Integrated Modelling

In this guide we introduce integrated modelling. You will load three projects containing a combination of 1D and 2D modelling components and simulations. For each, you will build the linked components needed to combine the relevant aspects and learn which data is required within the simulation itself to define the links. Finally, you will setup and run three fully integrated simulations and view the results from these.

Introduction

In the previous ‘Getting Started’ guides, we investigated 1D modelling and looked in detail at a river network and an urban network. We also considered 2D modelling, and created a model representing a floodplain in 2D.

Integrated modelling incorporates 1D river, 1D urban, and/or 2D modelling components with additional linking elements to enable them to exchange information dynamically as a simulation runs. This enables the user to take advantage of the best aspects of each modelling type.

In this guide, we will look at building these additional linked elements, and adding them to the simulations. This will be split into three parts: integrating river networks and 2D components, integrating river and urban networks, and integrating urban networks and 2D components.

We assume (and highly recommend!) readers of this guide have previously completed ‘Getting Started – Essentials’, ‘Getting Started – River Modelling’, ‘Getting Started – Urban Modelling’ and ‘Getting Started – 2D Modelling’ which can be accessed here.

Please note that there are a variety of ways to undertake different tasks in Flood Modeller. Throughout this guide, we provide details of selected methods only.

We will use data contained in the IntegratedModelling folder for this tutorial, which can be found within the GettingStartedData folder. Access this here if needed.

Tip: We recommend reading the entirety of each instruction, including the labels on the image provided, before carrying out each step.

Part One: River and 2D

You can integrate river networks and 2D components to allow (for example) water overtopping a riverbank to flow onto the floodplain. To integrate a river network and 2D components, you must first create the 'link-lines' to indicate which nodes are connected, and how the flow is transferred at each. The 'River 1D / 2D Link Line Generator' tool can be used to draw these link-lines directly onto the map view. After defining the link-lines, an integrated 2D simulation can be set up. This needs to specify your link-lines file and 1D river simulation, alongside your 2D components.

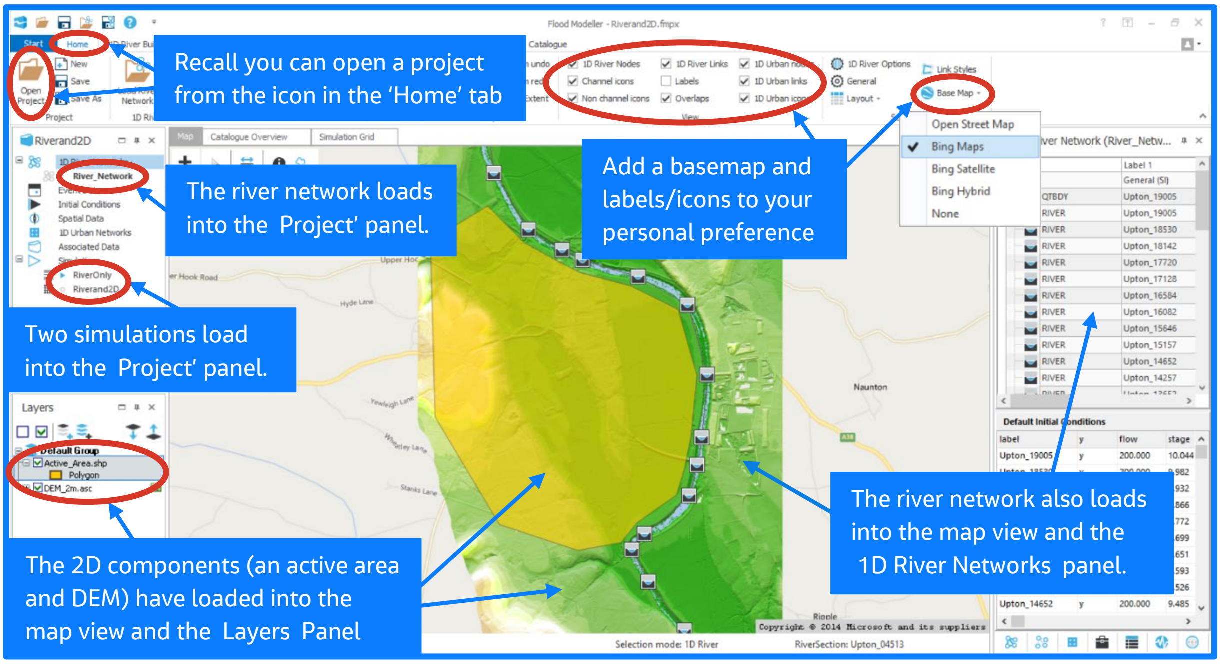
In the first part of this guide, we will integrate a river network and 2D modelling components. We will run a fully integrated simulation, allowing us to capture not only water overtopping the river and entering the floodplain, but also flowing back into the river as the topography allows.

Let's get going!

Step 1

Open the project Riverand2D.fmpx (in the IntegratedModelling>Riverand2D folder)

Various 1D river and 2D components will load into the interface – these should all be familiar and the guides 'Getting Started: River Modelling' and 'Getting Started: 2D Modelling' should be referred to for further details as needed.

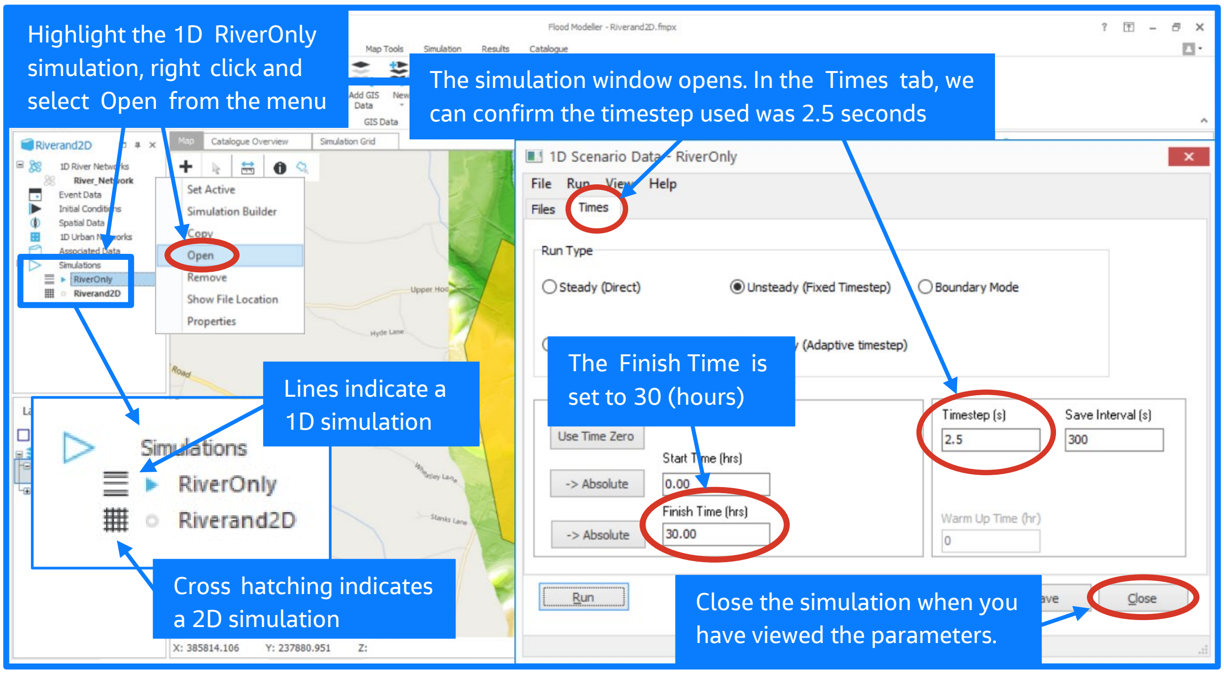


Tip: In the 'Layers' panel, right-click DEM_2m.asc and hover over 'Colour Ramps' to select a terrain option from the default list provided. Recall from 'Getting Started – 2D Modelling' an option such as 'Terrain_Hillshading' is most appropriate.

Step 2

Open the 1D simulation called 'RiverOnly'. The blue arrow to the left of the simulation name indicates the results are already available for this simulation.

Take note of the timestep used for this 1D simulation. This will be important when setting up the integrated simulation. Also notice the end time has been provided as 30 hours; we will set our integrated simulation to run over the same period. Close the 1D simulation after you have viewed the parameters used.



Step 3

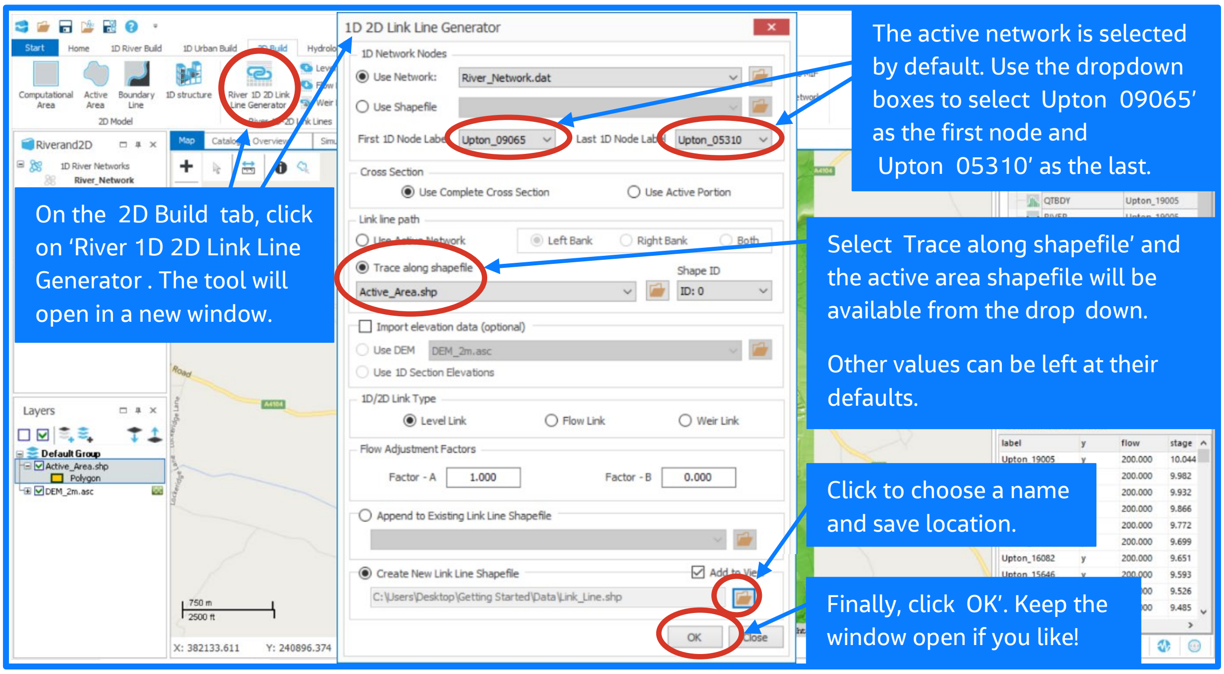
The first part of integrating river networks and 2D components is to create a link-line. This will determine where and how water can transfer to and from the river.

Use the ‘River 1D/2D Link Line Generator’ to create a link-line from Upton_09065 to Upton_05310. Trace along the active area shapefile to define the path for your link-line.

For this tutorial, we will consider the default link type of ‘Level Link’. This is typically used for flood flows discharging laterally into the floodplain over natural or non-walled banks (i.e. those without a linear defence). The water level in the river is calculated and passed to the 2D, and the discharge is extracted from/applied to the river network as a lateral outflow/inflow.

Please see the user manual for further details on ‘Weir Link’ types (typically used for flood flows discharging laterally into the flood area over a linear defence) and ‘Flow Link’ types (appropriate for a river discharging into a 2D area downstream, e.g. river modelled in 1D; estuary modelled in 2D).

Choose a filename and save location and click ‘OK’ to finish your link-line.

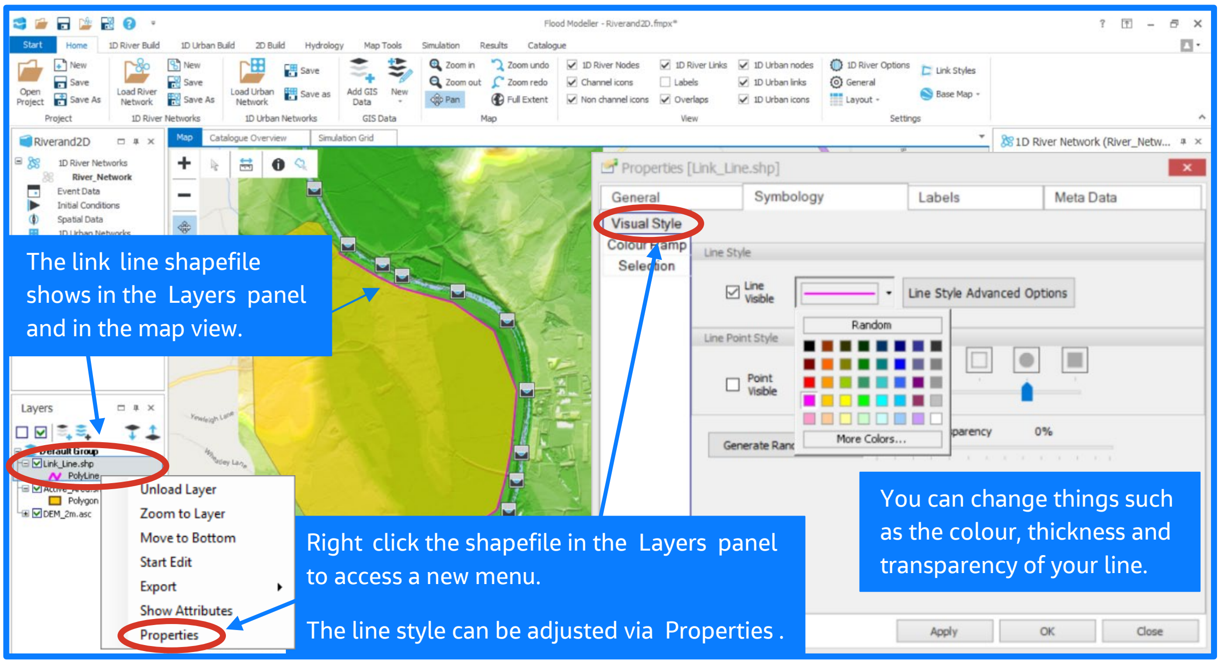


Note: If we were choosing the path based on the active river network, we would need to select ‘Right Bank’ as left/right is determined as if looking at the river *downstream*.

Step 4

Your link-line will now show in the map view. The shapefile is also added to 'Layers' panel. Adjust the visual style of the shapefile as needed to make the line more visible on the map.

Your link-line is now ready to use! Don't forget to save the project to add this shapefile to the other project files.



Step 5

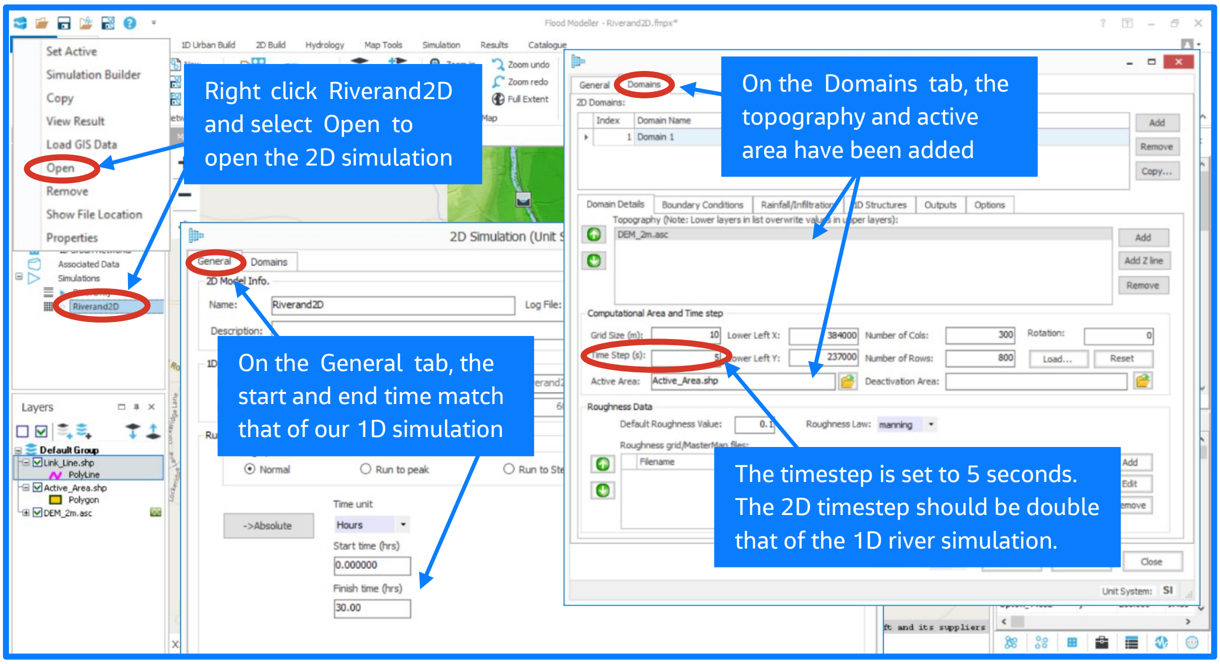
The second part of integrating river networks and 2D components is to add the 1D components and the link-line to a 2D simulation.

Open the 2D simulation ‘Riverand2D’ (or you could start a new 2D simulation here!).

You will notice the topography and an active area have been defined, and the run timing details are also already provided. This should all be familiar from ‘Getting Started: 2D Modelling’.

Note that the timestep (in seconds) is half of the grid size (in meters); we recall from ‘Getting Started: 2D Modelling’ that this is the recommended setup.

Also note the timestep is twice that of the 1D only simulation (from step 2 above). For integrated modelling, it is required that timesteps are multiples of each other, and recommended that a 2D timestep used is double any 1D timesteps used.

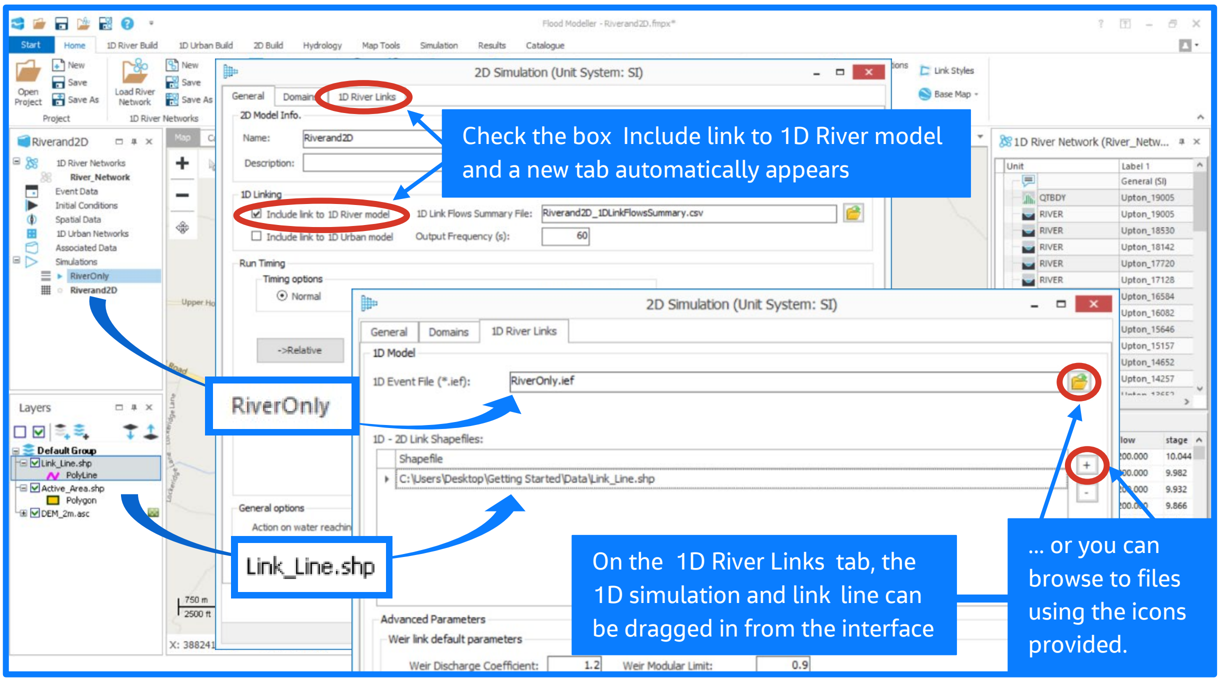


Step 6

Add the 1D components to the 2D simulation by navigating to the ‘General’ tab and simply checking the box provided to ‘Include link to a 1D River model’.

You will notice a .csv filename automatically populates the field immediately to the right – this file will be created at runtime and contain a summary of the flows across the linked aspects (the link-line, in this case).

A new tab will also automatically appear entitled ‘1D River Links’. In this new tab, fields are provided for the 1D river simulation file ‘RiverOnly.ief’ and your link line shapefile. These can be dragged over from the ‘Project’ and ‘Layers’ panels or browsed to via icons provided.



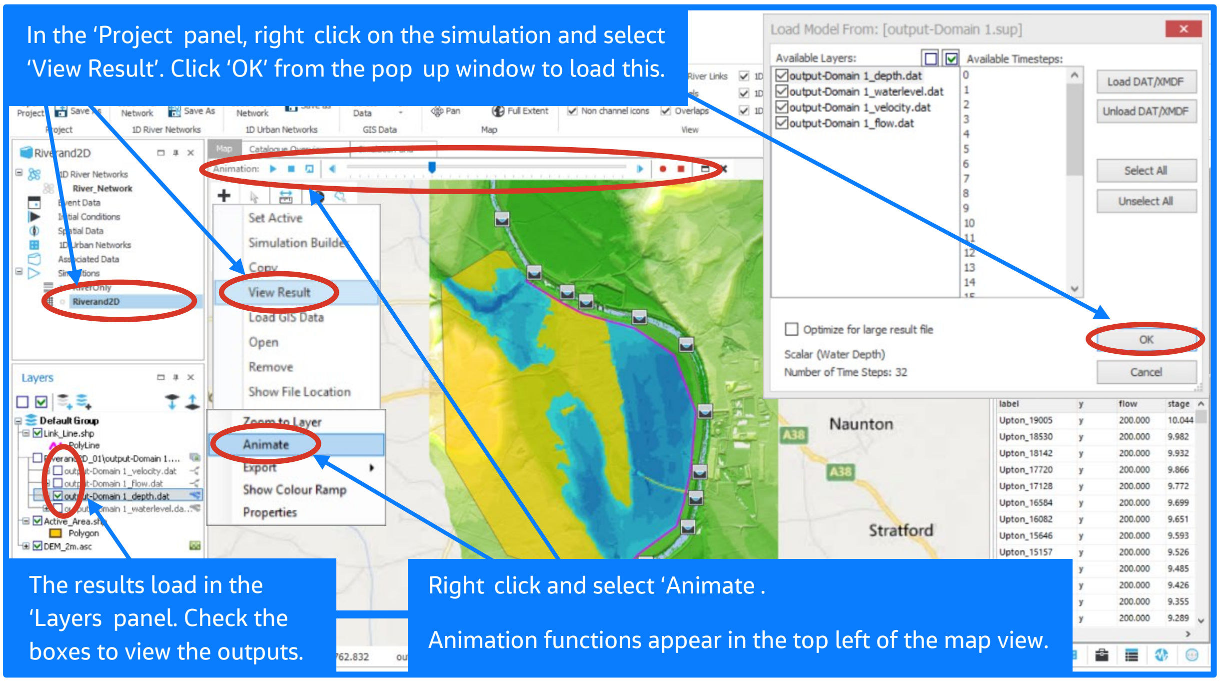
Tip: Don’t forget to save your simulation to keep your changes.

Step 7

Your integrated river-2D simulation is ready to run! If you find your simulation is very slow, you may find it helpful to increase the grid size, although recall from ‘Getting Started – 2D Modelling’ that this reduces the resolution of the results.

View the results from the simulation. Animate the water depth and investigate how much of your active area floods.

Is your active area big enough? Turn on the ‘flow’ output – are there any areas where the flow appears to reflect from the boundary of the defined active area? Increase your active area, ensuring it remains clear of grid cells with “no data” defined. Save and re-run the simulation – can you create an active area to contain all the water throughout the simulation time?



Tip: Remember to close the animation toolbar when you have finished viewing the animated sequence (leaving this open can cause unexpected things to happen when you continue working!)

Part Two: River and Urban

Integration of river and urban networks allows (for example) the outflow from a pipe to enter a river. To integrate a river network and urban network, you must initially set up the ‘link-references’ to indicate which nodes are connected, and how the flow is transferred at each. The ‘1D Urban / 1D River Linking Definition' tool is provided to assist with this. After defining the link-references, an integrated 1D simulation can be set up. This needs to specify your link-reference file, alongside your river network and urban network.

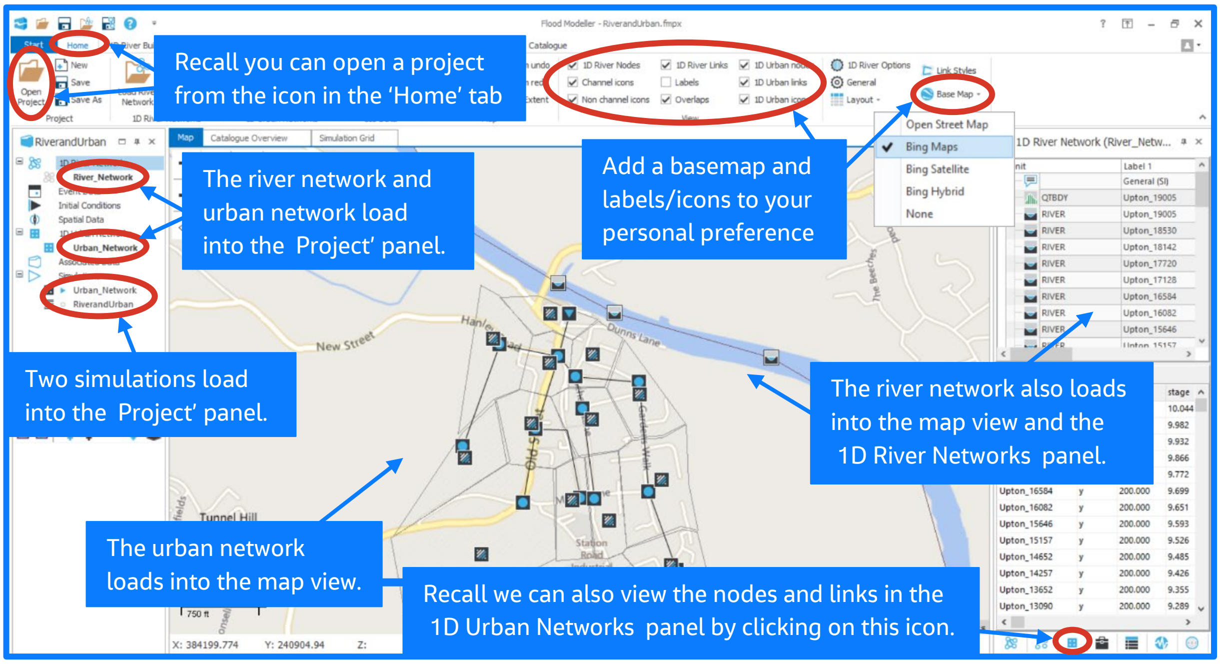
In the second part of this guide, we will integrate a river network and an urban network. We will run a fully integrated simulation, allowing us to capture not only the outflow from the pipe entering the river, but also any water entering back into the urban system if the water level in the river exceeds the outflow height.

Let’s get going!

Step 1

Open the project RiverandUrban.fmpx (in the IntegratedModelling>RiverandUrban folder)

A 1D river network and 1D urban network will load into the interface – both of these should be familiar and the guides ‘Getting Started: River Modelling’ and ‘Getting Started: Urban Modelling’ should be referred to for further details as needed.



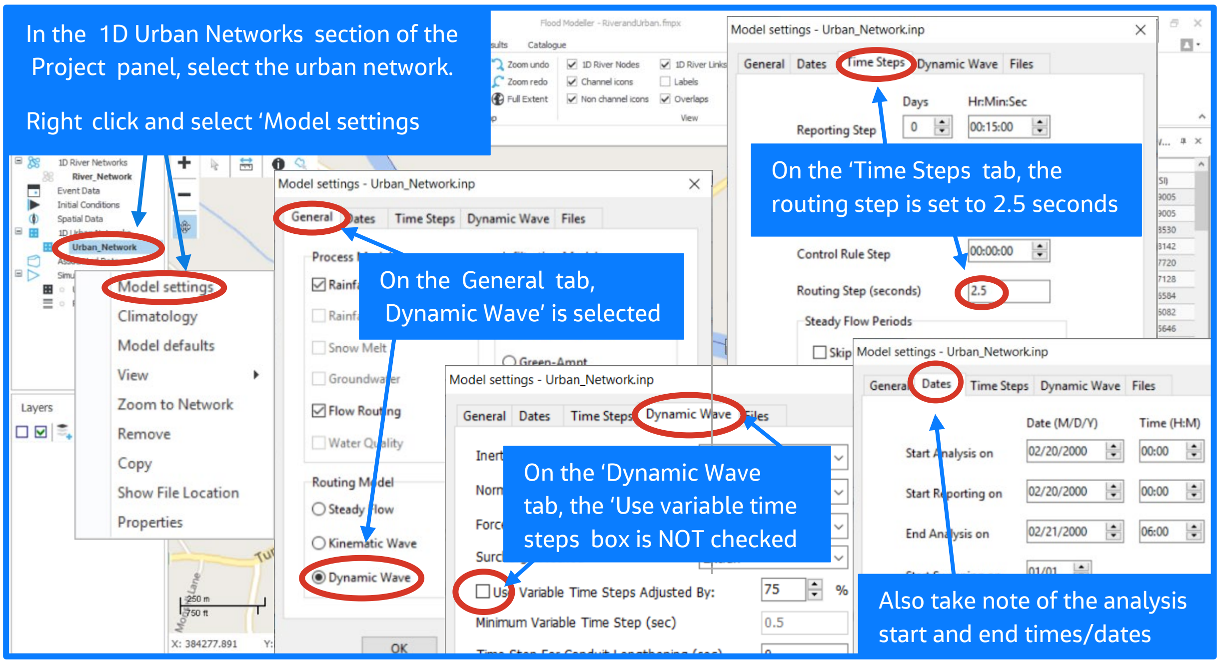
Note: On loading the project, the software will automatically set the selection mode to ‘1D River’. Recall that this can be adjusted via the right-click menu on the map.

Step 2

Let’s look at the details for the 1D simulation associated to the urban network. Recall from ‘Getting Started – Urban Modelling’ that the settings for this are all contained within the urban network itself.

Note that the dynamic wave routing model has been selected, and that variable timesteps are turned off; this must always be the case to integrate your urban network with other components (both river and 2D).

Take note of the timestep used for the 1D simulation. This will be important when setting up the integrated simulation. Also notice the start and end times have been provided as absolute dates; we will set our integrated simulation to run over the same period. Close the model settings after you have viewed the parameters used.



Step 3

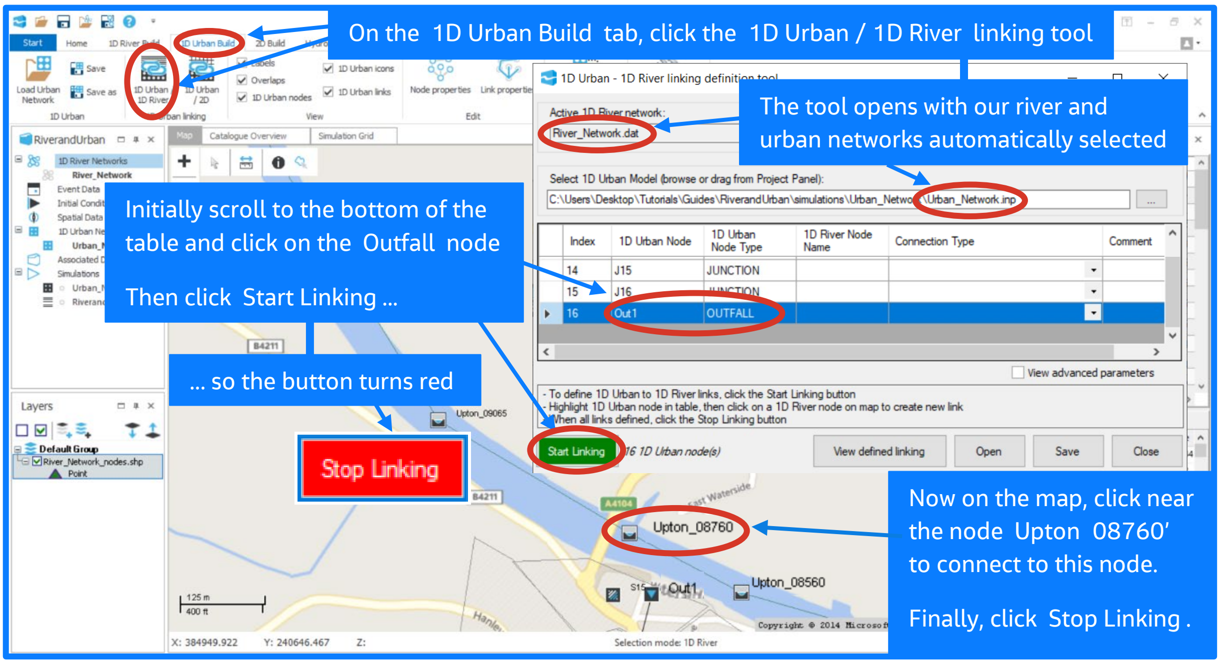
The first part of integrating river and urban networks is to create a link-reference. This will indicate which nodes are connected, and how the flow is transferred at each node. This information will be saved in a file with extension .isl.

For this tutorial, we are interested in connecting the outfall node ‘Out1’ of our urban network to the river network.

Use the ‘1D Urban / 1D River’ linking definition tool to create this link-reference.

For this tutorial, we will consider the default link type of ‘Flow to river, stage to urban’. This is typically used for flows discharging from a pipe network into a river. The urban network discharge is applied to/extracted from the river network as a lateral inflow/outflow, and the water level in the river is calculated and passed to the connected urban node(s).

In this instance of connecting an ‘Outfall’ node, no additional modelling parameters need be defined for the water level to be passed back to the urban network dynamically during simulation runtime. Please see the [user manual] for further details on connecting ‘Junction’ or ‘Flow Divider’ nodes, and on the ‘Stage to river, flow to urban’ link type (appropriate for a river discharging into an urban network downstream).

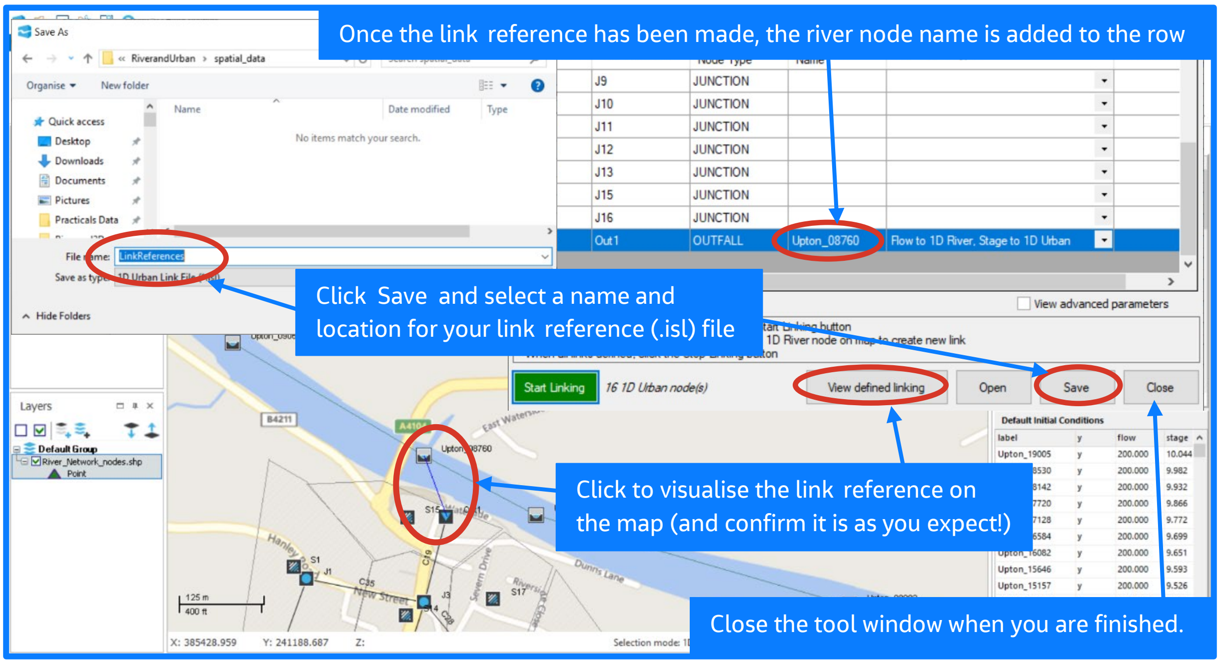


Note: The flow from ‘Out1’ is applied to the river network as a lateral inflow between ‘Upton_08760’ and the next downstream node; ‘Upton_08560’.

Step 4

Choose a filename and save location for your link-reference. Confirm visually the link connects the expected nodes. Now you can close the ‘1D Urban / 1D River’ linking definition tool.

Your link-reference is now ready to use!



Tip: Save your link-reference file (extension .isl) somewhere in the RiverandUrban folder (and remember where – you will need this later!)

Step 5

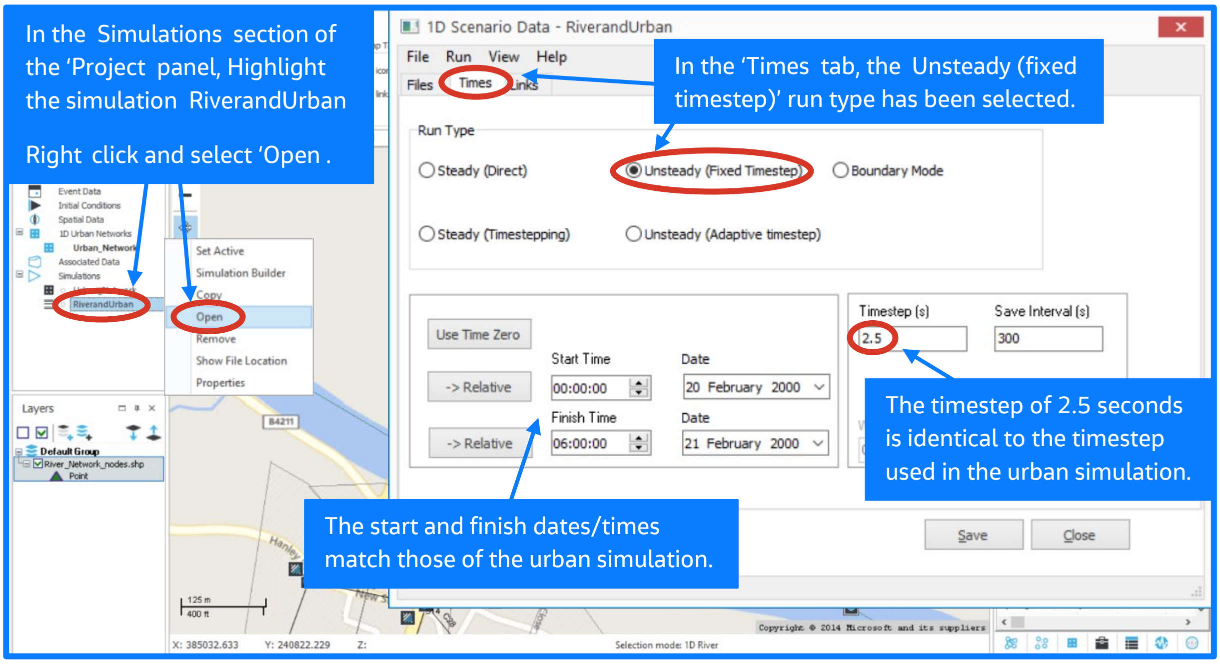
The second part of integrating river and urban networks is to add the 1D urban components and the link-reference to a 1D simulation.

Open the 1D simulation 'RiverandUrban' (or you could start a new 1D simulation here!)

You will notice our river network (and initial conditions – these are now contained within the river network) have been specified, this should all be familiar from 'Getting Started: River Modelling'.

Note that the timestep is the same as used in the simulation associated to the urban network (from step 2 above). For integrated modelling, it is required that timesteps are multiples of each other, and recommended that 1D timesteps used are identical.

Note also that the start and end time match the time within the simulation associated to the urban network (from step 2 above). Absolute times must be provided when linking to urban networks.

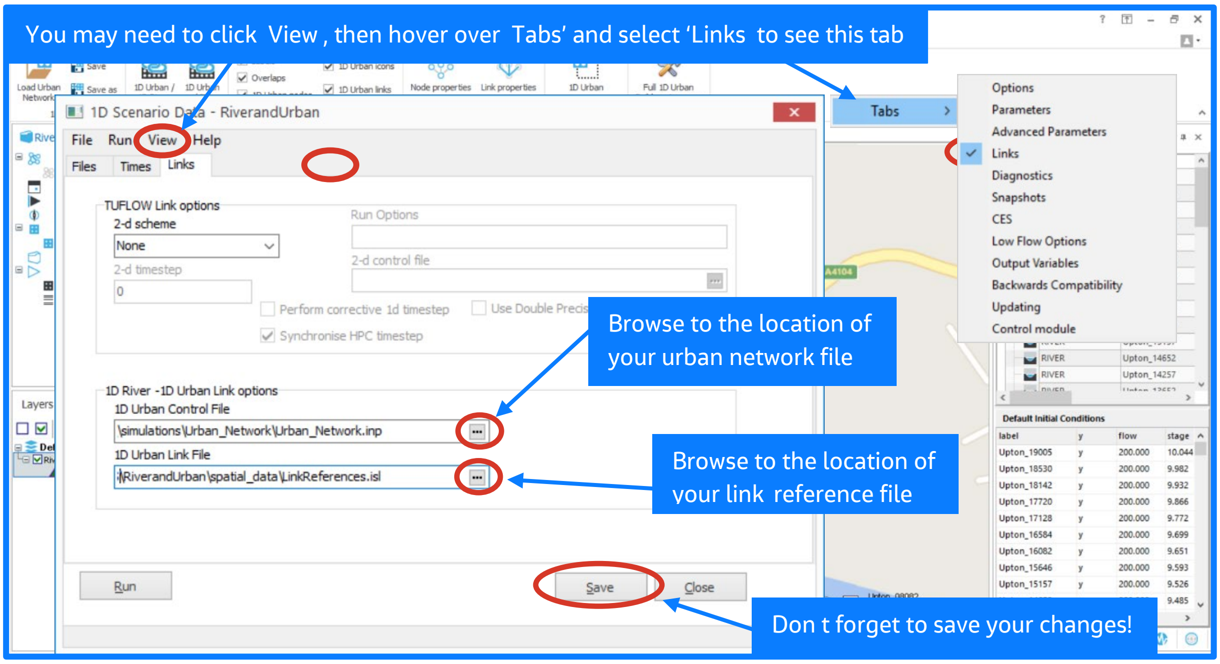


Note: Recall the river network details are provided on the 'Files' tab.

Step 6

Add the urban components to the simulation by navigating to the ‘Links’ tab. You may need to click ‘View’, then hover over ‘Tabs’ and select ‘Links’ to see this tab.

Fields are provided for both the urban network file and link-reference file. Simply use the button to the right of the field to browse to the location of your urban network and add this to the simulation. Similarly, browse to the location of your link-reference file to add this.



Tip: Your urban network file is in the folder ‘simulations’ > ‘Urban_Network’ (in the RiverandUrban folder). Your link-reference file (extension .isl) is wherever you saved it in step 4 above!

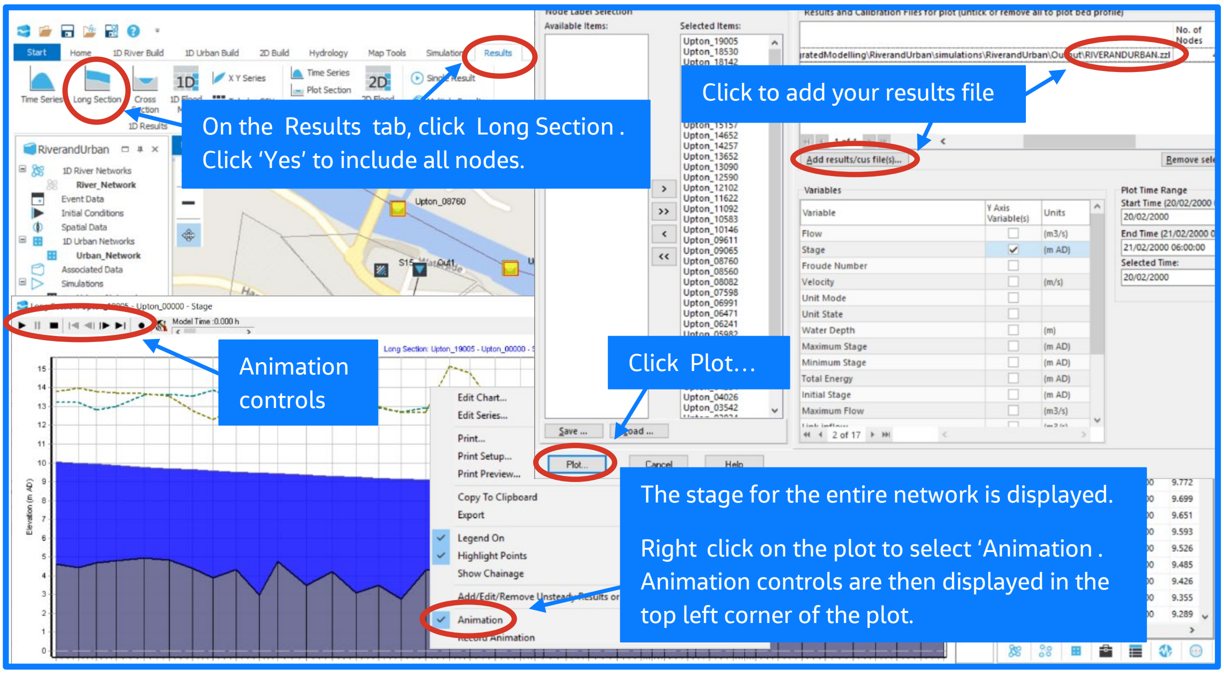
Step 7

Your integrated 1D river-urban simulation is ready to run!

Look at some of the results from your simulation. Animate a 'Long Section' plot to see the water levels changing along the entire river network.

The simulation has considered the 'Flow Time' boundary at the upstream end of the river (as we saw in the guide 'Getting Started: River Modelling'). The additional water discharging from the urban network 'Outfall' node (as we saw in the guide 'Getting Started: Urban Modelling') has also been added during simulation runtime.

There is a slight increase in the levels and flows in the river due to the discharge from the pipe, however this is negligible compared to the water already contained in the river.



Note: The results file by default will be located in 'simulations' > 'RiverandUrban' > 'Output' (in the RiverandUrban folder).

Part Three: Urban and 2D

You can integrate urban networks and 2D components to allow (for example) overflowing manholes and drains to discharge onto overland urban areas and floodplain. To integrate an urban network and 2D components, you must first create the ‘link-elements’ to indicate which nodes are connected, and how the flow is transferred at each. The '1D Urban / 2D Linking' tool is provided to create these link-elements in polygon, line, or point format. After defining the link-elements, an integrated 2D simulation can be set up. This needs to specify your link-element file and 1D urban simulation, alongside your 2D components.

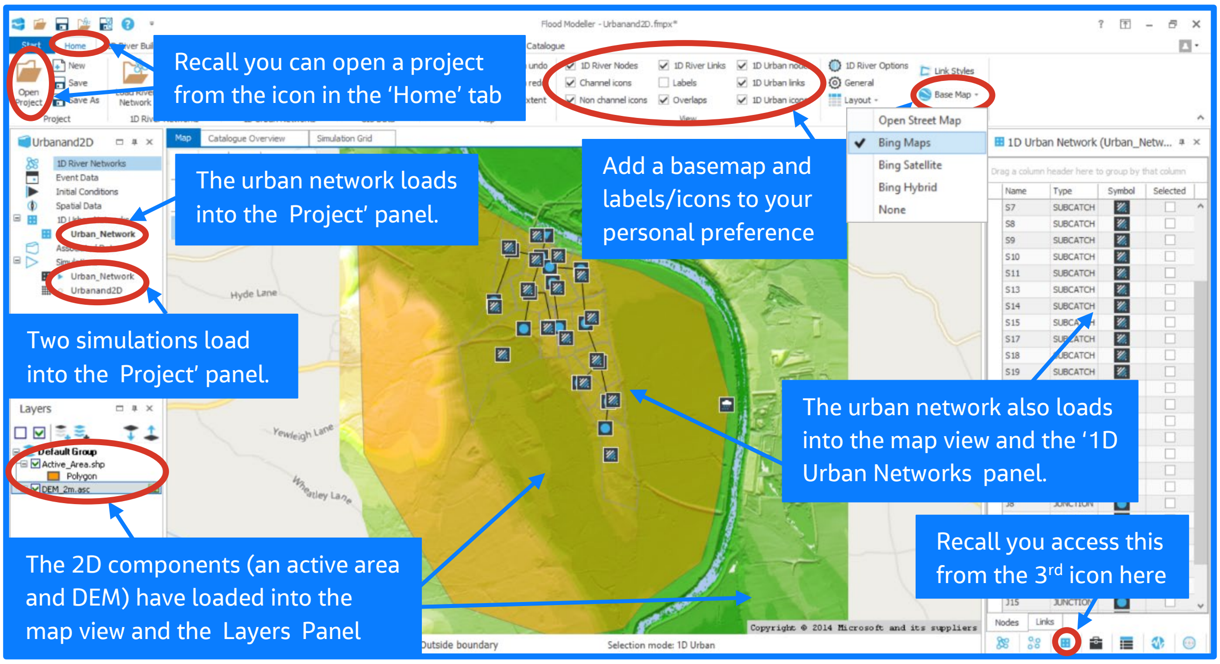
In the final part of this guide, we will integrate an urban network and 2D modelling components. We will run a fully integrated simulation, allowing us to capture flow exchange dynamically at runtime of not only the outflow from the pipe junctions entering the floodplain, but also any water entering back into the urban system.

Let’s get going!

Step 1

Open the project Urbanand2D.fmpx (in the IntegratedModelling>Urbanand2D folder)

Various 1D urban and 2D components will load into the interface – these should all be familiar and the guides ‘Getting Started: Urban Modelling’ and ‘Getting Started: 2D Modelling’ should be referred to for further details as needed.



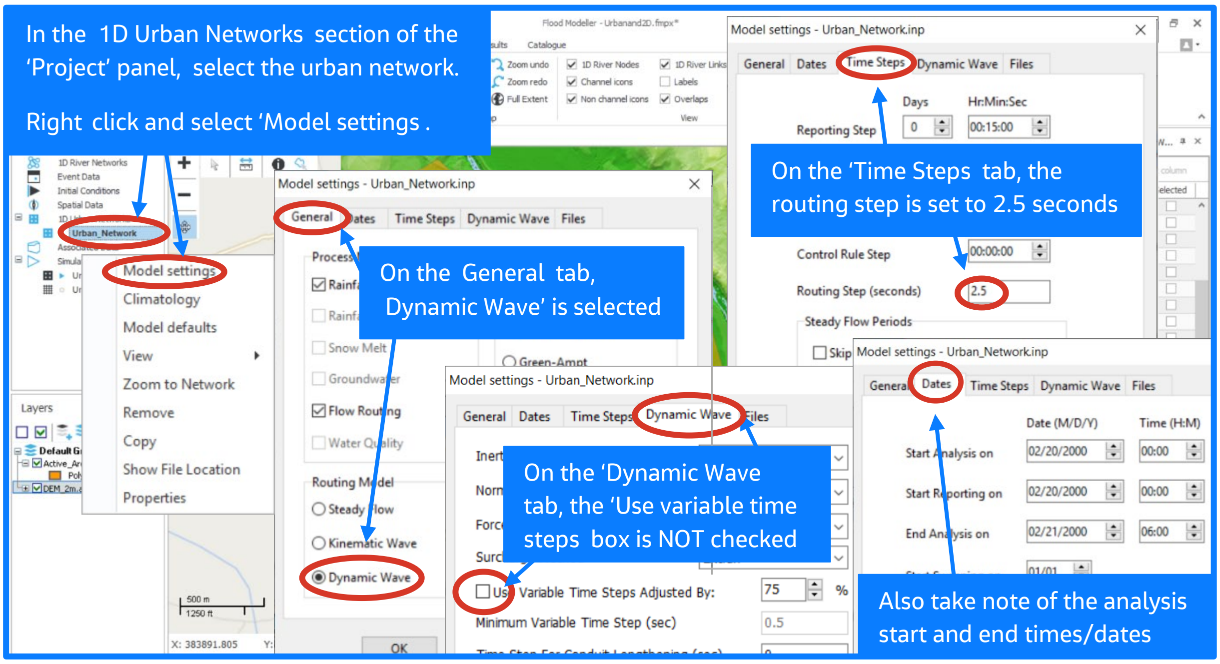
Tip: In the ‘Layers’ panel, right-click DEM_2m.asc and hover over ‘Colour Ramps’ to select a terrain option from the default list provided. Recall from ‘Getting Started – 2D Modelling’ an option such as ‘Terrain_Hillshading’ is most appropriate.

Step 2

Let's look at the details for the 1D simulation associated to the urban network. Recall from 'Getting Started – Urban Modelling' that the settings for this are all contained within the urban network itself.

Note that the dynamic wave routing model has been selected, and that variable timesteps are turned off; this must always be the case to integrate your urban network with other components (both River and 2D).

Take note of the timestep used for the 1D simulation. This will be important when setting up the integrated simulation. Also notice the start and end times have been provided as absolute dates; we will set our integrated simulation to run over the same period.



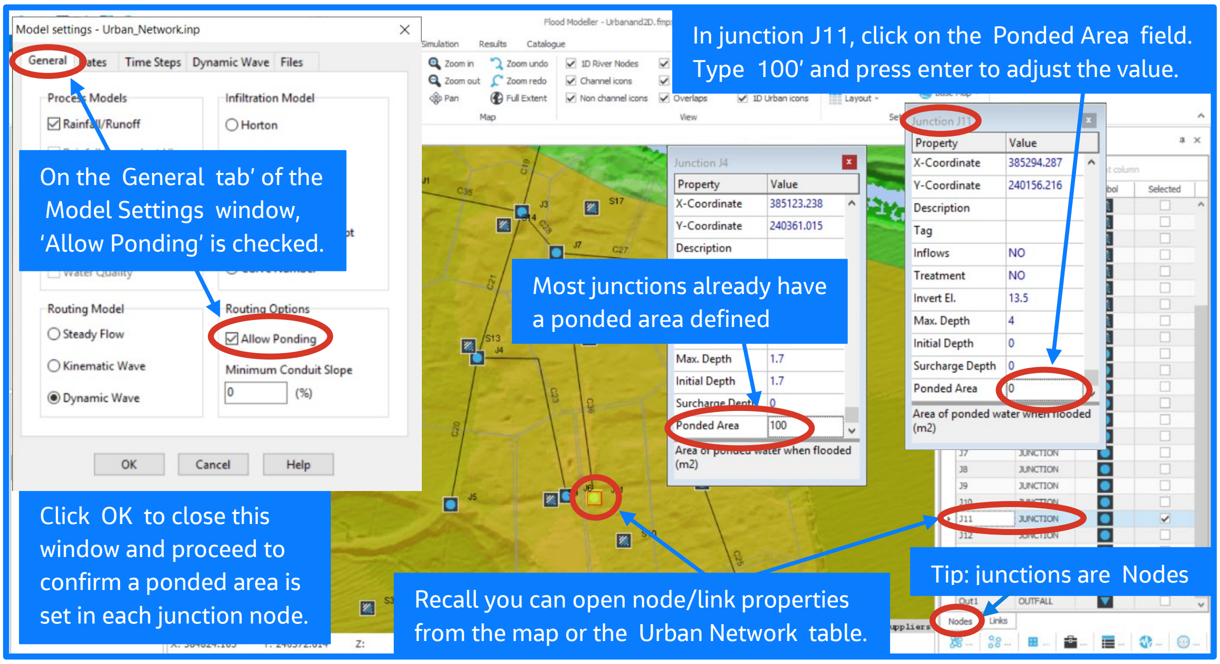
Step 3

We are interested in connecting urban junction nodes (rather than just outfall nodes) and desire a two-way exchange of flow (i.e. for flow volumes to also be returned to the urban system). It is therefore necessary to "Allow Ponding" and to ensure a ponded area is set for each of the junction nodes. In the case that the "Allow Ponding" option is not selected or the ponded area set to 0, water can discharge from the urban network to the 2D components, however no volume is returned to the urban network.

Note that "Allow Ponding" has already been selected for the simulation associated to our urban network.

Check the ponding area provided in the junction nodes themselves. A ponded area has been defined for every junction except for junction J11. Adjust the ponded area in J11 to 100 m^2. Remember to type your new value, then press enter to confirm the adjustment prior to closing the junction property window.

The ponded area set for a node connected to a 2D domain should be comparable to the area of the connection. The area for the default (polygon) connection is 9m^2, and the ponded area will be the area of the grid cells required to cover this. For this tutorial, we shall see the grid size is set to 10m, and thus the ponded areas are set to 100m^2, 200m^2 and 400m^2 (depending on whether the default polygon connection lies within 1, 2 or a set of 4 adjacent grid cells). Note that any changes to your active area may adjust the underlying grid cell placement, and thus the ponded area. It may be helpful in practice to run a model for a single timestep and adjust the ponded area based on the diagnostic messages provided.



Note: Don't forget to save your urban network after making this adjustment.

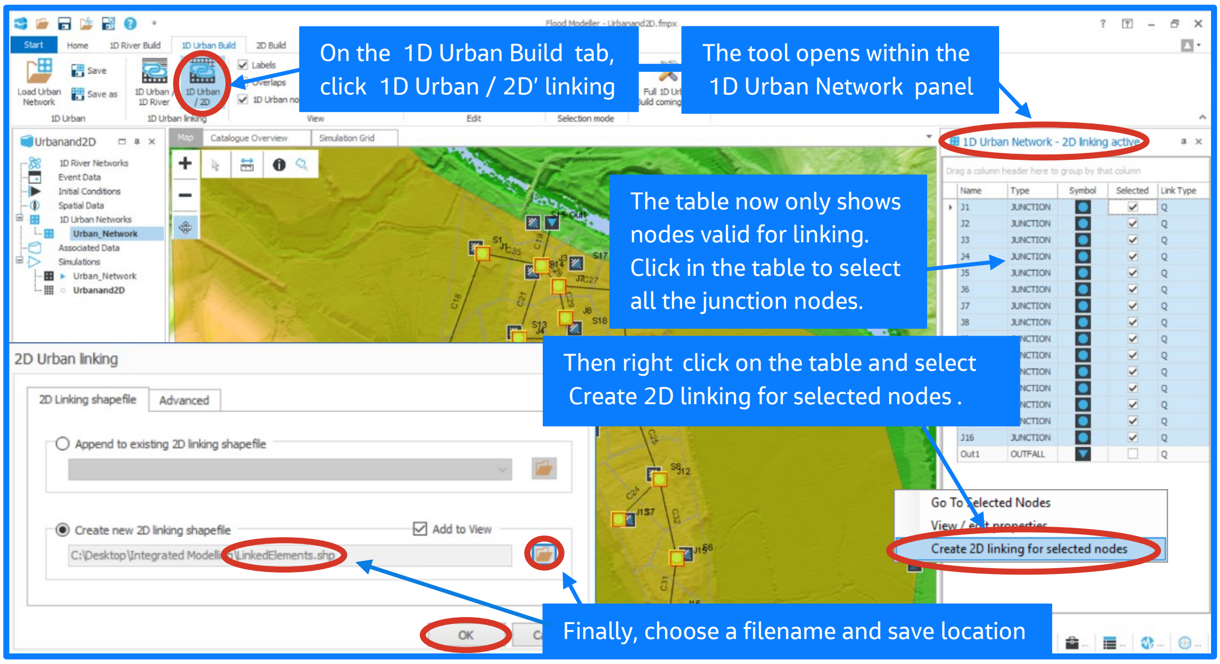
Step 4

The first part of integrating urban networks and 2D components is to create the link-elements. This will determine where and how water can transfer to and from the urban network.

Use the ‘1D Urban/2D’ linking tool to create the link-elements from all junction nodes to the 2D active area. This information will be saved in a file with extension .shp.

For this tutorial, we will consider the default link type of ‘Q (flow) Link’. This is typically used for flood flows discharging onto the floodplain. The discharge is applied to/extracted from the 2D domain, and the resultant ponded volume is calculated and passed back to the urban system. Please see the user manual for further details.

Choose a filename and save location and click ‘OK’ to finish your link-element file. This is now ready to use! Don’t forget to save the project to add this shapefile to the other project files.



Top tip: Hold the ‘Ctrl’ key to select multiple rows in the table. Use ‘Ctrl + A’ on your keyboard to select all nodes. [In this instance, to select all ‘Junction’ nodes, you could select all nodes then hold ‘Ctrl’ and select the ‘Outfall’ node (to deselect that node).]

Step 5

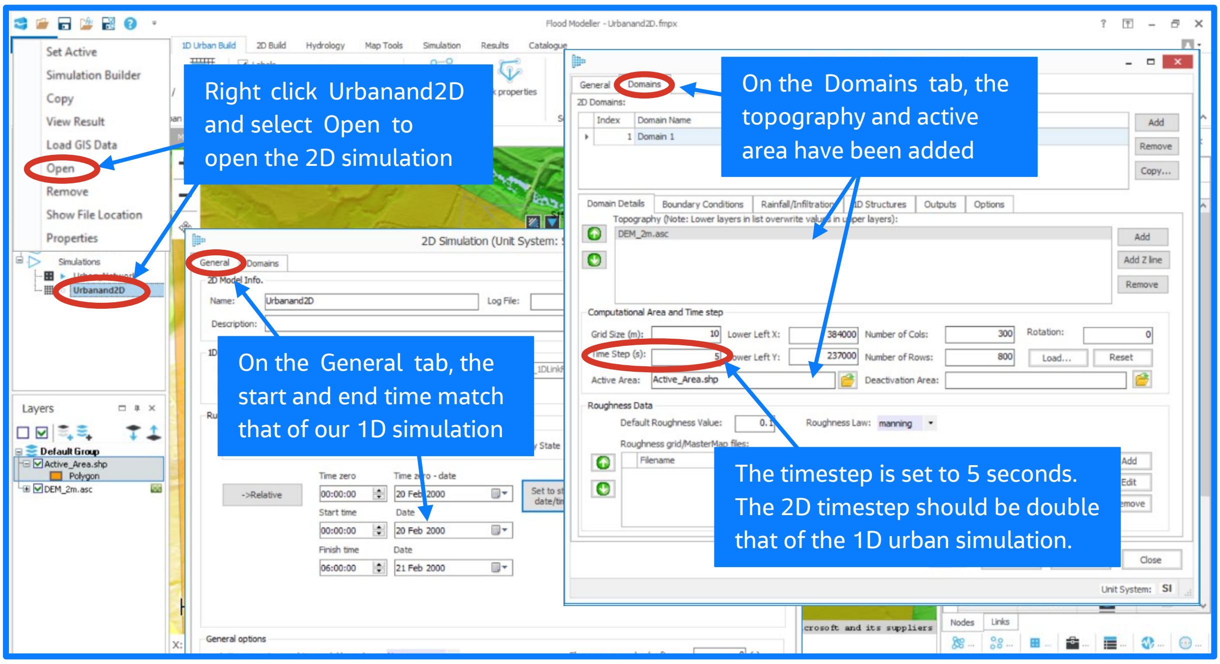
The second part of integrating urban networks and 2D components is to add the 1D components and the link-element to a 2D simulation.

Open the 2D simulation ‘Urbanand2D’ (or you could start a new 2D simulation here!)

You will notice the topography and an active area have been defined, and the run timing details are also already provided. This should all be familiar from ‘Getting Started: 2D Modelling’. Note that the start and end time match the time within the simulation associated to the urban network, as seen in step 2 above. Absolute times must be provided when linking to urban networks.

Note that the timestep (in seconds) is half of the grid size (in meters); we recall from ‘Getting Started: 2D Modelling’ that this is the recommended setup.

Also note the timestep is twice that of the 1D only simulation (from step 2 above). For integrated modelling, it is required that timesteps are multiples of each other, and recommended that a 2D timestep used is double any 1D timesteps used.

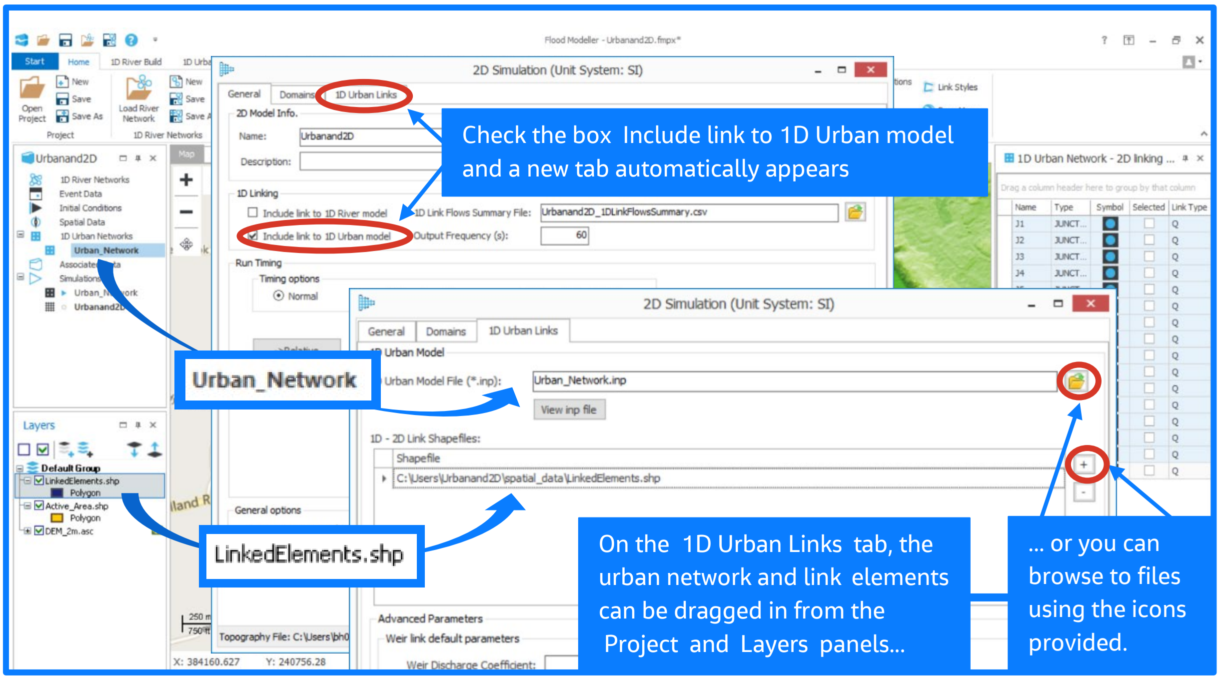


Step 6

Add the 1D components to the 2D simulation by navigating to the ‘General’ tab and simply checking the box provided to ‘Include link to a 1D Urban model’.

You will notice a .csv filename automatically populates the field immediately to the right – this file will be created at runtime and contain a summary of the flows across the linked aspects (the link-elements, in this case).

A new tab will also automatically appear entitled ‘1D Urban Links’. In this new tab, fields are provided for the 1D simulation associated to the urban network and your link-element shapefile. These can be dragged over from the ‘Project’ and ‘Layers’ panels respectively (or browsed to via icons provided).



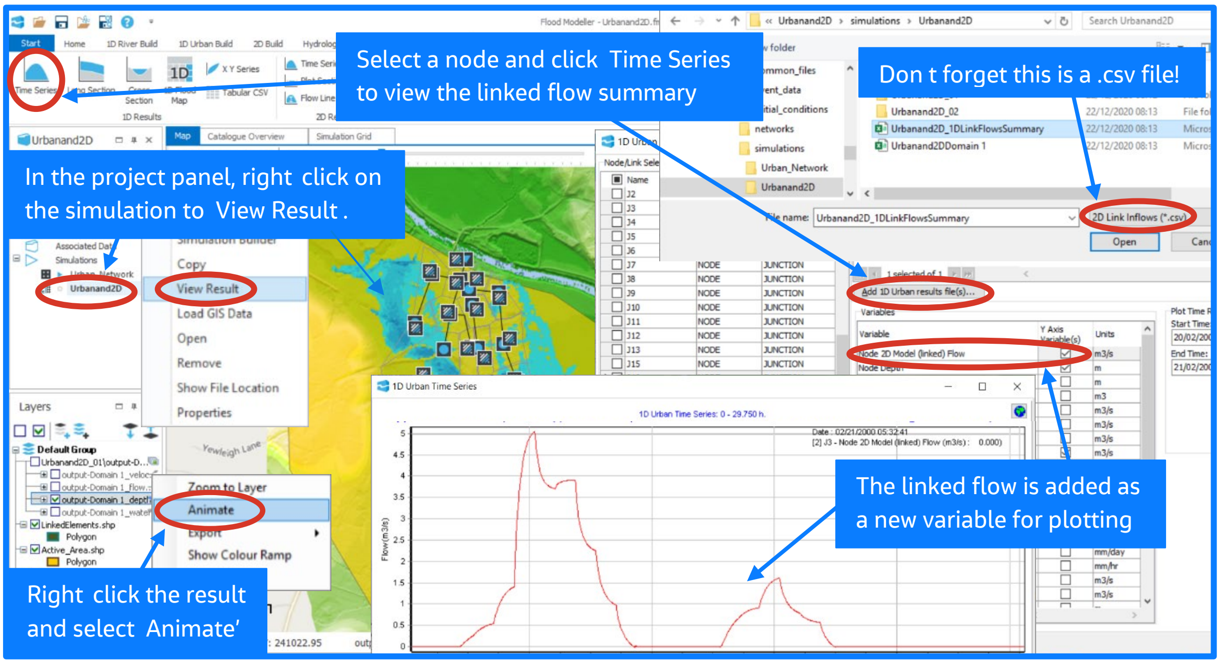
Note: The advanced parameters can be left at their default settings.

Step 7

Your integrated urban-2D simulation is ready to run!

View the results from the simulation as you would with other 2D results. Animate the water depth and investigate how much of your active area floods.

For integrated urban-2D simulations, the linked flow summary can also be plotted – this is the .csv file mentioned in step 6 above. Select a 'Junction' node and view a 'Time Series' plot of the linked flow. Note that at some of the junction nodes, little or no flow enters the 2D domain.



Summary

You now have had an initial introduction to integrated simulations.

Part One – River and 2D

In part one of this guide, we saw that a valid river network (and a stable 1D simulation using this) is required for integrating river networks, and that the 1D timestep is important to take into account for our linked simulation.

We saw that an underlying DEM is required when integrating 2D components and recalled how an active area can also be provided for 2D modelling, and how these can both be adjusted and manipulated in the ‘Layers’ panel of the interface. We saw that a link-line must be defined to connect the river network and the active area.

We used Flood Modeller’s built-in ‘Link Line Generator’ tool to create a shapefile for this line by simply choosing some options from drop-down boxes. This automatically created a link-line ready for use in our simulation.

Finally, we set up and ran our fully integrated simulation, animating the results from this to see the water flow from the river across the active area. We used a 2D timestep of 5 seconds, following the guidance that the timestep (in seconds) is half the cell size (in metres) as well as double the value of the 1D timestep (in seconds).

We considered the default link type of ‘Level Link’ typically used for flood flows discharging laterally into the floodplain over natural or non-walled banks (i.e. those without a linear defence). We discussed that the 1D and 2D components dynamically exchange data at runtime; the water level in the river is calculated and passed to the 2D, and the discharge is extracted from/applied to the river network as a lateral outflow/inflow.

Part Two – River and Urban

In part two of this guide, we saw that a valid urban network is required when integrating urban components and recalled how the model settings for the simulation associated to this network could be adjusted in the ‘1D Urban Networks’ section of the ‘Project’ panel. We saw it is required to select ‘Dynamic Wave’ as the routing model and to turn variable timesteps off. We also paid attention to the timestep and start/end times of the urban simulation.

We recalled that a valid river network is required for integrating river networks and saw that a link-reference must be defined to connect river and urban networks.

We used Flood Modeller’s built-in ‘1D Urban / 1D River’ linking definition tool to create this link-reference file with just a few clicks of the mouse. This automatically created a link-reference ready for use in our simulation.

Finally, we setup and ran our fully integrated simulation, visualising the results from this to see the increased flow in the river. We used a timestep of 2.5 seconds, following the guidance that 1D timesteps are equal to each other, and ensured the start and end times were provided in absolute value format to ensure correlation with the 1D urban simulation.

We considered the default link type of ‘Flow to river, stage to urban’ used for flows discharging from a pipe network into a river. We discussed that the river and urban components dynamically exchange data at runtime; the urban network discharge is applied to/extracted from the river network as a lateral inflow/outflow, and the water level in the river is calculated and passed to the connected urban node(s).

Part Three – Urban and 2D

In part three of this guide, we recalled that a valid urban network is required when integrating urban components and it is required to select ‘Dynamic Wave’ as the routing model and to turn variable timesteps off.

We saw that when linking nodes other than outfall nodes, it is required to ‘Allow Ponding’ and define a ponded area for each connected node.

We recalled that a DEM is required for 2D modelling and saw that a link-element must be defined to connect urban networks and 2D components.

We used Flood Modeller’s built-in ‘1D Urban/2D‘ linking tool to create the link-elements file. This automatically created a link-element ready for use in our simulation.

Finally, we set up and ran our fully integrated simulation, animating the results from this to see the water flow from the urban system across the active area. We used a 2D timestep of 5 seconds, following the guidance that the timestep (in seconds) is half the cell size (in metres) as well as double the value of the 1D timestep (in seconds). We also ensured the start and end times were provided in absolute value format to ensure correlation with the 1D urban simulation.

We considered the default link type of ‘Q (flow) Link’ typically used for flood flows discharging onto the floodplain. We discussed that the 1D and 2D components dynamically exchange data at runtime; the discharge is applied to/extracted from the 2D domain, and the resultant volume is calculated and passed back to the urban system.

What’s next?

If you would like to find out more about integrated modelling, check out our YouTube channel, user manual or get in touch with our support team.