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**Best practice guide for
hydraulic model
export**

Report

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Foreword

Edition 1

This is the first edition of this code of practice.

Concepts

This manual is intended to give best practices regarding the creation of EPANET models intended for KWR researchers created by modelers of water utilities.

Specific terms with their description are mentioned here or reference is made to an annex.

Composition of the project group

The supervision of the creation of this code of practice was done by the participants of the "Platform Leidingnetmodelleurs" in which modellers of Brabant Water, Dunea, Vitens, de Watergroep, Waterbedrijf Groningen and WMD participated in 2019-2021.

Management of the Code of Practice

Comments or comments regarding the design and/or content of this Code of Practice can be sent by e-mail to KWR Watercycle Research Institute: Martin.Meerkerk@kwrwater.nl. If applicable, this will be used as input for a next edition of the document.

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1 Introduction

Hydraulic network models are efficient decision support tools used for the effective management of water distributions networks (WDNs). Hydraulic network models provide multiple benefits to the WDNs such as:

- allowing for the testing of scenarios and will predict the behaviour within the WDN,
- improve the reliability and efficiency of an existing network design,
- optimize a new network design,
- assist in water quality analysis (e.g. water temperature, lead dispersion, discoloration, etc.), and
- support decision making process of operations and maintenance.

EPANET (current version 2.2) is a commonly used open source tool used for the development of hydraulic network models and their applications. EPANET files can be used by any programming language, manipulated easily, and commonly used in the research community. Additionally, new water analytic tools such as Gondwana, Vlindernet, Stormwater Management Model, pyswmm, WNTR, epanet-dev, etc. are based on the EPANET tool.

In this document, the best practices of hydraulic network models development and export are discussed. The success of the hydraulic models predictions is dependent on the accuracy of the input parameters and on calibration of the model. KWR researchers often work with hydraulic network models of the utilities to test their tools. Experience has taught us that it often costs a lot of time, going back and forth between researchers and modellers of the utilities, before an EPANET model is up to the standard where it can be used in research. This document describes the required standards and how to achieve those.

2 Information required: hydraulic network model

2.1 Information that is required in the header of the EPANET model

Use the following check list when preparing the hydraulic network model for export, all of the following information must be included and put into the header of the EPANET model (this ensures that no information gets lost when models are reused later):

- Project number of current project
- Name of contact person for this project
- Name of the person that created the EPANET model
- Date the model was submitted for this project
- Date of creation of the model
- Last update of the model (year)
- The purpose for which the model has been created (e.g. which project)
- Definition of demand pattern used for this model (average day, max day, holiday, specific day as taken from SCADA, etc.)
- Explanation of the meaning of e.g. “max dag”?
- Additional information considered relevant, e.g. has the model been skeletonized? Which criteria has been used? Is the model calibrated or not?
- Source of the model (e.g. InfoWorks model X date Y)
- Degree to which recent changes in the physical network have been included in the network model
- Allocation of number of customers linked to the demand junctions or pipes in a separate file. In some cases, this information is included in the section [DEMAND] of the INP file, but it is not always the case.
- Clarify which production plant is represented by each of the sources in the INP file. This is very useful in the case of the risk analysis of the production plant.

2.2 Information that is required for EPANET models

Use the following checklist when preparing the hydraulic network model for export; make sure all of the following information is current and applicable to the project:

- Elements of the Network: pipes, nodes, valves, pumps, etc.
- Clearly identify sources- represented by reservoirs or pumps.
- Verify all base demands and demand patterns.
- Check valve statuses
- Identify at least one pressure boundary condition.
- Clearly distinguish what in the network is pipes or valves.
- Clearly distinguish what is the network is a node or hydrant.

3 Common issues and other considerations for the creation of EPANET models

When creating the INP file, incorrect or missing data will result in error messages. Therefore, results will not be given and a textbox (Figure 1) will appear explaining why the error has occurred e.g. negative pressures, disconnected nodes, missing time patterns, etc.

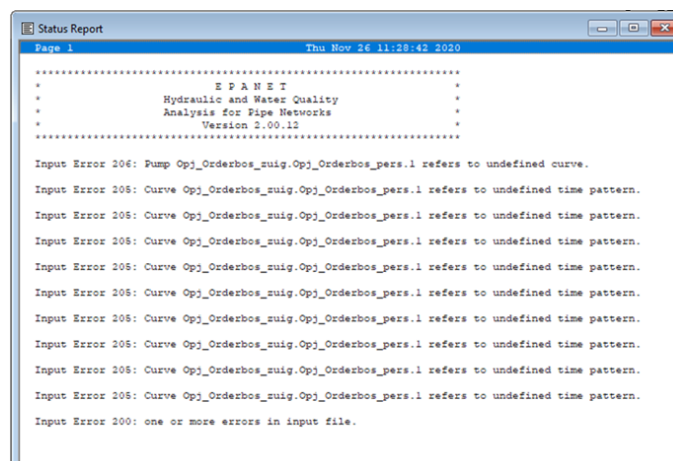


Figure 1 Example of errors occurring in an INP file

The following list includes common errors that can lead to error messages in EPANET:

- IDs elements length: EPANET has limitations on the number of characters used as ID for identifying the various elements in the model (Rossman, 2000). The maximum number of characters that can be used for each element ID is 31.
- IDs elements when using Epanet-MSX: if the hydraulic model is used for water quality simulations that imply the use of Epanet-MSX, keep in mind that names with “-” will give an error, so you will need to change the “-” for instance with a “_”. E.g. “Buiten-Almere.Almere1.1” becomes “Buiten_Almere.Almere1.1”
- Demand patterns: always check that the demand patterns assigned at the nodes have been exported in the INP file in the section [PATTERNS], including both residential and non-residential types. The minimum total patterns time is usually 24 hours. A maximum time step of 15 min is recommended, but take into account that these values can vary based on the purpose of the hydraulic model.
- Pumps: be sure that the corresponding head curve is available in the case that pumps are included in the INP file.
- Pump curves: should start from larger to smaller, in terms of head.
- Tanks: important information to make them work properly are the dimensions and the levels (initial, min and max level).
- Demand nodes: in the case that after running the model a node is disconnected, be sure that the adjacent pipe(s) are in the status OPEN.
- Partial hydraulic model: in the case that only part of the network is requested, do not forget to add in the INP the transfer nodes (see Annex I: How to model some elements in EPANET for more information) and the appropriate flow pattern to avoid to compromise the water balance.
- Valves: they usually give problems when Using EPANET-MSX. In this case the best option is just to remove them from the model.

- Status: pipe status can be set in pipe section, valve status should be set in status section.
- Controls and rules: if existing, they have to be imported in the INP file, check the keywords from EPANET documentation.
- Calibration: it is common that the hydraulic models are not calibrated. This implies that the water balance in the model might differ, even significantly, from measurements in the real system.
- Skeletonization: in some application, it is not necessary to keep a very detailed model. Is important to define correctly the criteria to use before simplifying the model, based on the usage of the model in a project. Another option is to let KWR skeletonize the model on our own criteria.
- Leakage: manually assign leakage size at node or automatically decide by hydraulic simulation at new leakage point on the pipe, in WNTR package. If not applicable, please make this explicit
- EPANET-MSX: at the moment it works only with the EPANET 2.0. The version for EPANET 2.2 has not been released yet.

4 General advice

4.1 For EPANET file exporters

- After the creation of the INP file it is requested to run the INP file to check whether the model runs without errors, such as negative pressures or the presence of disconnected nodes. Use EPANET 2.2 for most applications, for applications that will require EPANET-MSX use EPANET 2.0 (United States Environmental Protection Agency, 2022) (<https://www.epa.gov/water-research/epanet>)
- Always check that the total water balance of the system in the EPANET model corresponds with the original model. If using a package such as Infoworks, a good practice is also to take the flow/pressure time series of some nodes to make a comparison between the two models.
- Make sure that you have a conversion table between EPANET node/pipe ID's and GIS ID's. When assigning IDs to nodes, pipes, etc. always make sure that they have correspondence in the GIS. As an example, a possible solution might be to customize the GIS with a column containing the IDs that the various elements have in the model. This is particularly important when it is necessary to look for additional characteristics that are not contained in an INP file, e.g. the pipe material, wall thickness of the pipe and the burial depth. When one changes the IDs of the elements in the INP file, ensure always that it is possible to match them with the GIS IDs.
- Build the hydraulic model based on the purpose for which it will be used.
- When in doubt of whether information is necessary contact the user (KWR) of your exported file.

4.2 For users of the exported file

- Always make sure that the INP eventually generated during the development of a project (e.g. an INP file containing the results of an optimization design) can run in Infoworks without errors.
- In case the hydraulic model requires specific characteristics, make the requests to the modellers as soon as possible. Use the checklists in Chapter 2 Information required: hydraulic network model
- In case specific demand patterns and time steps are needed, make the request clear to the modeller.
- Prepare a centralized workspace to keep the track of customized modification of general useful tools, that would be interesting.
- Use WNTR package.
- Always check the final version of EPANET model with experts in water companies. Check its outputs (pressure, flow) with the outputs of their model.

5 References

Rossman, L. A. (2000). *EPANET 2: users manual*.

United States Environmental Protection Agency. (2022, February 1). *EPANET: Application for Modeling Drinking Water Distribution Systems*. <https://www.epa.gov/water-research/epanet>

I Annex I: How to model some elements in EPANET

One area that commonly causes errors are Feeding Points. The feeding points of a network model in EPANET can be simulated in two different ways:

1. Using a reservoir and assign the reservoir a fixed pressure or a pressure pattern.
2. Using transfer nodes and assigning a flow pattern to them (potentially with negative flow).

The latter is also used when we have the need to simulate flows that can both enter or leave the system, because the network model is part of a larger supply area. When the flow is “entering”, the demand at the node has to be negative and the opposite when the flow is “leaving” the system. For this purpose, a negative base demand can be assigned to the node while the sign of the multipliers of the correspondent demand pattern will determine in each time step if the flow is negative (multiplier positive) or positive (multiplier negative). See in Figure 2 an example of transfer node.

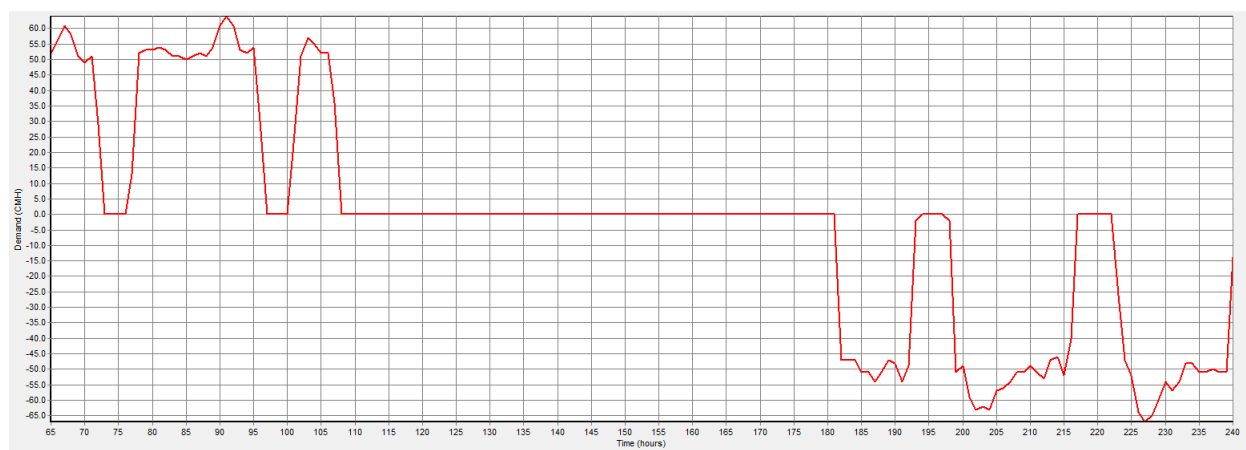


Figure 2 Example of flow in a transfer node

II Annex II: Extra information for Infoworks users

The model in Infoworks is layered:

- the first layer is the **Network**,
- the second layer consist of **Control** (i.e. pumps, valves and scenarios),
- finally the third layer consist of **Demand (pattern) Diagram**.

To export the model each layer should be exported.

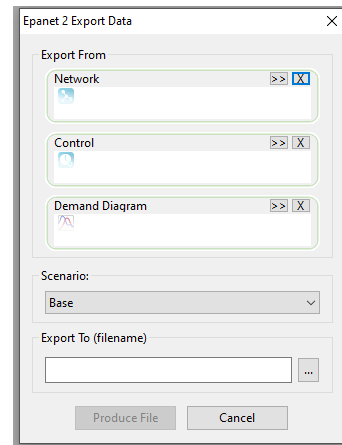


Figure 3 Infoworks EPANET 2 Export Data

II.I Import/export INP files To export data to an Epanet file:

- In the Model Group window or Explorer window, right-click the network model you want to export.
- Select Export To EPANET v2 file: this displays the EPANET 2 Export dialog (see).
- Optionally, select a control object and/or demand diagram to be exported from the dropdown list.
- Select the location to which the file is to be exported by clicking the ellipsis button in the **Export To (filename)** section.
- Click the **Produce File** button to carry out the export.

The file will always be saved with a default file extension .Inp.

To import a scenario or Network into EPANET:

- Select File >> Import >> Scenario or Network from the main menu.
- Use the Open File Dialog box that to select a scenario file to import.
- Click the OK button to accept your selection.

Item	Description
Export From	Network The network for which you started the export. You can change to another network if you want to. By default, the latest version of the network will be exported. If you wish to export another version, you can use the # button to open the Select Commit dialog.
	Control Optionally, a control to include in the export. By default, the latest version of the control will be exported. If you wish to include another version in the export, you can use the # button to open the Select Commit dialog.
	Demand Diagram Optionally, a demand diagram to include in the export.
Scenario	If the network has more than one scenario, you can choose which one to include in the export from the dropdown list.
Export To (filename)	The text box contains a suggested name for the export file. You can change this name if you want to. The ellipsis button opens a standard Windows Save As dialog for selecting the location to which the file is to be exported.
Produce File	Carries out the export.

Figure 4 EPANET 2 Data Dialog

Case Study Example (De Watergroep): The export function in InfoWorks have only 3 basic elements (network, control, demand diagram). However, models can have more elements such as, demand scaling. These additional elements need to be added to the basic model elements, for example the valves and pumps of the UPC scenarios can be added to the control objects, demand scaling can be added to the demand diagram. The UPC scenario can have more than one selection lists (see Figure 4 EPANET 2 Data DialogFigure 4) that can be chosen from the dropdown list to export.

II.II General information about InfoWorks toolbars

The below figures (5-9), show the toolbars that make editing the objects and scenarios possible. Especially the Scenario toolbar is an interesting one, to manage the scenarios and group commands, when there are more scenarios in the network. The selection toolbar is useful to group together commands that are used on a selection of network objects (see figure 9).

The toolbars can be shown or hidden, or the buttons on the toolbars re-organised. See [Customising the Toolbars](#).

- + File Toolbar
- + Edit Toolbar
- + Windows Toolbar
- + Docking Windows Toolbar
- + Scenarios Toolbar
- + Replay Control Toolbar
- + Results Toolbar
- + Validation Toolbar
- + GeoPlan Tools Toolbar
- + More GeoPlan Tools Toolbar
- + 3D Navigation Toolbar
- + GeoExplorer Toolbar
- + Modelling Grid Windows Toolbar
- + Selection Toolbar
- + Shared Actions Toolbar
- + User Actions Toolbar

Figure 5: InfoWorks Toolbar (source: https://help2.innovyze.com/infoworksicm/Content/HTML/ICM_IN_ILCM/InfoWorks_Toolbars.htm)

File Toolbar

Contains buttons for various basic file operations.



File Toolbar	
	Create a New Master Database. Enables typing of a new master database name as well as path selection.
	Create a New Transportable Database. Enables typing of a new transportable database name as well as path selection.
	Select a Master Database. Enables selection of a master database.
	Open a Transportable Database. Enables selection of a transportable database.
	Print the Current Active Window .
	Enables changes made in the current network to be copied to the master database. The network will be updated with any changes made by other users. Any conflicts must be resolved before changes can be committed. See Committing Your Changes for more information.
	Update the current network with any changes committed to the master database by other users. If conflicts occur a warning message will be displayed.
	Revert all changes on the current network made since the last commit.
	This button displays the User Defined Flags Dialog.
	This button displays the InfoWorks ICM About Box.

Figure 6: File toolbar

Edit Toolbar

Edit Toolbar

This toolbar contains buttons for the basic editing operations.



Edit Toolbar	
	Undo last data transaction. You can reverse the most recent action performed on your data. You can undo several times by repeatedly clicking this button, but you cannot undo past an update or a commit.
	Redo last data transaction. You can redo the most recent undo action performed on your data. You can redo several times by repeatedly clicking this button, but you cannot redo past a master database update or a commit.
	Click on the down arrow to list up to five actions that can be undone / redone. You can undo the most recent action and redo the most recent undo action from this list.
	Cut data and place it on the clipboard. Functionality mainly available in the grid windows.
	Copy data to the clipboard. Functionality available in the grid windows.
	Paste data from the clipboard. Functionality available in the grid windows.
	Use this button to toggle the Edit Flag feature on and off. When the feature is active, this button appears depressed, and the dropdown list is available. See Data Flags .
	Use this dropdown list to select the flag that will be used as the Edit Flag.

Figure 7: Edit Toolbar

- + File Toolbar
- + Edit Toolbar
- + Windows Toolbar
- + Docking Windows Toolbar
- Scenarios Toolbar

This toolbar groups together commands that are used primarily when working with scenarios. Scenarios are networks derived from a base network specified by the user, on which "what-if" scenarios can be investigated. See the [Scenarios](#) topic for further details.



Scenarios Toolbar	
	Create a new scenario. Clicking on this button displays the <i>Create New Scenario</i> dialog, where the name of the new scenario can be entered and where it can be specified if it is to be copied from the base network or an existing scenario.
Base	Indicate which scenario is current . Select the current scenario by choosing from the list. "Base" signifies that the current scenario is the base network, from which scenarios derive.
	Delete the current scenario. This buttons allows the user to delete the current scenario. This button is disabled if the base network is the current scenario.
	Rename the current scenario. When this button is clicked, the <i>Rename Scenario</i> dialog is displayed, allowing the user to enter a new name for the scenario. This button is disabled if the base network is the current scenario.
	Manage scenarios. Clicking on this button displays the <i>Manage Scenarios</i> dialog. A large variety of tasks can be performed on scenarios from this dialog (creating a new scenario, deleting the selected scenario, merging scenarios, making a scenario as the base network).
	Display a grid of excluded objects. Excluded objects are objects that are present in the base network but not in the current scenario. These objects are shown with high transparency in the GeoPlan view of the scenario and their properties can be seen in this grid. The grid is organised in tabs to accommodate for each object type.
	Restore selected excluded objects. Clicking on this button restores a <i>selection of excluded objects</i> in the current scenario. The user is prompted to confirm the restore action. This button is disabled if the base network is the current scenario.
	Restore excluded objects. Clicking on this button restores ALL the excluded objects in the current scenario. The user is prompted to confirm the restore action. This button is disabled if the base network is the current scenario.

Figure 8: Scenarios Toolbar

- Selection Toolbar

The Selection Toolbar groups together commands that are used on a selection of network objects.



Selection Toolbar	
	Click on this button to display the <i>SQL Dialog</i> . You can select network objects using an SQL Query. See SQL Queries .
	Click on this button to group all currently selected network objects of the correct type at the top of the current grid window.
	Select all objects in the network. If the <i>Excluded object select tool</i> or <i>menu option</i> is turned on, then all excluded objects will also be selected.
	De-select all currently selected network objects. If the <i>Excluded object select tool</i> or <i>menu option</i> is turned on, then all selected excluded objects will also be de-selected.
	Invert the current selection. Use this button to de-select all objects that are currently selected, and select all those that are currently not selected. This also applies to any selected excluded objects if the <i>Excluded object select tool</i> or <i>menu option</i> is turned on.
	Select all objects contained in the currently selected Polygon object. See Using Polygons for more information. This also applies to any excluded objects within the currently selected polygon if the <i>Excluded object select tool</i> or <i>menu option</i> is turned on.
	The link reversal tool allows you to quickly reverse the direction of selected links. This is particularly useful if you are having problems using the <i>Network Trace</i> tool to trace the route to an outfall.
	Delete all currently selected network objects.
	Selects excluded network objects from any <i>scenario</i> except the base network. Enabled when an applicable scenario is open in the currently active GeoPlan window, and the Show base scenario object ghosts option is checked in the <i>Visual</i> tab of the GeoPlan properties.
	Click this button to switch on the <i>Excluded object select tool</i> . Then click on an excluded object. The selected excluded object is displayed in a faded red colour. To select several excluded objects, hold down CTRL and then click on individual excluded objects. These are added to the current selection. Clicking on a selected excluded object while CTRL is held down removes the excluded object from the selection. To go to the appropriate record on the Excluded grid window, hold down CTRL+shift and double click on a network object.

Figure 9: Selection Toolbar

II.III Pipes and valves

Link data is exported to the [Pipes], [Pumps] or [Valves] section of the .inp file

Pipe data is exported to the [Pipes] section of the .inp file.

Pump station data is exported to the [Pump] section of the .inp file. For multi-pump stations, each pump is exported as a separate Epanet pump.

Pump station Bypass, if the IWWS PST Bypass option is checked, a separate pipe is exported to the [Pipes] section with the same ID as the PST appended by `_BP`. Status is set to CV (unless the IWWS PST **Pipe Closed** option is checked, in which case **Status** is set to **Closed**).

If **Control** data is exported in conjunction with the network, valves with the IWWS **Pipe Closed** option checked will be exported to the [Status] section of the .inp file.

Float Valve data is exported to the [Valves] section of the .inp file.

Back feed pipes, if the IWWS float valve Backfeed Pipe option is checked, a separate pipe is exported to the [Pipes] section with the same ID as the Float Valve appended by `_BF`. EPANET NODE 1 and NODE 2 are reversed and STATUS is set to CV (unless the IWWS Float Valves **Pipe Closed** option is checked, in which case **STATUS** is set to **Closed**)

Non Return Valve data is exported to the [Pipes] section of the .inp file. The EPANET Pipe STATUS is set to CV by default.

Meter data is exported to the [Pipes] section of the .inp file. If the meter loss coefficient is set, this is added to the pipe local loss after accounting for any difference between the pipe and meter diameters.

Tip: In infoworks try to convert valves into pipes, if they are not necessary in the model. Before exporting create a new .inp file with converting valves into pipes.

EPANET Parameter	IWWS Export
ID	Constructed from the From Node ID, To Node ID and Link Suffix of the IWWS Link: <From Node ID>.<To Node ID>.Link Suffix (Spaces in node names will be replaced by underscores.)
Status/Setting	CLOSED

Figure 10: IWWS export

II.IV Exporting nodes

Node data is exported to the Junctions, Reservoirs or Tanks section of the .inp file, depending on the type of node. The X and Y coordinate of the nodes are exported to the [Coordinates] section of the .inp file.

- **Basic nodes** data is exported to the [Junctions] section of the .inp file.
- **Reservoir node** data is exported to the [Tanks] section of the .inp file. Any demands allocated to the reservoir are exported in the same way as demand allocated to Basic nodes.
- **Transfer node** data is exported to the [Junctions] section of the .inp file in the same way as Basic nodes. If Control Data is exported in conjunction with the Network, Transfer Node Flow Control data is exported to the [Demands] section of the .inp file.
- **Fixed Head node** data is exported to the [Reservoirs] section of the .inp file.
- **Hydrants** data is exported to the [Junctions] section of the .inp file.
- **Well** data is exported to the [Junctions] or [Reservoirs] section of the .inp file.
 - If Control Data is not exported in conjunction with the network, or the well is Drawdown mode, well data is exported to the [Junctions] section of the .inp file (see Basic Nodes)
 - If Control Data is exported in conjunction with the network and the well is in the profile mode, well data is exported to the [Reservoirs] section of the .inp file.

Tip: ID names of the objects (nodes) should not be too long, this will give an error. The starting node and the ending nodes names will come together and this will produce a very long name that gives an error. To avoid this, the ID names should be kept as short as possible.

EPANET Parameter	IWWS Export
ID	Node ID (Spaces in node names will be replaced by underscores.)
ELEVATION	Elevation
BASE DEMAND FLOW	Average demands are calculated and exported to [DEMANDS] section
DEMAND PATTERN ID	Demand patterns are exported to [PATTERNS] section

Figure 11: parameters and their export mode in .inp file.

II.V Export pressure/demand patterns

Demand at a node is converted into an averaged demand value and exported to the [Demands] section of the .inp file. If a Demand Diagram is exported into conjunction with the network, the demand diagram categories used by the network are exported to the [Patterns] section of the .inp file.

EPANET Parameter	IWWS Export
PATTERN ID LABEL	Demand Category Name
MULTIPLIERS	<p>Demand Category Daily Profiles</p> <p>If the Demand Category profile timestep is greater than the timestep set in the [TIMES] section of the .INP file, additional multipliers will be added to the EPANET pattern to conform to the EPANET timestep.</p> <p>The status of the Linear Interpolation option for the IWWS Demand Category will be taken into account when inserting additional multipliers.</p>

Figure 12: Demand Parameters and their export mode in .inp file.

II.VI Skeletonizer

Skeletonizer option can be selected, to decide how to skeletonize your network automatically. This can be found under Tools Menu Bar and have different options to skeletonize the parameters as preferred.

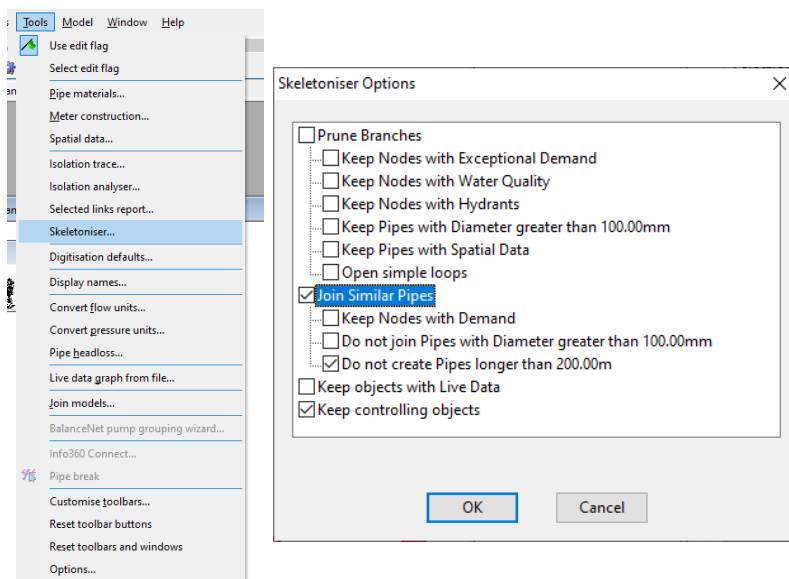


Figure 13: Skeletonizer tool and it options.

II.VII Change the IDs of elements

Model explorer → Command Center → Utilities group and then double click on Change ID. In Target Element Type, from the drop-down menu select the type of element for which you want to change the ID. Then type the Old ID and the New ID. When done, click on Apply. To perform a mass edit, open the database where the subject ID's are stored. Highlight and copy the ID's and paste the values into a software like Microsoft Excel. Next to each ID, enter the new value for the ID. Highlight all old and new ID's in Excel and use Ctrl+C to copy the highlighted area. Go back to Infoworks, use the Set Rows command to make the rows the same as those in the Windows clipboard. Once this is done, highlight the first cell in

the Change ID dialog box and use the Ctrl+V function to paste the values from the clipboard. Click Apply to change the ID's.

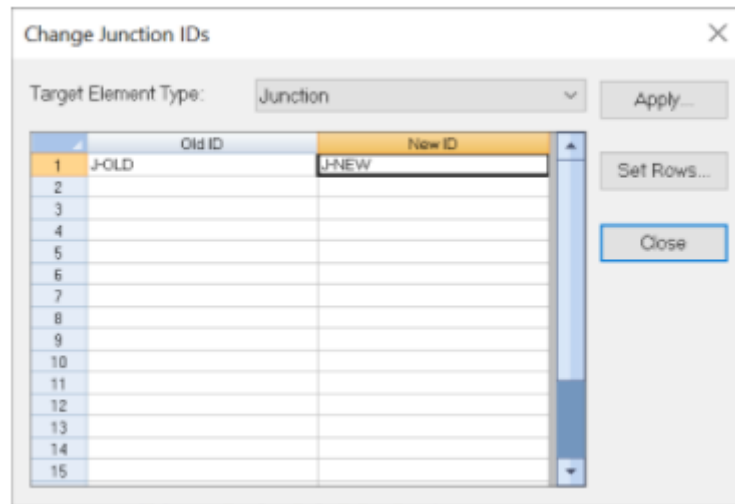


Figure 14 Infoworks windows to change the Ids of elements of the model.

Suggestion: It is useful to use the GIS names, when creating a network in infoworks. This is because it is easier to track back the links and other parameter, and the named used in GIS are less than 30 characters, which avoid the risk of having long names that cause an error by export.