Gunbower Koondrook Perricoota Forests Modelling

Flexible Mesh Model Development

Murray-Darling Basin Authority

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Dear Fathaha,

Flexible mesh Development for Gunbower Koondrook Perricoota Forests

This report documents the first stages of development of a 1D-2D model of the Gunbower Koondrook Perricoota (GKP) Forests, using flexible mesh and GPU Technology. Water Technology has setup a functional MIKE FLOOD flexible mesh model in close collaboration with MDBA. This report describes step-by-step the different processes to build the new model from the two existing models of the forests either side of the Murray River.

The model files have been transferred to MDBA to further develop the model and complete the calibration.

Yours sincerely

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1 INTRODUCTION

In 2003 the Living Murray initiative identified the Gunbower-Koondrook-Perricoota floodplain system as one of 6 “icon sites,” recognising the floodplain system as a key ecological asset of the River Murray. The location of each of the icon sites is shown in Figure 1-1. The Living Murray icon sites are considered a high priority for conservation and rehabilitation.

Gunbower Forest is a floodplain ecosystem reliant on flooding to maintain its ecological health. It is bounded by the River Murray to the north and Gunbower Creek to the south, with a number of watercourses and wetlands dispersed across the forest ranging from permanent to ephemeral. Many of the watercourses that provide flow into the forest from the River Murray and Gunbower Creek are regulated.

Koondrook–Perricoota Forest is located on the NSW side of the River Murray, adjacent to Gunbower Forest. In large natural flood events a large proportion of the River Murray flow enters the forest, flowing to the north and west.

Torrumbarry Weir is situated on the Murray River close to the upstream end of the Gunbower Koondrook-Perricoota Forests. The weir regulates the river flow to service a large irrigation district.

Regular floods of various sizes are required to maintain healthy and functioning ecological communities in the Gunbower Koondrook–Perricoota Forests. Regulation of the River Murray has resulted in a reduction in the magnitude, frequency and duration of natural floods. To enhance environmental outcomes, a range of environmental infrastructure has been constructed within the forests.
2 BACKGROUND

Numerous studies and investigations have been undertaken in the area, this results in a wealth of available data and existing numerical tools.

Currently MDBA uses two distinct hydraulic models covering the Gunbower Forest and the Koondrook-Perricoota Forest separately.

With the advance in computing capabilities and improvements to the available software, MDBA has commissioned Water Technology to assist in the development of a numerical model that covers both floodplain sites on either side of the River Murray.

The objective of this project is to convert the existing two separate models to a single MIKE FLOOD flexible mesh model, to allow for better resolution across the model domain in areas of interest. The revised model schematisation therefore focuses primarily on changes to the 2D model representation, however other improvements (i.e. to the 1D network and linking of the 1D/2D domains) are also made.

MIKE FLOOD 2017 allows for the coupling of a 2D flexible mesh domain with a 1D network. Simulations utilise parallelized calculations via the Graphics Processing Unit (GPU) for the 2D component and the Central Processing Unit (CPU) for the 1D component. This parallel solution technique results in increased calculation speed, allowing for higher precision (greater resolution) without drastically increasing simulation times.

This document details, step-by-step, the process of developing the new combined model of the Gunbower Koondrook-Perricoota Forests (referred to as GKP hereafter).
3 STEP BY STEP MODEL DEVELOPMENT

As requested by the MDBA, the development of the new model is described in detail in this document. It is a step-by-step manual, of which sections were intermediately sent to MDBA to aid in the development of the model, which was developed by Water Technology and MDA concurrently.

3.1 Digital elevation models and survey

A number of topographic and structural survey data sets used in previous investigations were available. Several new datasets are now also available. These are detailed below.

3.1.1 LiDAR

The major dataset used to develop the 2D component of the model was a LiDAR data-set provided by the MDBA. The dataset covered the full study area and had a grid resolution of 1 m.

LiDAR was used to interpolate the model topographic data applied to the elements of the flexible mesh. The first step was to convert the dataset to a format compatible with the Mesh Generator tool (*.xyz or *.dfs2 format).

The objective is to convert the LiDAR from a raster to a *.dfs2 format.

- Export the LiDAR raster to an Ascii file using a GIS software tool (to reduce the size of the file, resampling and exporting a 2m grid is recommended);
- Convert the Ascii file to a *.dfs2 using the MikeZero Toolbox
  - Open MIKE Zero : MZ Toolbox → GIS → Grd2Mike
  - Follow the dialogue prompts

- Select the Ascii file:
Specify the projection to match that of the input data:

Specify the output file name and execute the tool. A pop up message should appear, indicating that a file has been created.

Open the *.dfs2 that has been created and edit the properties of the following items:

- name,
- type (=bathymetry) and,
- delete value = 999 (or any value larger than the maximum elevation in the file)

Save the file.

This grid is now ready to be used to interpolate the topography on the mesh elements.
3.1.2 Feature survey data

Survey data containing waterway cross sections, levee profiles and crest heights as well as hydraulic structures were compiled during past investigations. All the data available in the existing models was maintained and imported into the new model. Details for specific structures are given in the following sections of this document.

3.2 1D component

Several models in the area have been developed in the past, focusing on either side of the Murray River with the Gunbower Forest on the Victorian side and the Koondrook-Perricoota Forests across the border to New South Wales.

The current 1D models are constructed with MIKE11. It should be noted that DHI have replaced MIKE11 with MIKE HYDRO in the recent software versions. In order to benefit from the latest developments of the software, as well as support from DHI for technical issues in the future, the new model was implemented using MIKE HYDRO. Conversion tools allow easy conversion from MIKE11 to MIKE HYDRO format. The figure below illustrates the process used to create the first version of the combined 1D model of the GKP forests.

The following sections describe the set-up of all existing data into a single “GKP” model.

3.2.1 Branches and cross sections

In order to create the new model covering the entire area of the Gunbower and Koondrook-Perricoota forests, the first step is to create a combined 1D network from all existing models. It is necessary to import all 1D branches into a new single network, keeping the same naming (branch and TOPO ID) and chainage definition to ensure all cross sections are correctly located along the waterways.

The easiest approach is to export the network branches from one model to a shapefile, and import the latter to create the missing branches in the other model. The tools for this are found in the network editor (*.nwk11), shown in Figure 3-1.

It was decided to include Gunbower Creek in the 1D hydraulic model to allow the transfer of flows to key delivery points along the creek, however this branch will not be laterally linked to the floodplain as the interest is in managed flows along the creek that are within bank.
Figure 3-1  Export branches to shapefiles and generate branches within the network editor (*.nwk11)

The process of exporting the branches from the Koondrook-Perricoota model and generating the branches from those shapefiles within the new network based on the Gunbower model, should yield a network with the following characteristics:

- 54 branches
- 14 weirs
- 1 culvert
- 1 regulating structure
- 9 control structures

The addition of structures can be done manually in the network editor (MIKE11) or imported automatically from a shapefile using MIKE HYDRO, given the necessary attributes exist (structure ID, type and branch name).

Water Technology chose to manually add the structures in the network file in MIKE11 before converting the model to MIKE HYDRO. It should be noted that regulating structures are not supported in the conversion tool to MIKE HYDRO. Furthermore, the approach to control/regulating structures has changed slightly from MIKE11. A specific section will describe in detail the set-up of the regulating structure located on the right bank of the Murray River, at the chainage 167000m approximately (MRC reg).

Figure 3-2 shows the different networks from existing models that are combined to create the single GKP model.
Figure 3-2  1D networks from existing hydraulic models
Once the necessary branches have been imported into the new network, connections between branches and subsequent open boundaries must be defined in the network and boundary files respectively.

Cross sections can easily be exported and imported from one cross section editor (*.xns11 file) to another following these steps:

- **File > Export All Section or Export Selected Sections > Export Raw Data**
  - Select the cross sections to be exported in the cross-section editor (right click river name > select all or double clicking specific cross sections)

- Exporting cross sections creates a text file that can be imported in another *.xns11 file
- Open the cross-section editor in which the data will be imported.
  - **File > Import > Import raw data & recompute**

- The cross sections should now appear in the list
3.2.2 Converting MIKE 11 to MIKE HYDRO

The conversion of a MIKE 11 set-up to MIKE HYDRO is straightforward and is described in the following steps:

- Open a new MIKE HYDRO file
  - MikeZero > new > MIKE HYDRO > MIKE HYDRO Model

- In MIKE HYDRO: File > Import > Import from MIKE 11 > Simulation File and all [...] 

- All elements of the set-up should be imported into the "*.mhydro" file except for the cross section file. The cross sections remain stored in a separate "*.xns11" file.
After the import, MIKE HYDRO connects to the existing xns11 file. To ensure no data is lost or overwritten by mistake, it is advised to create a copy of the cross-section data and connect to the latter in the MIKE HYDRO simulation file.

The map should show the following layout:

- A number a background layers (DEM, images or shapefiles) can be added, provided they are in the same projection.
3.2.3 Control structures

A number of hydraulic structures are regulated to control the flows in and out of the Murray River and its tributaries.

Control structures are used whenever the flow through a structure is to be regulated by the operation of a movable gate (e.g. sluice gate, overflow gate, underflow gate, radial gate) or the flow is controlled directly as in the case of a pump or a turbine.

- Control structures in MIKE HYDRO River are defined through a CONTROL STRATEGY
- The control strategy is the sequence of CONTROL RULES that determine the way a structure can be operated in MIKE HYDRO River
- A structure can have any number of strategies, defined by a sequence of conditional statements evaluated as TRUE or FALSE during simulation

During the conversion from MIKE11 to MIKE HYDRO the control structures should have been recreated except for the “Regulating” structure for the MRC regulator located on the branch named “Return”. This structure will have to be redefined in MIKE HYDRO.

The key components in defining a control structure in MIKE HYDRO are the sensor, control object and the control rules. The control strategy follows a logical decision tree based on the list of prioritised conditions, at each time step the conditions are evaluated one after the other. If a condition is true then the action is performed.

There are currently 9 control structures defined in the model:

- 6 gates (4 underflow and 2 overflow structures)
  - Yarren Creek (chainage 30m and 5290m)
  - Murray River (Torrumbarry)
  - Hipwell dummy structure
  - Barhamcut Creek (“New central Bays” and “New Sidebays” at ch. 35.5m)
- 3 direct discharge
  - Cutting
  - Gunbower Creek (“National Channel” at ch.100m and another at ch. 18950m)
The “Return MRC” structures in the existing MIKE 11 model defines a discharge flowing back to the Murray based on a Q-H relationship. The levels conditioning the flow calculation are those arriving in the channel from the floodplain.

The tabulated relationship between water levels and discharge has been extracted from the existing 1D model. The structure is defined as “Direct discharge”.

- Branch: “RETURN” and Chainage: 396m

The control strategy will be a direct application of the Q-H curve.

To implement the control strategy it is necessary to define the channel outlet (floodplain end) as a sensor.

- Branch “RETURN” and Chainage: 0m

The simple control rule is defined as follows:

- If the water level at the channel entry is zero then do nothing
- If there is water, the discharge applied must follow the tabulated values defined in the Action section

![Figure 3-3 RMC structure definition](image-url)
3.3 Preliminary Mesh creation

The generation of a flexible mesh is an iterative process. This section describes the first iteration of the mesh generation for the 2D component of the GKP model.

Once the model has initialised and the "link data" has been created, the mesh can be refined in the *.mdf using the river data from the 1D component.

Figure 3-4  Mesh generation process
The following section details the process described in the Figure 3-4, leading to the export of a “rough” mesh, serving as a dummy for the creation of “link data”. Used subsequently to refine the mesh based on the 1D river model.

3.3.1 Model boundaries (extent)

As shown in the figure above, the first step is to create a rough mesh that will be used to export the link data between the 1D branches and the floodplain from MIKE FLOOD.

- Create a new Mesh Generator file and import the LiDAR data created earlier (dfs2 file). The DEM will serve two purposes. Firstly as a background layer showing the topography, and secondly this DEM will be used to interpolate and append elevation values to the nodes of the mesh.

- Data > Manage scatter data > Add (remember to display the data, it can take some time if the file is big and click Apply). Will need to resample the 1 m resolution LiDAR to a lower resolution.

- Digitize the boundaries of the model around the extent of the LiDAR. Drawing a closed polygon defines the outer limits of the mesh that will be created. Ensure polygon is within the limits of the DEM.

  - Use the “Create arcs” tool and draw a closed polygon; or
  - import the boundary from an existing file (*.xyz created from a shapefile for example)
Generate a mesh with large elements (150,000 m\(^2\) for example). This will create a triangular mesh within the limits defined by the polygons previously defined. The maximum element area defined in the pop-up menu is the biggest area an element can be, hence this value controls the number of elements triangulated during the mesh generation. The smaller the value, the higher the number of elements. The mesh generator aims at triangulating the biggest allowable elements within the boundary. The smallest allowable angle controls the shape of the triangles generated. Theoretically, the perfect mesh is composed of equilateral triangles only. However, this isn’t practical because it would lead to very small elements. A smaller angle generates bigger elements but with acute angles, which can create instabilities during simulations. Usually, a good compromise is to use a smallest allowable angle between 26 and 30°.

Mesh > Generate mesh

Once the mesh has been generated (reminder that this is the preliminary mesh, other steps are required prior to interpolation when creating a mesh but will be described in section 3.4) interpolate the topography on the mesh in order to append elevation values to the nodes.
Mesh > Interpolate (remember to select “Set value from scatter data”, this option reduces the interpolation time considerably)

When the interpolation has completed remember to export the mesh to a *.mesh file:
Mesh > Export Mesh > select type: Mesh File

3.3.2 MIKE FLOOD: preliminary 1D/2D linking

Once the preliminary mesh has been exported, we can now create the 2D model set-up that will be linked to the 1D model via MIKE FLOOD.

Import the mesh (*.mesh file) into a new *.m21fm file and complete all the necessary information to allow the model to run independently (2D only).
The same must be done for the 1D component, where the model should run (at least start, they do not have to successfully complete the simulation at this stage) independently prior to linking it to the 2D model in MIKE FLOOD. Once both models can initialize we can link them through the coupling software.

**More technical details on the coupling between the models is given in section 3.5.**

In MIKE FLOOD, there is an automatic tool that allows to define different types of links. We will be using the lateral and standard links.

- In the link definition tab, right click the graphical window and select the option “Link River Branch to MIKE21”
- Select the type of link to define and complete the necessary information to define the link, as shown in Figure 3-5.
- The following links were created:

**Table 3-1** List of MIKE FLOOD links

<table>
<thead>
<tr>
<th>Type</th>
<th>Branch name</th>
<th>River chainage (From – To)</th>
<th>M11 side</th>
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<tr>
<td>Standard</td>
<td>OFFTAKE_128106S</td>
<td>234</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>WATTLES_LAGOON</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
The lateral links are defined by polylines that will be imported to the mesh generator. These polylines will act as forcing lines and represent the banks of the river in the mesh.

It is generally recommended to exclude the river channel which is modelled in MIKE HYDRO from the mesh. In this way you avoid double conveyance in the river channel and you can include the link lines directly in the mesh which will improve the flow across links.

Each point of the polyline will be a vertex along an arc once imported in the mesh generator. Hence, in order to avoid small elements in the mesh, it is necessary to “clean” the polylines in MIKE FLOOD as much as possible before exporting the link lines. More editing is possible in the Mesh Generator so the “cleaning” here does not necessarily need to be perfect.

The objective here is to have the maximum distance between vertices while preserving as much as possible the shape of the line representing the river banks.

- Highlight the link by selecting the corresponding row in the link Definition tab,
- When the link is selected, a toolbar should appear allowing to delete, move and add points
- Delete, move or add points along the link as required and save the *.couple file
To help you include link lines in the mesh, you can generate a text file from a MIKE FLOOD setup, which will contain the coordinates of the linkage lines. This file lists all points along links and can be imported as boundary in the Mesh Generator to generate a detailed mesh.

- Before you launch the simulation; open your *.m21fm file in a text editor, and search for the following section:

  [STRUCTURES]
  [RIVER_LINKS]
  type_of_coupling = 2
  line_information = 2
  output_of_link_data = 0
  file_name_curve = 'river_curve.xyz'
  file_name_section = 'river_section.xyz'
  EndSect // RIVER_LINKS

  Set the ‘output_of_link_data’ option to 3 instead of 0, and save the *.m21fm file.

- You are ready to start the intermediate MIKE FLOOD simulation. During the pre-processing step, the program will export all link coordinates to the river_curve.xyz and river_section.xyz files located in a sub-folder containing result files from MIKE 21 FM. You don’t need to run the entire simulation and can stop it after a few time steps.

- Before you continue, open and verify that *.xyz files were created during the pre-processing step.
3.4 Mesh refinement

The compromise between run-time and model resolution is key to the model development. The 2D mesh can be supplemented with detailed linear features representing roads, channel banks and levees.

The mesh is developed by digitizing essential hydraulic and topographical features by way of polylines and/or polygons, such as waterways, channels, roads and levees that will dictate the triangulation of elements within the domain. Mesh resolution parameters (e.g. maximum cell size) are also defined for specified areas, thereby enforcing finer elements where needed to represent smaller drainage lines and connections between wetlands.

In section 3.3 a preliminary (coarse) mesh was created to simply start a MIKE FLOOD model and export the 1D/2D lateral links. In the following section, the mesh will be refined as more detail will be incorporated aiming to create the optimal mesh in terms of resolution and run time.

3.4.1 Use the created text files to generate a mesh that excludes the river channels and includes link lines

This section describes the step of importing the river banks represented by the lateral links created in MIKE FLOOD. Importing these polylines allows to exclude the rivers from the 2D domain and only be accounted for in the 1D model. Using the link polylines as arcs in the mesh also ensures the mesh is properly defined along the watercourse and improves the flow calculations between the two models both in terms of accuracy and stability.

- Open the Mesh Generator file created previously and rename it.
- Delete the existing mesh: Mesh > Delete Mesh.
- To import the new *.xyz files as boundaries go to menu Data > Import Boundary. Browse for your files and verify the information before you click [OK].
  - Column sequence: check by clicking “Data Info” > select X, Y, Z and Connectivity
  - Select the appropriate projection: GDA_1994_MGA_Zone_55
  - Select “Use connectivity information”

- 26 arcs should be imported
From the imported arcs you need to generate polygons representing the river branches that will be excluded from the mesh. Look at the distribution of the different vertices along the arcs and make sure that they are relatively evenly distributed. Avoid for example very close vertices as they will force very small elements in the mesh. You may also need to add arcs, modify, move or delete nodes and vertices.
You should spend some time working on this step as the output mesh is very important. An example is shown in the image below.

- If it makes it easier to work with, you can remove the display of the scatter data in the background (Data > View Scatter Data on/off).

- A useful tool to verify the arc definition is “redistribute vertices”
  - Select an arc and right click
  - Select Redistribute Vertices in the pop up menu

- A window showing information on the selected arc appears. Pay attention to the minimum segment length that indicates the closest vertices within the arc. If this value is small you can either redistribute vertices along the entire arc or manually delete or move the vertices that are close to each other.

- It may help to do a few iterations of all the steps: generate the mesh, inspect the elements, delete the mesh, apply some changes to vertices/arcs, re-generate the mesh, etc.
To locate small elements within the mesh, and apply the necessary changes do the following:

- Generate mesh
- Go into Mesh editing mode: Mesh > Mesh Editing
- Select: Mesh > Analyse mesh
- This window will list the smallest elements, by clicking Zoom, the window will move to the element.

Return to Mesh > Arc Editing and apply the necessary changes (delete/move/connect vertex or node)
When you are satisfied with your mesh, use the smoothing tool to readjust elements with small angles (creates a more stable mesh)

- Mesh -> Smooth Mesh

- Then use interpolate Mesh and,

- Finally export the mesh.

Adding new river links to the existing mesh that already has river links included

If you are importing additional links that weren’t included in the mesh previously, you will have to process the *.xyz file exported from MIKE FLOOD. It is only necessary to import the newly created links and not the links already part of the mesh.

The easiest way to achieve this is to:

- Run MIKE FLOOD again with the new links and import the updated “river_curve.xyz” file to an empty *.mdf file. This should show all the river links from MIKE FLOOD (cf. section 3.4.1)

![Figure 3-8. New Mike Flood links imported into the Mesh Generator. Deletion of lateral links already included in the mesh, keeping only the newly created links from the latest iteration of the model development (here these are standard links added after the lateral links).](image)

- Select and delete the redundant link lines (in the example above we are only keeping additional standard link lines)

- export the remaining arcs to a new *.xyz file: select all the arcs > Data > Export Boundary > Selected Arcs and save the *.xyz file.

- import in the mesh generator created previously.
3.4.2 Other Forcing lines

3.4.2.1 Dike structures

Several linear structures such as roads and levees that have the potential to act as hydraulic controls, can be added to the 2D domain using “dike” structures. Dikes in the model are polylines that control the flow through specific geometry which can be sampled from the detailed LiDAR information. The location and crest levels of these features were extracted from the LiDAR and overtopping is calculated in the model via weir equations.

In order to have accurate mapping as well as flow calculations along these structures it is recommended to include them in the mesh via specific arcs. The latter will enforce the triangulation and help create an optimized mesh.

The first step is to define the linear structures that will be defined as dikes with a GIS software.

Our spatial team here at Water Technology have developed a specific tool that allows to pick up the crest level of these elements based on shapefiles and a DEM. This tool has been developed for the ESRI software Arcmap. The advantage it offers is that it uses a search buffer along the shapefile to locate and extract the highest point corresponding to the crest level of the structure and then move the vertex of the shapefile to that point. This avoids the very time consuming, manual digitization of the exact crest of roads or levees.

In addition to the structures extracted from the LiDAR, survey data is available along Gunbower Creek from previous studies. This information will be included in the mesh and the model via dike structures as well.

The map below shows the location of the “dike” structures that will be included in the model.
Figure 3-10 Location of Dikes structures to be included in the model (14/06/2017)
The process to define the structure location within the Mesh Generator is similar to the process of excluding 1D branches. The lines are imported as boundaries. Therefore, the following step after digitizing the linear structures is to convert the shapefiles (lines, with the crest level attribute) into *.xyz format. To do so, use the Shp2xyz tool in the MikeZero Toolbox.

The output file can then be imported into the mesh generator as a boundary. Repeat the steps listed in section 3.4.1. After cleaning up the data and making the necessary changes to the arcs, vertices, etc… the generated mesh should look like this (using a maximum area of 80,000 m², smallest allowable angle = 30°).
Figure 3-11  Mesh generated with 1D branches excluded and “dikes” imported (14/06/2017)
After the location of “dike” structures to be included in the model has been defined in the mesh, it is necessary to create these structures in the simulation file of the 2D model (*.m21fm)

As mentioned above, we have previously converted the shapefiles to *.xyz files that can be directly imported into the 2D simulation editor. This is done by following the steps here-after:

- Open the *.m21fm file and go to the structures menu and dikes
- In the “list view” tab, create the number of dikes required

![Diagram of the 2D simulation editor](image)

- Click on “Go to…” and open the dike editor. The *.xyz file can be imported from the “Location and geometry” tab. Specify the crest level as “varying in space”.
- Specify the correct projection and browse for the *.xyz file that contains the dike coordinates and crest level. The Coordinates and crest level should populate the table in the tabular section.
- By clicking on “dikes” in the menu on the left of the window, the geographic view should appear, showing the location of the dikes on the model domain.
  - Note: they should be aligned with the mesh elements (we have previously enforced the lines in the mesh generator).
  - Note that dikes can also be edited graphically in this window
3.4.2.2 Other digitized elements

In addition to dike structures, some elements such as buildings or waterways can be forced upon the mesh to improve the resolution, flood connectivity or mapping outputs of the model.

In the case of the GKP model it is necessary to define a certain number of waterways or flood runners within the 2D flexible mesh to ensure the flow capacity, as well as the connectivity within the wetlands are well described. This approach applies to waterways not represented by 1D branches, however this tool could also be used to define new 1D branches within the floodplain.

The following figure shows several offtakes on the Murray River (first few hundred meters) as well as Barbers Creek that have been digitized and imported into the mesh.
Figure 3-12  Digitized waterways (2D model) – 21/06/2017
3.4.2.3 Mike Hydro Tracing tool

MIKE HYDRO allows to automatically trace waterways based on a delineation tool using a topographic dataset. This tool creates a 1D branch which we will convert to a shapefile and a *.xyz file that can be imported into the mesh generator.

- Open a new MIKE Hydro *.mhydro file and load a DEM. To speed up the process, a 10m resampled DEM has been used (a *.dfs2 file can easily be resampled using the tool in MZtoolbox > Transformation > Rotate grid)

- In order to use the river tracing and catchment delineation on the map, the digital elevation data must be preprocessed by clicking the button ‘Preprocess digital elevation data’. The DEM is preprocessed to create a raster file with flow direction information that is used to delineate river branches and catchments. After changing the spatial extent or resampling the elevation data, the DEM must be preprocessed again. The processed data is saved in a ppdd-file. If no location is specified, then the ppdd file is saved by default in the same location as the model setup.

- When a DEM has been loaded the ‘Add Trace’ button is enabled on the Branch ribbon. Clicking on the upstream location of the river will trace down to the outlet of the river based on the DEM data.

- To help locate the existing network you can load the shapefile of the 1D network (Map configuration > Background layers)
In the image below several flood runners have been digitized.
- Once the tracing is done, export the branches to shapefile and convert them to *.xyz files that can be imported into the mesh.

The arcs can now be added to the mesh and improve the connectivity within the wetland areas through better resolution where it matters.
Figure 3-13  Flood runners tracing from MIKE HYDRO
3.4.3 Polygons: optimizing resolution areas

The general cell size, or general maximum area used during the mesh generation is defined at the last step before generating the mesh. *Mesh -> Generate Mesh:*

![Mesh Generation Interface](image)

This value (maximum element area) will be applied to the entire domain except where local value will have been defined. These local values are defined in the mesh generator via polygon markers within closed polygons, formed by one or several arcs.

![Polygon Selection Tool](image)

Once the polygon has been graphically placed on the mesh, the polygon selection tool allows to edit the properties of the selected polygon (*select -> right click -> properties*).

![Polygon Example](image)

By default, the inserted polygon will be set to exclude the area from the mesh (no elements generated within the polygon area).
In the properties menu, change the option to “Apply triangular mesh” then select “use local maximum area”. This value will have to be smaller than the general Maximum Element Area, thus allowing the definition of higher resolution areas within the domain.

3.5 Details on 1D/2D linking

MIKE Flood is a coupling software that dynamically links 1D and 2D components in a single model. The fluxes are exchanged both ways via different links between the rivers (1D) and floodplains (2D).

3.5.1 Standard links

Standard links connect the end of a MIKE HYDRO branch to MIKE 21. Standard links are used to define the transition from 1D flow to 2D flow.

- MIKE HYDRO imposes a discharge in MIKE 21 (calculated as a source)
- MIKE HYDRO requires a water level from MIKE 21

A standard link is defined with one chainage which must correspond to a water level boundary in MIKE HYDRO with a cross section. The water level boundary in MIKE HYDRO is “dummy” and doesn’t affect MIKE FLOOD.

When using a flexible mesh:

- Linkage line mapped onto 1 or more element faces
- Link works as a boundary condition in MIKE 21
- Coupling line should be within the mesh
- The predictor to estimate discharge in M11 is not used (#rectangular grid)

Several parameters that are used for calculation through links are available in MIKE FLOOD. They are listed below:

- Momentum Factor: Value controlling whether the momentum exchange is to be included. Neglecting momentum has a stabilizing effect on set-ups.
  - A value of 0: no momentum exchange
  - A value of 1: full momentum exchange
Extrapolation Factor: Value controlling the forward estimation in time of M11 discharge at next time step. Not applied when using flexible mesh.

Depth Adjustment: If selected the discharge is distributed according to the local water depth in M21 cells. This is considered appropriate for links on natural terrain or channels. Higher discharge will be applied to the cells with greater depth and conversely.

Exponential Smoothing Factor: It introduces an exponential smoothing of the water level values transferred from M21 to M11

- 1 = no smoothing
- 0 = strong smoothing

Lowering this value has a stabilizing effect on set-ups.

The following section has been extracted from the MIKE FLOOD User Manual:

“The smaller the value the greater the smoothing will be. The parameter impacts the dynamics by smoothing out steep gradients (in time) through the links.

In general, the exponential smoothing factor should be adjusted when a structure exhibits unstable behaviour (oscillates wildly). The following approach should be followed if a link shows instability:

1. Set the exponential factor to 0.2 – 0.4
2. Run the model
3. If a link still "misbehaves", (i.e causes a blow-up OR the discharge hydrograph is very ‘noisy’) then check the results file, the model link location, the MIKE 21 topographic grid, the coupling, etc. for problems, and inconsistencies.
4. Re-run the model if changes are made.
5. If the link still “misbehaves” then the smoothing factor may be further reduced. Note that a small smoothing factor will cause a time lag in the transfer of the values from one model component to the other model component.
6. Rerun the model.
7. If a small value of the smoothing factor is required, you need to satisfy yourself that the results are reasonable and the results for the overall model have not been significantly delayed.”

3.5.2 Lateral links

Lateral links allow linking between the banks of a river and the floodplain, to capture any overflow that may occur, as described in Figure 3-14. In this section the lateral links set-up, calculations and options will be discussed in detail.
1D water level calculation points are connected to 2D cells and water is exchanged between the channel and the floodplain based on water levels in either domain. Therefore, flooding above banks and returning flows to the river bed are dynamically calculated along the laterally linked branches. A distinction is made between the right and left bank of the river, it is therefore important to accurately describe bank levels in at least one of the two models (1D and 2D).

A lateral link is defined from an upstream to a downstream chainage. By default, the selection of cells in the 2D Grid is determined from the cross-section width (markers 1 and 3) and coordinates (if any).

Note: it is possible to use an external file, and/or graphically edit the links’ location afterwards.

The lateral link consists of many internal small structures/segments describing the levee (river bank). The number of internal structures depends on whether there are more MIKE 21 grid cells in the link or MIKE HYDRO grid points.

The flow is exchanged in MIKE HYDRO only at h-points - but at all coupled MIKE 21 cells/elements. The flow is distributed according to chainage and distance along grid cell centres. Water levels are interpolated from relative locations of 1D h-points and 2D cells, this interpolation is distance dependent and minimises inconsistencies (in case the h-points are few and far apart and interpolated levels overlap).

In the “Lateral Link Options” menu in MIKE FLOOD, several options are available under the “Structures” section.
Type refers to the type of flow calculation, where several weir equations or rating table can be used to describe the flow;

The structure source determines where the levee height comes from:
- M11: from bank markers of MIKE 11 cross-sections
- M21: from cell or topography in MIKE 21
- HGH: highest of MIKE 11 markers and MIKE 21 topography
Using HGH is recommended since it yields more stable calculations.
- EXT: levee height supplied in external file as a function of chainage along levee

It should be noted that the source also determines the number of internal small structures within the link:
- M11: internal structures only located at MIKE 11 h-points locations
- M21: internal structures only located at MIKE 21 cells' locations
- HGH: highest density of MIKE 11 and MIKE 21
- EXT: internal structures located at chainages from the external file and from MIKE 11 h-points

Depth Tolerance is used to dampen out oscillations when water level difference is small across the link. A value of 0.1 m is recommended but may be increased in some cases

The following points should be kept in mind while creating lateral links:
- As mentioned above, water levels are interpolated along the lateral links between h-points for the 1D component. However the levee height of the internal structure uses the closest h-point with a 1D cross section marker (whether it's an h-point at a cross section location or an interpolated h-point, cf. “max dx” of the 1D branch). This value is not interpolated, therefore it is recommended that the number of cross sections in the 1D model is sufficient to accurately describe the river banks.
- At the start and end of the lateral links, the closest cross section within the range of start and ending chainages will be used for the levee height in the 1D component. Cross section outside of the start and ending chainages in the 1D will be ignored, even if closer. This is illustrated in the Figure 3-15 below where the cross section at chainage 200 m will not be used in the definition of the height of the levee. Indeed it is located outside of the start and ending chainages of the link.
The number of h-points in the 1D model should also be carefully assessed to accurately describe sudden changes in water levels, such as around weirs for example. Ideally, an h-point for every cell would be perfect but not necessary nor practical in certain cases. As a rule of thumb, a factor 5 between h-points and 2D cells is recommended.
4 RESULTS

After several iterations of development and testing, the results presented below come from a coupled model using a Mesh with approximately 170,000 nodes and 332,000 elements, and a 1D model containing 54 branches and 24 structures.

The performance of the GPU modelling with this resolution is as follows:

Table 4-1 Model run-time (version sent in September 2017)

<table>
<thead>
<tr>
<th>Period of simulation</th>
<th>Calculation time</th>
<th>Run time (hr/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/09/2016 to 31/10/2010</td>
<td>5.76 days</td>
<td>10.6</td>
</tr>
<tr>
<td>(61 days)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The widespread inundation of the GKP forests is well represented at this stage, with flood runners and their connectivity well defined.
Figure 4-1  Maximum depths (August-October 2016 event)
The dynamics of the flooding of the area, in terms of extent and timing, will have to be compared to observations in order to assess accuracy.

The results show numerical stability and the volume balance is good as shown in Table 4-2.

Table 4-2 Volume balance table

<table>
<thead>
<tr>
<th></th>
<th>Volume in m$^3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A: Initial volume in model area</td>
<td>0</td>
</tr>
<tr>
<td>Final volume in wet area</td>
<td>159,541,575</td>
</tr>
<tr>
<td>Final volume in dry area</td>
<td>2,458</td>
</tr>
<tr>
<td>B: Final volume in model area</td>
<td>159,544,033</td>
</tr>
<tr>
<td>Source inflow</td>
<td>0</td>
</tr>
<tr>
<td>MIKE 11 inflow target</td>
<td>2,108,813,031</td>
</tr>
<tr>
<td>MIKE 11 inflow correction</td>
<td>-0.03</td>
</tr>
<tr>
<td>Source outflow</td>
<td>0</td>
</tr>
<tr>
<td>MIKE 11 outflow target</td>
<td>1,990,219,883</td>
</tr>
<tr>
<td>MIKE 11 outflow correction</td>
<td>-40,950,886 (2%)</td>
</tr>
<tr>
<td>C: Total volume from source</td>
<td>159,544,033</td>
</tr>
<tr>
<td>D: Total volume from precipitation/evaporation</td>
<td>0</td>
</tr>
<tr>
<td>E: Total volume from boundaries</td>
<td>0</td>
</tr>
<tr>
<td>F: Continuity balance (B-A-C-D-E)</td>
<td>0</td>
</tr>
</tbody>
</table>
5 RECOMMENDATIONS

The model transferred to MDBA requires calibration and can be further developed to better represent the dynamic behaviour of the GPK forests during flood events.

Water Technology suggest considering the following steps that could be taken to improve the modelling of the GPK forests:

- **Calibration:**
  - the use of different flood extents for various events should be compared to model results, as well as flood levels if available. Based on the comparison results, MDBA could further optimise the mesh resolution.
  - inclusion of a roughness map based on landuse could improve the model results across the floodplains

- Addition of 1D branches representing the flood runners in the floodplain and linking them to the 2D model. In the current model the flood runners within the forests are represented in the 2D mesh, with smaller elements to ensure connectivity. Laterally linked branches could possibly improve the representation of the dynamic flooding through those intermittent waterways while reducing the number of small elements in the mesh, thus reducing model run-time.

- Linking Gunbower creek to the 2D model and including the potential exchange of flows through flooding along this waterway. It appears that in certain areas the current model boundary blocks water and the model could be extended further south to better represent flooding in the area.
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