory. Examples are:
  - Green2Red
  - Red2Green

- Blue2Red
- Hot: Same as Blue2Red
- Red2Blue
- Cold: same as Red2Blue
- Green2Blue
- Blue2Green
- Hotter

- **Method**: the string describing the calculation method that is being used to derive this attribute for each reach, from the time series for each reach. Fundamentally for each reach a time series of the attribute is available. However when summarizing the information into a Map, where each reach is colour coded based on a single value, the user needs to specify how the time series is “compressed” into a single value. Options are the calculation method such as “mean”, “min”, “max” etc. Below a list of possible calculation methods is given:
  - **Mean**: uses the mean value of the attribute time series.
  - **Median**: uses the median value of the attribute time series.
  - **Max**: uses the maximum value of the attribute time series.
  - **Perc. 1%**: uses the first percentile value of the attribute time series distribution.
  - **Perc. 5%**: uses the fifth percentile value of the attribute time series distribution.
  - **Perc. 25%**: uses the 25th percentile value of the attribute time series distribution.
  - **Perc. 75%**: uses the 75th percentile value of the attribute time series distribution.
  - **Perc. 95%**: uses the 95th percentile of the attribute time series distribution.
  - **Perc. 99%**: uses the 99th percentile of the attribute time series distribution.
  - **Min**: uses the minimum value of the attribute time series.
- **LabelPrec**: a string label used during the plotting (time series) and map plot process.
- **XLabelStr**: the string used as the x-axis label on the time series plots.
- **YlabelStr**: the string used as the y-axis label on the time series plots.
- **Interval**: the information needed to determine the colour ranges for the Map plot (see description in Section 13.1.1 below).
- **Hist**: the information needed for creating histogram plots of the data when colouring in the map. When the user colours the map, a histogram is also generated where the time series plots normally appear. Further settings are described in Section 13.1.2 below.
- **Box1 to Box4**: the information required for updating the fields next to the attribute tree in the main CHES window.



The fields “Txt1”, to “Txt4” are updated according to those settings and additional metadata can be supplied for the calculation of this attribute. See description in section 13.1.3 below.

10.1.1 Interval

The following information is important for the generation of the colour bar that is visible for each map. Here the number of colours and the value range for each colour is being specified. This is achieved with the following two settings:

- Interval_Val:
- Interval_Inc: A string that contains information on the range for each individual specified colour. Options are:
  - **SmallerEqual**: Supplied value under “Interval_Val” and small values are part of the colour range.
  - **Smaller**: Supplied value under “Interval_Val” is not part of the colour range, but smaller values are.
  - **Equal**: Only Supplied value is part of the colour range.

10.1.2 Hist

The Hist (histogram) property has three elements:

- **XLabelStr**: the string used as the x-axis label.
- **Colour**: a string indicating the colour to be used for this attribute in the histogram. Options are the normal colours, such as “red”, “green”, etc.
- **LegendStr**: the string used within the legend of the histogram. LaTex math style can be used here, meaning that by writing “\Delta”, a “⍰” will appear instead in the legend.

10.1.3 Box1 to Box4

The Box1 to Box4 set the fields next to the attribute tree on the main CHES window, and have the following elements:

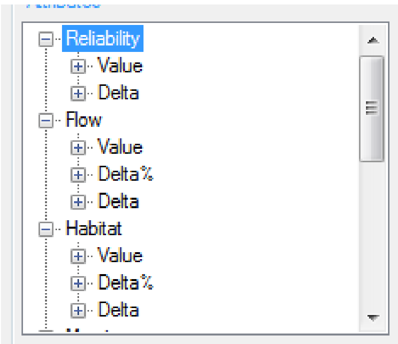
- **LabelStr**: a string for the label above the editable field box in the main CHES window.
- **LabelVis**: a Boolean indicating if the field can be edited or not.
- **TextBox_Val**: the number that will be placed in the edit field.

- **ToolTipStr**: a string describing the tool tip that will appear if the cursor is hovered over the field box/label.
- **FileName**: a string/value that is required for calculating the attribute.

10.2 File description

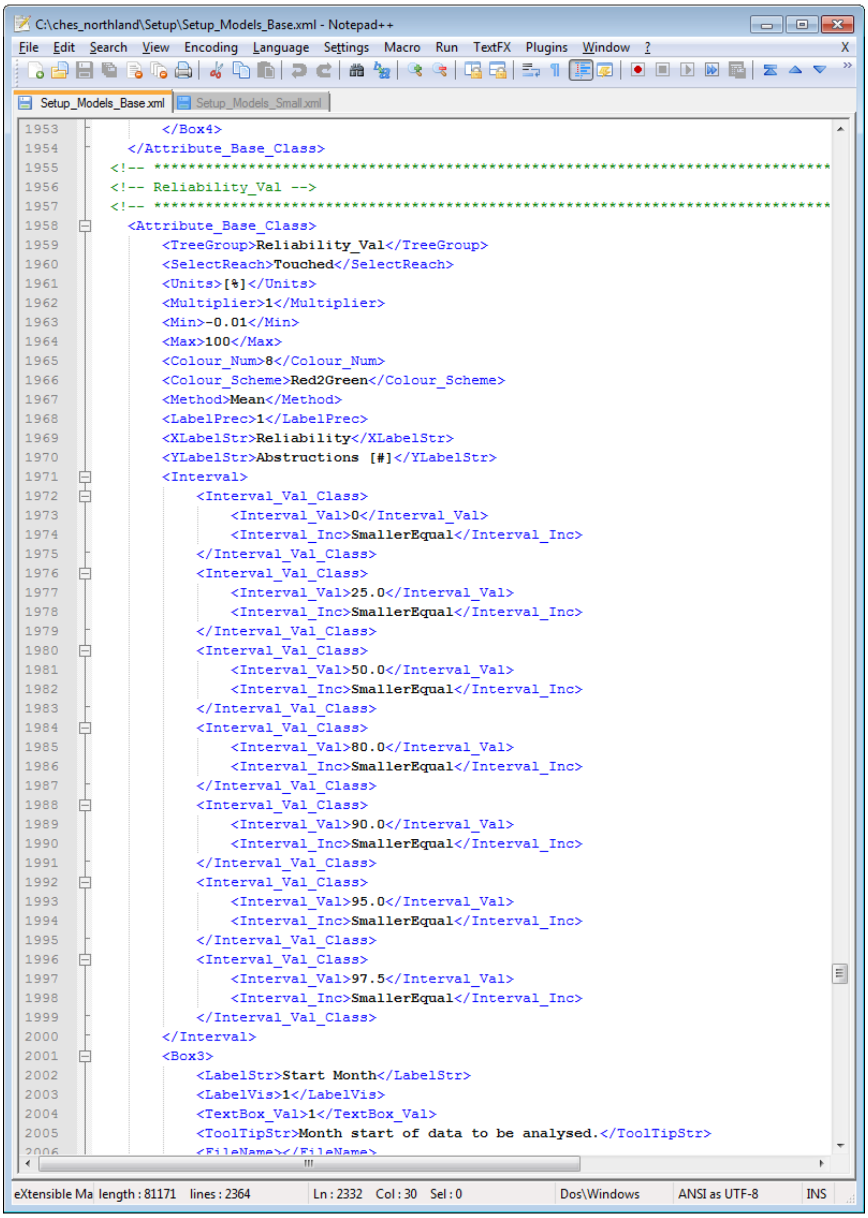
The two Setup files have slightly different purposes, though both are setting the values for each attribute. The files supply information to a large range of applications within CHES. Information from both files is used to generate the attribute tree, for colouring the maps, and for creating histogram plots.

The file “Setup_Model_Base.xlm” sets default values for each attribute, done on a sub-tree level (attributes within a branch of the main branch, e.g., see screenshot below).



The main branches “Reliability”, “Flow”, “Habitat”, etc., are shown in the screenshot above. The main branch “Reliability” has two sub-branches: “Value” and “Delta”. Setting default values for any attribute under the sub-branch level, refers to attributes that would appear if sub-branches of the tree are expanded.

The default settings for the attributes under the tree branch “Reliability/Value” are shown below:




```xml
            </Box4>
        </Attribute_Base_Class>
    <!-- ****************************************************************************** -->
    <!-- Reliability_Val -->
    <!-- ****************************************************************************** -->
        <Attribute_Base_Class>
            <TreeGroup>Reliability_Val</TreeGroup>
            <SelectReach>Touched</SelectReach>
            <Units>[%]</Units>
            <Multiplier>1</Multiplier>
            <Min>-0.01</Min>
            <Max>100</Max>
            <Colour_Num>8</Colour_Num>
            <Colour_Scheme>Red2Green</Colour_Scheme>
            <Method>Mean</Method>
            <LabelPrec>1</LabelPrec>
            <XLabelStr>Reliability</XLabelStr>
            <YLabelStr>Abstructions [#]</YLabelStr>
            <Interval>
                <Interval_Val_Class>
                    <Interval_Val>0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>25.0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>50.0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>80.0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>90.0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>95.0</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
                <Interval_Val_Class>
                    <Interval_Val>97.5</Interval_Val>
                    <Interval_Inc>SmallerEqual</Interval_Inc>
                </Interval_Val_Class>
            </Interval>
            <Box3>
                <LabelStr>Start Month</LabelStr>
                <LabelVis>1</LabelVis>
                <TextBox_Val>1</TextBox_Val>
                <ToolTipStr>Month start of data to be analysed.</ToolTipStr>
                <FileName></FileName>
```

A vast number of settings have been given for the attributes, ranging from <Min>, <Max>, <Colour_Num>, <Units>, etc.; these settings apply to all attributes which are listed under this attribute branch.

The attributes are linked through the <TreeGroup> parameter. Only the following <TreeGroup> labels are allowed to be used within this file (and will be referred to as "Tree Group members"):

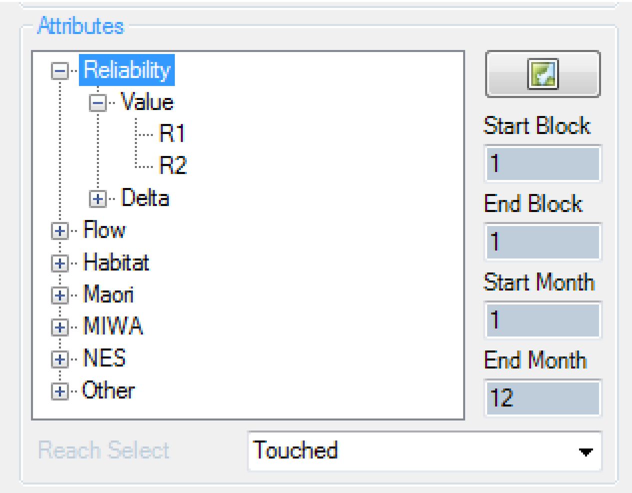
- **Reliability_val**: this branch will contain reliability values of the active scenario.
- **Reliability_delta_u**: this branch will contain change in reliability values by comparing the active and the reference scenario.
- **Flow_val**: this branch will contain statistical flow properties, such as min, max and mean, of the active scenario.
- **Flow_delta_p**: this branch will contain the percentage change of the same flow properties from "Flow_Val", using information from the active and the reference scenario.

- **Flow_delta_u**: this branch will contain the change of the same flow properties from "Flow_Val", using information from the active and the reference scenario.
- **Habitat_v_nhc**: contains all the fish species, and the attribute "Daily average net habitat change" for the active scenario being calculated.
- **Habitat_v_ahr**: contains all the fish species, and the attribute "Daily average habitat reduction" for the active scenario being calculated.
- **Habitat_v_ahi**: contains all the fish species, and the attribute "Daily average habitat increase" for the active scenario being calculated.
- **Habitat_v_thr**: contains all the fish species, and the attribute "Time habitat reduced" for the active scenario being calculated.
- **Habitat_v_thi**: contains all the fish species, and the attribute "Time habitat increased" for the active scenario being calculated.
- **Habitat_v_nhr**: contains all the fish species, and the attribute "Max duration reduced habitat events" for the active scenario being calculated.
- **Habitat_v_nhi**: contains all the fish species, and the attribute "Max duration increased habitat event" for the active scenario being calculated.
- **Habitat_v_shr**: contains all the fish species, and the attribute "Daily average habitat reduction over reduced habitat events" for the active scenario being calculated.
- **Habitat_v_shi**: contains all the fish species, and the attribute "Daily average habitat increase over increased habitat events" for the active scenario being calculated.
- **Habitat_p_nhc**: same as "Habitat_v_nhc", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_ahr**: same as "Habitat_v_ahr", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_ahi**: same as "Habitat_v_ahi", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_thr**: same as "Habitat_v_thr", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_thi**: same as "Habitat_v_thi", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_nhr**: same as "Habitat_v_nhr", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_nhi**: same as "Habitat_v_nhi", however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_p_shr**: same as "Habitat_v_shr", however numbers are given as a percentage change between the active and the reference scenario.

- **Habitat_p_shi**: same as “Habitat_v_shi”, however numbers are given as a percentage change between the active and the reference scenario.
- **Habitat_d_nhc**: same as “Habitat_v_nhc”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_ahr**: same as “Habitat_v_ahr”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_ahi**: same as “Habitat_v_ahi”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_thr**: same as “Habitat_v_thr”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_thi**: same as “Habitat_v_thi”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_nhr**: same as “Habitat_v_nhr”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_nhi**: same as “Habitat_v_nhi”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_shr**: same as “Habitat_v_shr”, however numbers are given as an absolute change between the active and the reference scenario.
- **Habitat_d_shi**: same as “Habitat_v_shi”, however numbers are given as an absolute change between the active and the reference scenario.
- **Maori_val**: this branch will contain Maori values of the active scenario.
- **Maori_delta_p**: this branch will contain the percentage change of the same Maori attributes from “Maori_Val”, using information from the active and the reference scenario.
- **Maori_delta_u**: this branch will contain the absolute change of the same Maori attribute from “Maori_Val”, using information from the active and the reference scenario.
- **Doc_val**: this branch will contain Department of Conservation (DoC) values of the active scenario.
- **Doc_delta_p**: this branch will contain the percentage change of the same DoC attributes from “Doc_Val”, using information from the active and the reference scenario.
- **Doc_delta_u**: this branch will contain the absolute change of the same DoC attribute from “Doc_Val”, using information from the active and the reference scenario.
- **Nes_val**: the branch containing the NES related attributes.
- **Other_val**: this branch will contain other/additional values of the active scenario.
- **Other_delta_p**: this branch will contain the percentage change of the same other/additional attributes from “Other_Val”, using information from the active and the reference scenario.

- **Other_delta_u**: this branch will contain the absolute change of the same other/additional attribute from “Other_Val”, using information from the active and the reference scenario.

If the tree is expanded further, the real attributes become visible within the attribute tree, e.g., reliability R1 and R2 within the “Reliability/Value” tree branch:



As R1 and R2 might cover different ranges, each attribute might need non-default values, which are supplied through the “Setup_Model_Small.xml” file. For example, the tool-tip will be unique for each attribute, so a ToolTip entry will be found for each reliability value. For an attribute to appear in the attributes table, the following values are required as a minimum in the file “Setup_Models_Small.xml”:

- **<TreeGroup>**: has to be a string, from the tree group members.
- **<Name_Unique>**: has to be a unique name.

Any new entry in this file will mean coding changes, as the underlying data will need to be generated. Therefore in this file, the user can only make changes to the values of each entry, such as reducing the number of colours, or the range of colours or the colour range, etc.

For example, to change the number of colours for all attributes in the branch “Reliability/Value” so that they are all the same, the following changes need to be made:

- In the “Setup_Models_Base.xml” file, for the <Attribute_Base_Class> with setting <TreeGroup> = Reliability_Val, change the value for <Colour_Num>.
- In the “Setup_Models_Small.xml” file, find the entries for <TreeGroup> = Reliability_Val, and remove the line with “<Colour_Num>…</Colour_Num>” (if present).

To set different colour schemes for “Reliability/Values/R1” and “Reliability/Values/R2”:

- No changes to the file “Setup_Models_Base.xml” are required.
- In the “Setup_Models_Small.xml” file, find the entries for “<TreeGroup> = Reliability_Val”, and then “<Name> = R1” or “<Name> = R2”, and make changes to the entry for “<Colour_Scheme>” accordingly. Any value given in this file will not use the default value supplied by the file “Setup_Models_Base.xml”.

11 Appendix 1: CHES benchmarking

ArcGIS is a software application that runs as a 32-bit process. The following describes the computer used for the benchmark test as listed in the table below:

- Processor: Intel® Core™ i7-3720Qm CPU @ 2.6 GHz, 8 cores
- Install memory (RAM): 8 GB
- System type: 64-bit operating system
- Hard Drive: Solid state hard drive

Table 11-1: CHES test runs where different scenario sizes (e.g., number of reaches, number of abstractions, and model length in years) for comparison.

# of Reaches (#)	# of Abstract. (#)	Model length (years)	Calc. time (MM:SS)	Sum. time (MM:SS)	File Size (MB)
137	0	1	00:02	NA	0.4
137	0	10	00:12	NA	4
137	0	30	00:24	NA	12
662	0	1	00:07	NA	1.9
662	0	10	1:15	NA	19
662	0	30	3:50	NA	56
137	14	1	00:05	00:10	0.5
137	14	10	00:13	00:35	5
137	14	30	00:28	00:15	15
662	49	1	00:09	00:25	2.6
662	49	10	1:08	00:15	26
662	49	30	5:20	0:10	80

Column descriptions:

- # of Reaches: the number of reaches in the selected catchment.
- # of Abstract.: the number of abstractions in the selected catchment (sum of takes, dams, and storage).
- Model length: the length of the set up simulation in number of years.
- Calc. time: the length of time it took the above computer to carry out the simulation.
- Sum. time: the time it took the above computer to generate a summary sheet containing two out-of-stream attributes and four in-stream attributes, and having one scenario versus the base scenario.
- File size: the file size of the output file (netCDF format).

There should be only a minor difference in simulation running and summary generation times if your computer only has four cores, as the above computer only uses four cores out of its eight, and because ArcGIS runs as a 32-bit system and can only use four cores. In addition only 4 GB of memory was used, as ArcGIS can only use this amount, not the supplied 8 GB.

A larger difference in times will be seen with different processor speeds and between solid state and conventional spinning hard disks (the computer above has a solid-state hard disk).

12 Appendix 2: Generation of ETDB

Please see document “GenerationOfExistingTakesFile_CHES.docx” for further information on how to set up the input file of abstractions, that is being used by a MatLab exe file to generate the CHES abstraction input file.

13 Appendix 3: RAT

This section describes the method used to determine the irrigation needs for an abstraction.

CHES is a tool which simulates the surface water flow in respect of surface and ground water abstraction. The abstracted water amount can be supplied from the Existing Takes Abstraction Data Base. However usually this would be the upper take limit, and in respect of irrigation, water may only need to be abstracted from the river if the soil moisture drops below a wilting point. CHES has been extended to include a RAT (Rapid Assessment Tool; Woods et al. (2012)) module that simulates the soil moisture. The RAT uses the following information as input:

- PET: potential evapotranspiration, i.e., the amount of water that would evaporate if a sufficient water source were available. This time series is supplied by the TopNet input files.
- Rain: the natural recharge. This data is also supplied by the TopNet input file.
- Spatial data: further spatial data is required, which is supplied via the spatial input file from TopNet
- Irrigation user information: information in respect of area to be irrigated, crop that is planted, a user specified minimum soil moisture.

With the above information RAT simulates the soil moisture on a daily time step, where soil moisture is recharged with the rain, further reduced due to evaporation, and any additional needed water supplied through the abstraction if possible.

For places such as the wet West Coast of the South Island, water is seldom abstracted, as the natural rain recharges the soil on a continuous basis. However for the drier region of Canterbury, irrigation using abstracted water from the surface and ground water is much more common.

14 Appendix 4: Setting water take rules

CHES can be supplied with Water Take Rules, such as the Proposed NES. For this the user needs to specify three separate aspects:

- As there can be several sub-groups of reaches, the user can group reaches in respect of a flow property. For example, group one contains all reaches with a mean flow smaller than 1 l/s., group two contains reaches with flows between 1 l/s and 10 l/s, and group three contains reaches that have a mean flows larger than 10 l/s. However the user could also use “MALF” instead of “mean”.
- A rule will need the minimum flow limit, which the user needs to specify in some way. It could be given as a constant value for each sub-group, or derived from reach specific property, as 10% of MALF, or 50% of Mean(flow), to just name a few.
- A rule needs the total allocation for each sub-group. Here again, this value for each sub-group could be given as a constant abstraction value, or relative to a reach property, same as for the minimum flow value.

So how is this done in CHES? The information for this is supplied in an XML file, which needs to be modified outside of CHES using the instructions in this section. The file name is “WaterTakeRules.xml” and is found in the Setup folder. An example file is given below, where the proposed NES rules have been implemented.

```
<?xml version="1.0"?>
<WaterTakeRules_Class xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema">
  <WaterTakeRules>
            <WaterTake>
                  <Name>NES</Name>
                  <ReachSelectType>MALF</ReachSelectType>
                  <FlowChangeType>Percent</ FlowChangeType >
                  <Rules>
                        <Rule>
                              <MinFlow>0</MinFlow>
                              <MaxFlow>500000</MaxFlow>
                              <deltaQ>3000</deltaQ>
                              <QManage>9000</QManage>
                        </Rule>
                        <Rule>
                              <MinFlow>500000</MinFlow>
                              <MaxFlow>210000000</MaxFlow>
                              <deltaQ>5000</deltaQ>
                              <QManage>8000</QManage>
                        </Rule>
                  </Rules>
            </WaterTake>
            <WaterTake>
                  <Name>Paul</Name>
                  <ReachSelectType>MALF</ReachSelectType>
                  < FlowChangeType >Percent</ FlowChangeType >
                  <Rules>
                        <Rule>
                              <MinFlow>0</MinFlow>
```

```
                    <MaxFlow>210000000</MaxFlow>
                    <deltaQ>4000</deltaQ>
                    <QManage>9000</QManage>
                </Rule>
            </Rules>
        </WaterTake>
    </WaterTakeRules>
</WaterTakeRules_Class>
```

The following settings are given, and we start off with the more simple ones:

- **<Name>**: a rule with the name "NES".
- **<Rules>**: this states that there are **rules** starting. This is just a key word, indicating that individual groups of reaches (rules) are to follow.
- **<Rule>**: each block of <Rule> to </Rule> contains information on how much water can be abstracted, ("FlowChangeDeltaQ"), the minimum flow setting ("FlowChangeQManage"), and how the reaches are being selected for this sub-group ("ReachSelectMinFlow", "ReachSelectMaxFlow").

For each sub-group the following values need to be given:

- **<ReachSelectMinFlow>**: reaches are selected in respect of a reach specific flow value. The lower bound value is given through the ReachSelectMinFlow value, where the value supplied is in the unit of *100 a.u.. For example, if a value of 190 was given in the setup file, then the value used within CHES is 1.9 a.u..
- **<ReachSelectMaxFlow>**: here the upper bound value for the sub-group is supplied. This value is supplied in the same way as the ReachSelectMinFlow.

After having explained how values are supplied in the setup file, some crucial information is missing: is this minimum and maximum flow value an absolute or a relative value??? For this we have the following two settings:

- **<ReachSelectType>**: the crucial information missing for the reach selection. Values given in ReachSelectMinFlow and ReachSelectMaxFlow are absolute values, but of what?? Hence, here the user has the option of saying that the above values shall be either the in respect of the “Mean” reach flow value or the “MALF” value of the reach.
- **<ReachSelectMulti>**: the user needs to specify what units the ReachSelectMinFlow and ReachSelectMaxFlow are given in. Options are “Flow” and “Percent”.

With the above settings we now have the information needed to fully select reaches for the different sub-groups. Further the minimum flow setting and the total allocation needs to be supplied. This is done with the following parameters:

- **<FlowChangeDeltaQ>**: sets how much water can be abstracted from the river, which must be a number. Value needs to be given in units of *100 a.u.. For example, a value of 100 would be used as 1.00 within CHES.

- **<FlowChangeQManage>**: sets the value for the minimum flow value. The unit is *100 a.u..
- **<FlowChangeType>**: the user needs to specify the "units" for the above values. Options are "MALF" and "Mean". If "MALF" has been selected, then the FlowChangeDeltaQ and FlowChangeQmanage are given in respect of MALF.
- **<FlowChangeMulti>**: the last setting is the FlowChangeMulti, and has the options of "Flow" and "Percent". For example, FlowChangeMulti is "Percent", FlowChangeType is "Malf" , FlowChangeDeltaQ is 3000 and FlowChangeQManage is 80000, then the ΔQ and Q_{min} are as follows: ΔQ = 30% of MALF, Q_{min} = 800% of MALF.

15 Appendix 5: Spot data

This section describes how reach specific flow attribute relationships can be incorporated into CHES. This attributes/relationships can be used for the map plotting and summary generation.

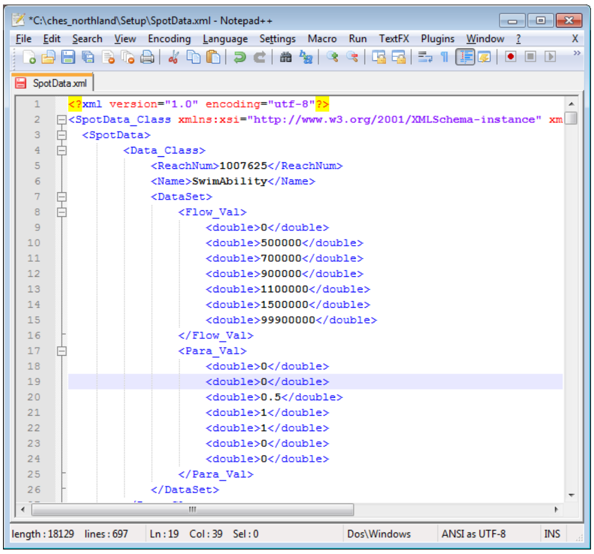
This will be explained with an example:

Imagine that one knows for a single location (NZReach 1007625) the swim ability of the river reach:

No swimming below 5 m^3/s, average swim ability around 7 m^3/s, perfect swim ability between 9 and 11 m^3/s, and no swim ability for a flow above 15 m^3/s. This could be represented in the following way:

Flow (m^3/s)	Swim ability (0..1)
0	0
5	0
7	0.5
9	1
11	1
15	0
999	0

Below is a screen shot of the entries for a single reach:



The entries for element (<Data_Class>) are:

- **ReachNum**: the reach number of the reach from which the flow relationship has been given.
- **Name**: the string of the name.
- **DataSet**: indicates that below this the flow-attribute relationship is given. It contains the following two entries:

- **Flow_Val**: this will contain the flow values in units of l/s * 100. Each flow value needs to be supplied individually, as a value between the labels: <double> and </double>, e.g.:
  - <double>500000</double>, which is the flow value of 5000 l/s.
- **Para_Val**: this will contain the attribute value (units of a.u., here no prior multiplication is required). Each value needs to be supplied individually, and in the same way as the “Flow”Val” value, e.g.:
  - <double>0. 5</double>, which is the attribute value of 0. 5.

16 References

Cengel, Y.A., Cimbala, J.M. (2006). Fluid mechanics fundamental and applications. (2nd ed.). New York: Mc Graw Hill

RAT: Woods et al., Hydrosoc 2012.

MIWA: Hicks, D.M.; Shankar, U.; Booker D.J.; Poyck, S. (2009). "MIWA: a tool for mapping the impacts of water allocation schemes on river morphology." Presentation to the New Zealand Hydrological & Freshwater Sciences Societies Joint Conference, Whangarei, Northland, 23-27 November 2009. Index record, see source title. A conference jointly hosted by The New Zealand Hydrological Society and the New Zealand Freshwater Sciences Society 23rd - 27th November 2009 Forum North Whangarei. 331 p.; 30 cm.

MfE 2008: Proposed National Environmental Standard on ecological flows and water levels. *Ministry for the Environment Discussion Document*, ME 868: 61.

Khatsuria, R.M. (2004): Hydraulics of Spillways and Energy Dissipators, Marcel Dekker, New York, 2004, Section 4.3.

Jowett, I.G., Hayes, J.W., Duncan, M.J. (2008) A guide to instream habitat survey methods and analysis. *NIWA Science and Technology Series No. 54*: 121.

Booker, D.J. (2016) Generalized models of riverine fish hydraulic habitat, Journal of Ecohydraulics, 1:1-2, 31-49

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