SARFIIP

Refinement and calibration of Pike and Katarapko floodplain flexible mesh models

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Foreword

The Department for Environment and Water (DEW) is responsible for the management of the State's natural resources, ranging from policy leadership to on-ground delivery in consultation with government, industry and communities.

High-quality science and effective monitoring provides the foundation for the successful management of our environment and natural resources. This is achieved through undertaking appropriate research, investigations, assessments, monitoring and evaluation.

DEW's strong partnerships with educational and research institutions, industries, government agencies, Landscape Boards and the community ensures that there is continual capacity building across the sector, and that the best skills and expertise are used to inform decision making.

John Schutz
CHIEF EXECUTIVE
DEPARTMENT FOR ENVIRONMENT AND WATER

Acknowledgements

The South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) is a $155 million investment program funded by the Australian Government and implemented by the South Australian Government to improve the watering and management of River Murray floodplains in South Australia's Riverland.

We acknowledge the program leadership and support provided by staff from the Water Infrastructure and Operations Branch within DEW. We also acknowledge the contribution of Strategy, Science and Corporate Services Division, Information and Communication Technology Branch within DEW, in particular Matt Gregory – Systems Administrator, for maintaining the high-performance modelling servers and related software required for producing the modelling component of this work.

The authors would also like to acknowledge the peer review contribution to this report by Luke Mosley (The University of Adelaide).

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Summary

The following technical note was originally completed for internal use to support decision making related to the South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP). It is now being published, following program completion, to document the modelling activities conducted in support of the program. The modelling work contained in this technical note uses the best data available at the time, and aspects of it may have been superseded by later modelling work using improved data and operational knowledge.

SARFIIP has relied on MIKE FLOOD models since its inception for hydrodynamic modelling requirements at Pike and Katarapko floodplains. MIKE FLOOD models consist of a 1–D model component that represents channels, minor flow paths and a variety of in channel structure types, and a 2–D component representing the wider floodplain area. These components are coupled together to allow water transfer between channels and floodplains, enabling a high level of flexibility in the development of modelled scenarios.

The original MIKE FLOOD models have had their 2–D components developed with a grid-based (finite difference) topographic representation. Limitations of these models, include fixed grid sizes making representation of narrow and convoluted channels on the floodplains difficult, limited model domain area due to simulation speed considerations and reliance on CPU power for simulation. These issues, coupled with the acquisition of high performance computer hardware by the Department for Environment and Water (DEW), provided the impetus for converting the grid-based models to flexible mesh (FM) versions. FM models present a number of advantages including more effective scaling of mesh elements to represent different channel and floodplain morphologies and parallel processing of model runs using GPU hardware to enable satisfactory run times. The FM model framework also provided an opportunity to expand the model domains (area spanning from Locks 3 to 6) for more flexible scenario specification. The initial conversions to FM models were performed by the MIKE software developers, DHI Water and Environment. However, this did not include calibration of the models or inclusion of refinements incorporated in the latest MIKE FLOOD grid-based models by DEW since the conversions were commenced. Hence, to enable these models to be relied upon for floodplain management, model performance checking and refinement was required.

Refinement and calibration of the Pike and Katarapko FM models was performed using historical monitoring data and satellite imagery for comparison, and the 2016 high River Murray flow and floodplain inundation event presented an excellent opportunity for model validation under current conditions. Refinement and calibration work involved a number of iterative steps including:

- updates to the 1–D components (i.e. the floodplain channels and in-channel structures) of each model to match the latest grid-based model configuration
- adjustments to mesh resolution, such as reducing the size of elements in floodplain areas with a high variability in elevations (e.g. minor flood runners) to ensure appropriate capture of floodplain detail, and readjusting the mesh structure to incorporate changes to 1–D model components
- re-extraction of point elevations from the DEM (digital elevation model) at locations of updated mesh vertices/nodes, and a corresponding adjustment of point elevations where applicable to best reflect localised elevations (e.g. minor flood runners and gaps in the DEM)
- updating 1–D/2–D model coupling links to account for changes to both model components
- running calibration scenarios and identifying instabilities in the outputs or other functional issues, with changes implemented as appropriate. This includes addition of 2–D dike structures to avoid instabilities caused by large changes in elevations over small distances (e.g. on the outside of bends in the main channels and/or at cliff areas) and revising 1–D/2–D links as appropriate
- comparison of outputs with observation data for each calibration simulation and implementing further adjustments as required, such as adjustment of localised elevation data where artificial high points in the

mesh may be preventing flow, and adjustment of Manning's roughness values in 1–D and/or 2–D components where finer adjustments were required.

Final model outputs for both Pike and Katarapko Floodplain models showed acceptable correspondence with observed data (i.e. in-stream monitoring data and inundation extents) through a flow range of between 10 000 and 75 000 ML/d, while also matching the observations from the 2016 high flow event. Water levels within the floodplains, River Murray (and Katarapko Creek in the case of the Katarapko model) at established monitoring sites against River Murray flow were compared with modelled results. These comparisons generally indicated the modelled values were falling between the upper and lower boundaries of observations, representing the approximate rising and falling limbs of various flow events in the historical record. The refined model performance in this respect was substantially greater than the unrefined model, which showed a large overestimation in water levels at low flows in particular.

Note that some sites had limited observed data within the floodplain available for comparison with modelled results (particularly for Katarapko Floodplain), and not all potential scenarios were assessed. It is therefore recommended that further testing and refinement of models should be conducted into the future for continuous model improvement as new data becomes available. However, based on the data available at the time of model refinement and calibration, these models can now be confidently applied for management scenarios into the future.

1 Background

Hydrodynamic models for both Pike and Katarapko floodplains have been used extensively to date for South Australian Riverland Floodplains Integrated Infrastructure Program (SARFIIP) hydrodynamic scenario requirements. These models are composed with the MIKE FLOOD hydrodynamic modelling software package, and are comprised of:

- A 1-dimensional (1–D) component to represent creeks, rivers, and in-stream structures through each system, and
- A 2-dimensional (2–D) component to represent the over-bank flow areas, focused on a floodplain-scale model domain.

These components are coupled together to allow exchange to occur between channels and floodplain areas.

The original MIKE FLOOD models have their 2–D components composed in a grid-based (finite difference) configuration. These models are described in McCullough (2016a) for Katarapko Floodplain and McCullough (2016b) for Pike Floodplain, respectively. Fixed grid cell sizes are selected based on a trade-off between floodplain detail and simulation times e.g. halving the cell size results in up to four times the number of calculations required for a given time step, impacting significantly on simulation run times. Each cell in the grid represents an average elevation over the area within the cell. The Pike and Katarapko finite difference models employ grid cell sizes of 30 m^2 and 20 m^2, respectively.

Transferring to a flexible mesh (FM) model arrangement with finite volume solution scheme provides a number of potential advantages over the MIKE fixed grid models, including:

- more effective scaling of the detail captured in the topography compared to the existing grid-based models, including improving detail in narrower flow paths while reducing detail in areas that do not have large variations in elevation, such as flat floodplain areas,
- the ability to use GPUs in parallel for simulations, potentially enhancing simulation speed with an optimised mesh compared to CPU only processing,
- the ability to produce an expanded model domain without sacrificing simulation speeds of the fixed grid models due to the advantages listed in the previous two points.

The acquisition of high-performance computing infrastructure by the Department for Environment and Water (DEW) for modelling purposes, including high specification GPU hardware, provided a platform to take full advantage of the benefits of FM modelling. This provided further impetus to shift from MIKE FLOOD fixed grid to FM model schemes for each floodplain study area.

DHI Water and Environment were commissioned to perform the conversion of each existing model to MIKE FLOOD FM in 2015. Conversions were based on the latest MIKE FLOOD fixed grid model versions available at the time of the conversions, and also the latest survey data available (digital elevation model/DEM, and bathymetric survey data). Conversion work included:

- Development of flexible mesh domains covering from Lock 3 to Lyrup (i.e. Gurra Gurra wetland inlets) for the Katarapko model, and from Lyrup to Lock 6 for the Pike model. Note that the models were not combined into a single model to avoid excessively long simulation times with currently available technology.
- Conversion of River Murray and Katarapko Creek components in each model from 1–D to 2–D, providing a total length of River Murray simulated in 2–D across the two models of approximately 190 km.
- Adjustments to the 1–D model scheme to ensure compatibility with the mesh.

- Updates of 1–D to 2–D coupled linkages and various hydrodynamic model parameters as required.

The conversion work did not include calibration of the FM models, which is an iterative process that may require model refinements such as modification of mesh detail, adjustment of elevations, and adjustments of hydrodynamic parameters (e.g. bed roughness). Instead, a high-level comparison of each model against observational data was conducted as a first evaluation step under three different flow scenarios – base flow, high flow and managed inundation. These comparisons raised calibration issues that required further investigation of potential sources of error, relating particularly to an overestimation of water levels in the River Murray in both models under the tested scenarios. Further details of the conversion work, including comparison results, is contained in the model conversion report by DHI (2015).

Additionally, there have been progressive changes in SARFIIP infrastructure planning (e.g. blocking alignment adjustments, changes to regulating structure locations, etc.) that have been implemented since the model conversions were completed. These changes require a number of updates to the converted models provided by DHI, including additions/changes to the 1–D model components and updates to the mesh to incorporate these changes.

The aim of this project was to validate FM models for Pike and Katarapko floodplains against observed data and undertake model refinements as required to improve performance. This included taking advantage of data arising from the River Murray high flow event in 2016 for further model validation purposes, which occurred during the model refinement process.

2 Methodology

2.1 Model refinement and calibration approach

2.1.1 Model updates

A number of updates to each MIKE FLOOD grid-based floodplain model were implemented in parallel to the FM conversion work to address changing infrastructure designs and modelling requirements, as required through scenarios presented in McCullough and Montazeri (2016) and McCullough et al. (2016). Further details of basic model setups are contained in McCullough (2016a, 2016b) for Katarapko and Pike models, respectively. Model updates included:

- to the 1–D model including new/modified branches, cross-sections, structures, etc., and
- to the blocking alignment and incorporated components (i.e. ancillary structures, spillways).

These updates were not included in the converted FM models, and as such required incorporation in the models prior to commencing the refinement and calibration process. Note, however, that some changes were implemented to the 1–D model components during the FM conversion process to ensure efficient model coupling and elimination of model instabilities, and as such all changes required careful merging rather than simple replacement of one by the other. General updates to each model include:

1. addition of new model branches (i.e. representing channels/flow paths) or adjustment of existing branches in the 1–D network file,
2. addition of new or updated cross-sections in the cross-sectional file, including preserving updates made to the sections at the start and end of branches for model coupling purposes in the FM converted model,
3. modification or update of the mesh structure to ensure mesh areas underlying the updated 1–D branches are excluded from the mesh (i.e. no creation of elements in these areas to avoid double counting of flows),
4. change to the blocking alignment coordinates in each model to reflect latest designs, with a corresponding adjustment of the mesh structure to facilitate a smooth separation of inundation upstream and downstream of the blocking alignment,
5. 1–D/2–D links in the couple file to reflect the above modifications.

Note that the first step above includes a rationalisation of 1–D components to determine whether any branches may be alternatively represented in 2–D in the refined mesh. Reducing the number of 1–D branches may provide benefits to overall simulation speeds given that 1–D calculations are processed only by the CPU rather than GPU, and thus may represent a bottleneck during the processing of each time step in the simulation. This rationalisation process is a partially-subjective exercise that includes consideration of:

- whether control structures are present in the branch (note that these cannot be represented in the 2–D model domain),
- whether hydraulic data, particularly discharge, is frequently required from the branch, and
- size of the branch (e.g. small flow paths may be better represented as a 1–D branch if their size would cause overly small elements to be formed – thereby requiring small calculation time steps – and the branch has particular interest in modelling scenarios).

Incorporation of these resulted in updated 1–D and 2–D (i.e. mesh) model components, with which the calibration process proceeded as described below.

2.1.2 Model refinement

A general approach adopted for the refinement of each FM model is shown in Figure 2.1. The approach was iterative, requiring the model to be run under certain flow conditions (step 1), assessed against available data including in-stream observational data for lower flows and/or satellite imagery for higher flows (step 2), and identifying areas of the model domain requiring refinement (step 3).

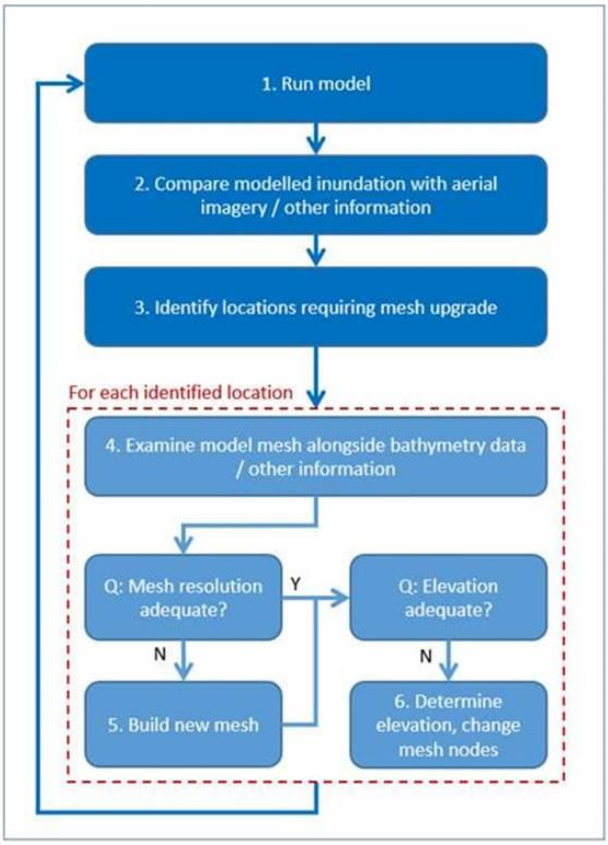


Figure 2.1. Model refinement and calibration process flow sheet (Bonifacio *et al.* 2016).

Steps 4 to 6 in Figure 2.1 highlight that a flexible mesh is made up of two main components:

- The mesh structure, which is a collection of elements (triangular or rectangular) that are positioned and sized primarily by the mesh generation software. Limited user control of element scaling and positioning is implemented by the use of arcs and/or polygons within the model domain that locally force the placement of element nodes and allow maximum element sizing at various parts of the model to be defined.
- Scatter data, which represents point elevations that are interpolated to the mesh nodes to define the bathymetric elevations. Multiple scatter data sets may be used for a single mesh, with the ability to prioritise interpolation of the data sets to the mesh nodes.

The mesh structure was the initial predominant focus of mesh refinement, with later stages of the iterative calibration process shifting to scatter data editing as required. Once the mesh is refined the process of model performance checking begins again (Step 1), and the whole process proceeds iteratively until acceptable comparisons between the model and observed data is obtained.

2.2 Calibration scenarios

Scenarios used for testing the calibration of the models were similar to those used for the model evaluation runs used for updating the fixed grid floodplain models as described in McCullough (2016a,b), which include:

- Base flow condition (~10 000 ML/d)
- Medium flow condition (~40 000 to 45 000 ML/d)
- Medium to high flow condition (~60 000 ML/d)
- Unregulated high flow condition (~75 000 ML/d)

Steady state simulations of each flow condition were used in preference to dynamic simulation of actual flooding events due primarily to gaps in available flow and level data at elevated flows. For instance, the Lock 5 flow rating, which provides the most appropriate source of inflow boundary data for the Pike model, becomes invalid at flows between approximately 30 000 to 60 000 ML/d in the historical record, leaving only calculated Flow to South Australia (QSA) as the nearest valid flow reference. Travel time from the State border to Lock 5 as well as upstream losses (e.g. through Chowilla floodplain) differ between events, which complicates the development of accurate hydrographs for simulation of historical events. Although the Katarapko model inflow boundary can more reliably be represented by a combination of Lock 4 flow rating (at low to medium flow conditions) and Lyrup gauging station rating (under medium to high flow conditions), steady state simulation was also used to ensure consistency of methodology between the models. Model boundary conditions were thus set by using the targeted flows indicated above and selecting the downstream tailwater level boundary from the approximate midpoint of historical observation scatter data from a plot of level versus flow, noting some estimation of flows based on QSA at high flows.

Given future scenarios are anticipated to focus on updated floodplain infrastructure rather than historical structures and banks that will eventually be superseded, simulations were performed using the proposed SARFIIP structures as surrogates for historical infrastructure. For example, for Pike Floodplain, Tanyaca Creek regulator replaces Banks D, F and F1, and Pike River regulator replaces the control at Col Col Bank and Spillway. Where these surrogate structures are used for simulating historical events, operations of these structures are set to best represent the hydraulic effects imparted by the historical banks. This may however create localised differences in inundation extents, such as the area between Banks D, F, F1 and Tanyaca Creek regulator, and between Pike River regulator and Col Col Bank and Spillway. In the case where structures are being constructed where no current structure exists, such as at the Splash outlet and Sawmill Creek in Katarapko Floodplain, the structures are set as fully open for all simulations.

Additionally, full managed inundation of each floodplain was also conducted to ensure that the model configurations operate effectively to inundate the floodplain to full height without leakage through the bank or other instability issues occurring. Note that comparison data, other than that available outside the blocking alignment for given flows, were not available to validate a managed inundation simulation given the proposed nature of the new infrastructure. However, a comparison against previous MIKE FLOOD grid-based outputs with similar model set ups was made for reference.

Following the calibration scenarios, the high flow event in late-2016 (peak QSA ~94 200 ML/d) provided an excellent opportunity to conduct further model validation. The peak flows simulated for validation, accounting for losses through the system, were as follows:

- Pike model inflow: ~90 000 ML/d
- Katarapko model inflow: Approximated from peak at Lyrup gauging station, ~ 82 000 ML/d

Model configuration details used for each flow simulation are presented in Appendix A.

2.3 Comparison data

Data available for model calibration include high flow events up to and including the most recent events in 2011 (peak of ~94 000 ML/d) and 2016 (peak of ~94 500 ML/d). Data sources are as follows:

- Continuous and daily monitoring data from the State Water Data Archive (see Figure 2.2 and Figure 2.3 for location of sites on Katarapko and Pike Floodplains, respectively), including:
    - Rated flow: Calculated QSA (from 1977), Lyrup Gauging Station (>35 000 ML/d, from 1993), Lock 5 (less than ~ 50 000 ML/d, from 1981), Lock 4 (less than ~45 000 ML/d, from 1994), Katarapko Creek (from 2013)
    - Main channel water levels: Locks 3 to 6 (upstream and downstream, from 1920s), Lyrup (A4260663, from 1993), Berri (A4260537, from 1974), Solora (A4261065, from 2000) and Loxton (A4260550, from 1974) Pump Stations, Katarapko Creek downstream of The Splash outfall (A4261225, from 2013)
    - Floodplain water levels
        - Pike Floodplain (from 1996, depending on site): North Pike Lagoon (A4261106), Ex-Coombs Bridge (A4261055), Col Col Bank upstream (A4261053) and downstream (A4261052), Lettons (A4260644), Picnic Ground (A4260645 – discontinued), Mundic Creek at Bank B2 (A4261247), Bank C on Mundic Creek side (A4261244) and River Murray side (A4261245), Tanyaca Creek 800 m downstream of Mundic Creek (A4261246), Pike River downstream of environmental regulator site (A4261248)
        - Katarapko Floodplain (from 2016): Ngak Indau (temporary, from dissolved oxygen (DO) monitoring, A4261265), Eckert Creek upstream Log Crossing (A4261255), Car Park lagoon (temporary, from DO monitoring, A4261264)
        - Gurra Gurra wetlands (from 2016): Gurra Gurra lake at Tortoise crossing (A4261272)
- Flow gaugings (including velocity data) conducted at various locations including:
    - Main channels: Lyrup Gauging Station (from 1993), Katarapko Creek D/S of Splash outlet (from 2013)
    - Pike Floodplain (from ~2003): Margaret Dowling Creek, Deep Creek, Coombs Bridge, Col Col Bank, Rumpagunyah Creek, Lettons, and Bank B2 (N.B. predominantly under normal flow conditions).
    - Katarapko Floodplain (from 2012): Bank J, Log Crossing, Sawmill Creek (N.B. limited data available)
- Inundation imagery from United States Geological Survey (USGS) Landsat Imagery (from 1972 to present).

Note that the three Katarapko Floodplain water level sites listed above were only installed in 2016 and thus do not have long term trends to reference. Of these sites, A4261265 and A4261264 were not operating at the peak of the 2016 high flow event due to the temporary nature of their installation (i.e. as a secondary parameter to DO), resulting in equipment removal following water damage concerns. Instrument error at site A4261255 also resulted in invalid data at the event peak resulting in a limited dataset from these sites for comparison with the 2016 event model simulations.

Plots of river flow versus water levels at the various sites spanning the modelled range of flows were used to compare to model results of model inflow to water levels at corresponding locations in the outputs. In order to obtain a continuous flow record in the river for both Pike and Katarapko Floodplains, two separate sources were required for flow comparisons given that the lock ratings (Locks 4 and 5) become invalid above flows in the range of 30 000 to 60 000 ML/d in the historical record, as indicated Section 2.2. For Pike, the higher flows were estimated from calculated QSA, with an approximated shift in the water level data against the flow data to account for average travel time from downstream of Lock 7 (i.e. calculation point of QSA) to Lock 5. At Lock 5, a time shift of 3 days was used, while at Lyrup the level data was shifted by 5 days to account for additional travel time through the floodplain. Note that this method does not account for any losses experienced in the system between QSA and the floodplain, while the travel time may vary depending on the characteristics of each event. For instance, the 2016 flow event had a peak travel time of approximately 8 to 9 days from Lock 7 to Lock 5, which is a relatively extended period compared to earlier high flow events where the travel time was about 3 to 4 days.

For Katarapko, the flow rating at Lyrup gauging station (A4260663) was used above approximately 40 000 ML/d with no time shift implemented given the close proximity of the gauging site to the Katarapko Floodplain inlets upstream of Lock 4.

USGS Landsat imagery used for inundation extent comparisons to actual events were selected as close as possible to the peak of events representing the simulated flows to allow the closest representation of steady state conditions possible. Given that the comparison data remains only a snapshot of flow conditions at the time rather than a true representation of steady state conditions however, this may result in an overestimation of inundation extent for each simulation, depending on the closeness to the peak of the imagery selected. This difference should be taken into account when assessing modelled against observed data from each steady state simulation.

Note that inundation in the USGS Landsat Imagery becomes obscured in areas of thick vegetation, which reduces the ability to delineate flooded from dry areas. This effectively removes the ability to use quantitative comparisons between modelled and observed inundation extents, and thus only visual comparisons can be achieved.

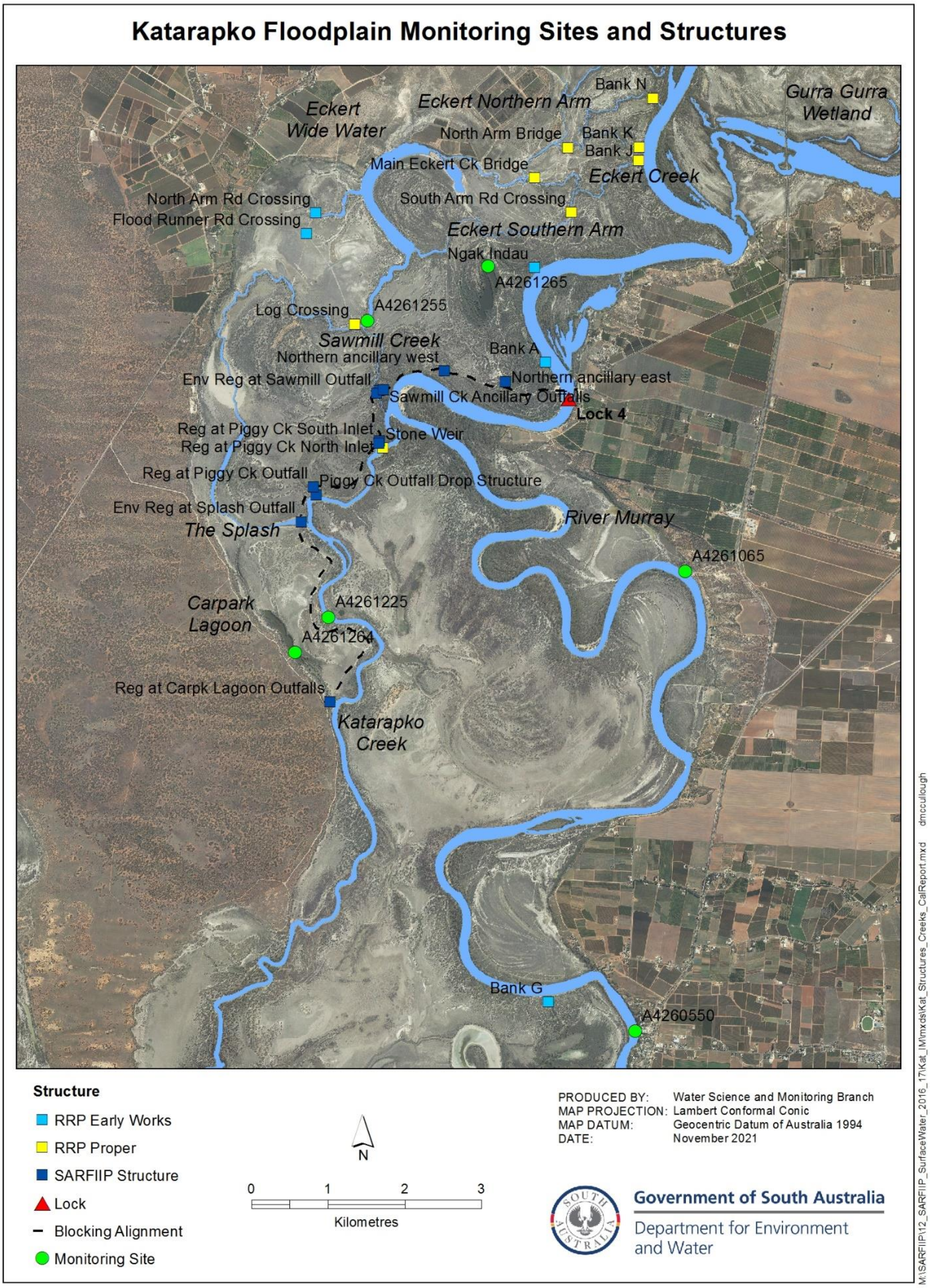


Figure 2.2. Surface water monitoring sites and modelled structures in and adjacent to Katarapko Floodplain.

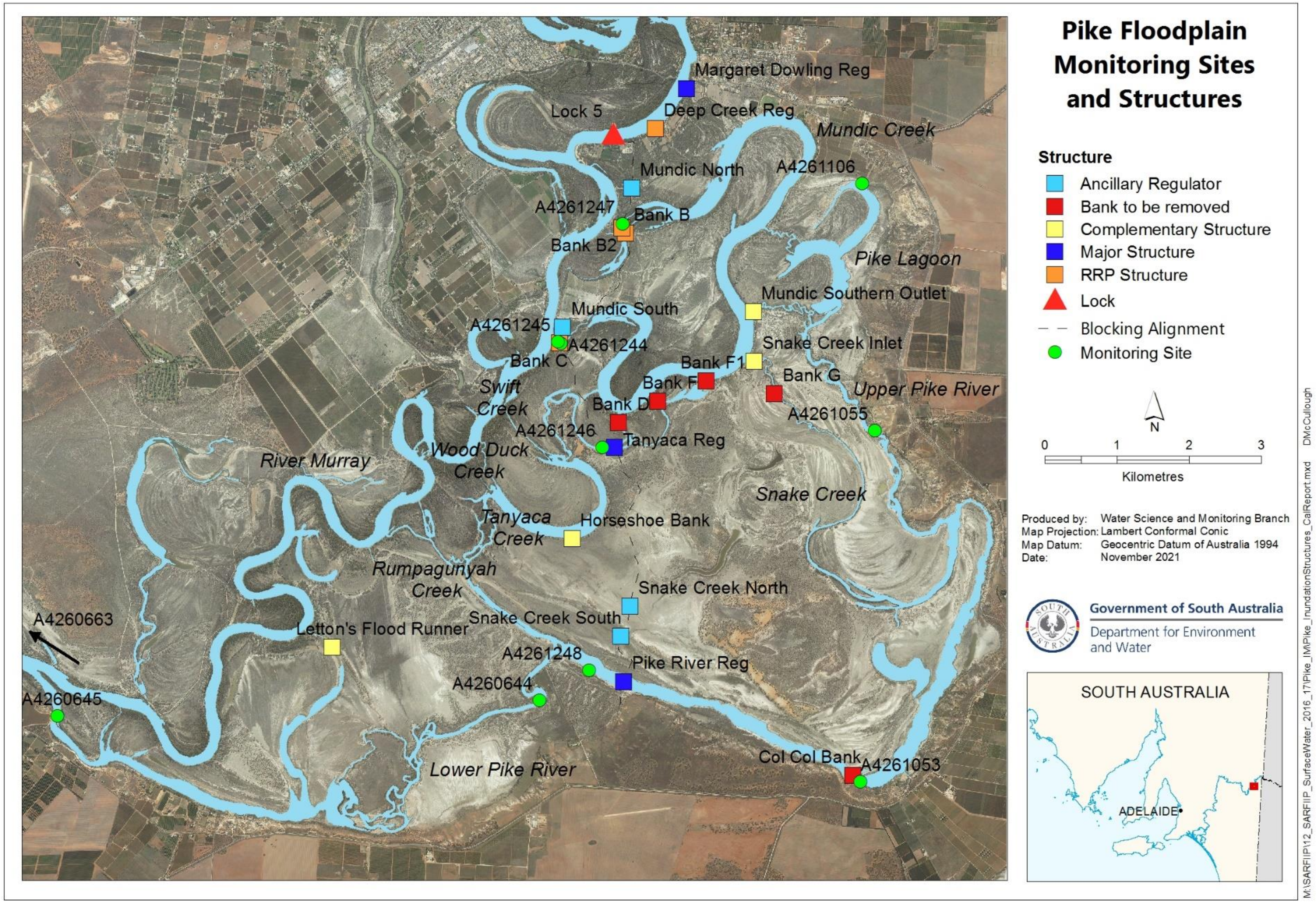


Figure 2.3. Surface water monitoring sites and modelled structures in and adjacent to Pike Floodplain.

3 Model refinement summary

The following sections summarise the general refinements common to both Pike and Katarapko Floodplain models, and specific refinements applied to the individual models. Further details are included in the model update logs presented in Appendix B. Note that many of the summarised model modifications included numerous iterations during the refinement process (as per Figure 2.1).

3.1 General model refinements

3.1.1 Mesh refinements

The model mesh element sizing was adjusted to ensure that appropriate detail was being captured for each area, in particular this involved a reduction in element size for better representation of narrower flow paths in the floodplain areas. Details of the key locations of element adjustment are contained in the floodplain-specific model update sections below.

To support the definition of minor flow paths in the refined mesh, a number of arcs were defined to force element vertices to consistently align along the length of these flow paths during mesh generation. This allowed preservation of point elevations adjusted along these paths during editing.

Where 1–D branches were added or modified, the bank coordinates of the updated 1–D branches were exported to allow areas underlying branches to be defined as arcs and excluded from the mesh in each case. This prevented potential double counting of flows in both 1–D and 2–D domains.

Following mesh structure refinement, elevations of all nodes and vertices in the mesh were updated using the following procedure:

1. Extract coordinates of all nodes and vertices in the updated mesh and create a GIS point shapefile,
2. Assign an elevation for each point in the shapefile based on the corresponding spatial location in the DEM,
3. Where gaps in the DEM exist, use survey data or estimation to populate the missing elevations in the mesh,
4. Inspect the new mesh elevations and edit as required to ensure that erroneous elevations (e.g. where water surface is captured as land in the DEM) are adjusted appropriately, and also ensure that minor flow path minimum elevations are appropriately captured,
5. Export as a spatial elevation ('xyz') file and import into the updated mesh structure.

Note that once the mesh structure was finalised, iterative adjustments only required steps 4 and 5 to be completed. Floodplain-specific edits are contained in the model refinement sections below.

3.1.2 2–D dike structures

'Dike' structures were defined in the model along the banks of the main channels (i.e. River Murray and Katarapko Creek) at locations where large changes in elevations were occurring over a small distance perpendicular to the flow direction. Such occurrences were found to promote localised instabilities in the model, appearing as large changes in water level gradient, which were found to result in substantial under or overestimation of the water level profile in the main channels for a given flow. This was mainly found to occur on the outside of bends where bed depths were substantially lower than the bank height and/or at cliffs adjacent to the channels. The specifics of dike creation in each model are presented in the floodplain-specific model refinement sections below.

3.1.3 1–D/2–D model linkages

Where changes to 1–D branches were made in each model, lateral and standard links were adjusted or added as appropriate to ensure correct coupling between 1–D and 2–D models. This included adjustments to lateral (side) links as required where instabilities occurred in calibration simulations. Instabilities were generally found near the start or end of branches if lateral links were set too close to the standard (terminating) link of the branch, causing a localised water level gradient that affected levels throughout the model domain in some cases.

Lateral links for branches that spanned the blocking alignment in each case were found to promote bypassing of flow across the blocking banks through the 2D model component when attempting to simulate full managed inundation events (i.e. 16.4 m AHD for Pike, 13.5 m AHD for Katarapko). This was addressed by splitting lateral links crossing the bank alignment to allow a minimum of one to two element spacing from the end of each link to the blocking bank, thereby ensuring that all flow through the blocking alignment passed through the 1D model component only.

Elevations at standard links between 1–D and 2–D model components were also matched to reduce model instabilities, this is particularly a concern when low flows are simulated. This involved adjustment of point elevations in the mesh and/or elevations of 1–D cross-sections at link locations as appropriate.

3.2 Pike Floodplain specific refinements

3.2.1 1–D model component

Model branches, and associated cross-sections, not included in the original Pike FM model conversion were added, including ancillary structures in the blocking alignment at Mundic North, Mundic South, Snake Creek North and Snake Creek South regulators.

Cross-sections were updated to match the latest information used in the grid-based model, in particular in Tanyaca Creek downstream of the regulator, which included erroneous depths in some cross-sections that biased water levels high. Cross-section elevations also required modification at the terminal ends of some branch locations where they were adjusted incorrectly during the FM conversion process due to the DEM incorrectly picking up water surface as land elevation. These modifications included a restructuring of existing branches at Mundic southern outlet (Branch 10) and Tanyaca Creek (Branch 4_1) at their 1–D/2–D coupling link locations with Pike lagoon and Tanyaca horseshoe, respectively. Adjustment of cross-sections also required modification of point elevations in the 2–D mesh in some locations for 1–D/2–D linkage consistency, as indicated in section 3.2.2.

The lowest chainage cross-section in the section of Pike River between the Pike River/Rumpagunyah Creek junction and the Letton's floodrunner branch (i.e. Branch 13) was found to be located only approximately 0.2 m upstream of the end of branch chainage in the uncalibrated model. This resulted in a model instability at 10 000 ML/d River Murray flow due to the exceedingly small distance between adjacent calculation points in the branch that this cross-section location created. The instability presented as a localised water level elevation, as shown in Figure 3.1, resulting in underestimation of water levels at the upstream end of the branch and an overestimation of water levels downstream of the branch. Shifting the cross-section to the end chainage of the branch addressed the instability.

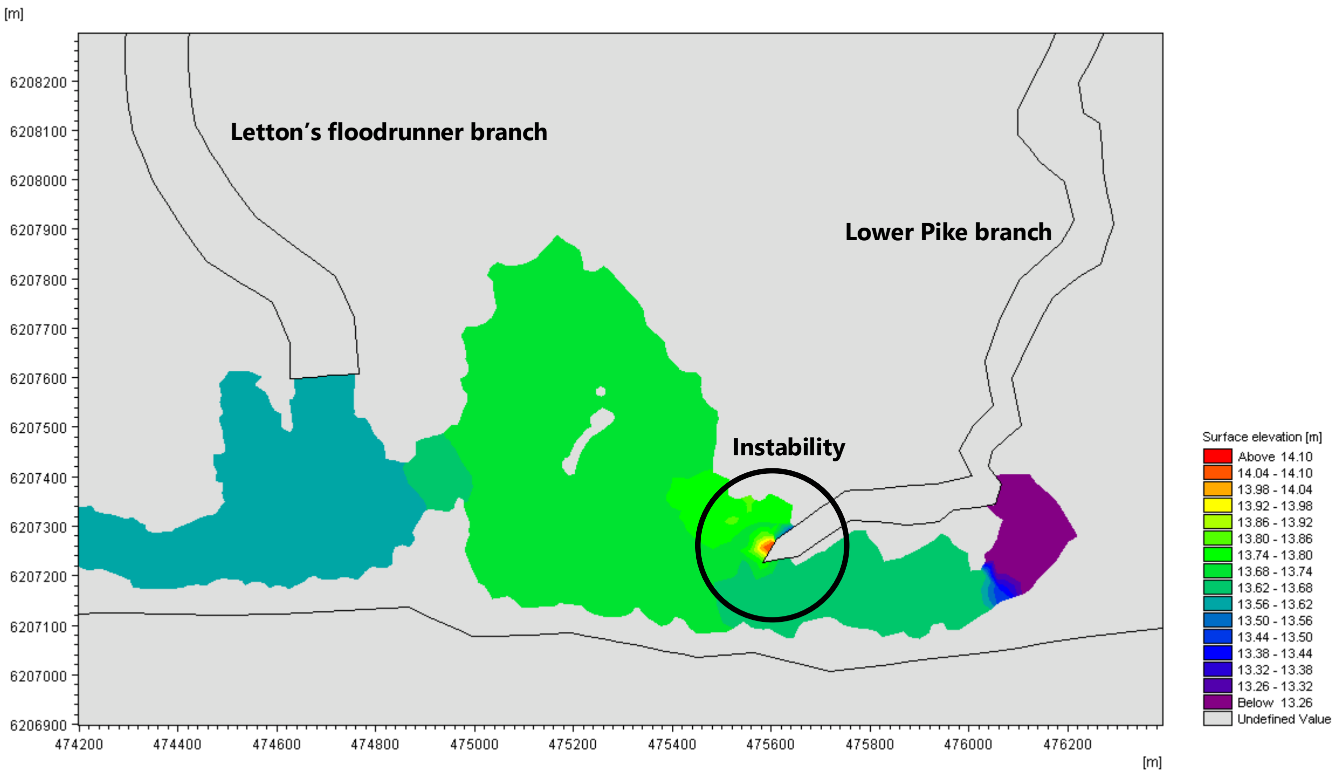


Figure 3.1. Water surface elevation model output showing instability (circled) at 10 000 ML/d River Murray flow scenario between Lower Pike River and Letton's floodrunner branches.

3.2.2 2–D model component

The blocking bank alignment, present as a 2–D dike structure in the converted FM model, was refined to match the latest design alignment, which required only minor realignment at a limited number of locations. The blocking bank dike structure is presented in Figure 3.2 (purple line).

Additional 2–D dike structures are also presented in Figure 3.2, created primarily along the River Murray and at the outlet of Pike River to reduce model instabilities as noted in section 3.1.2.

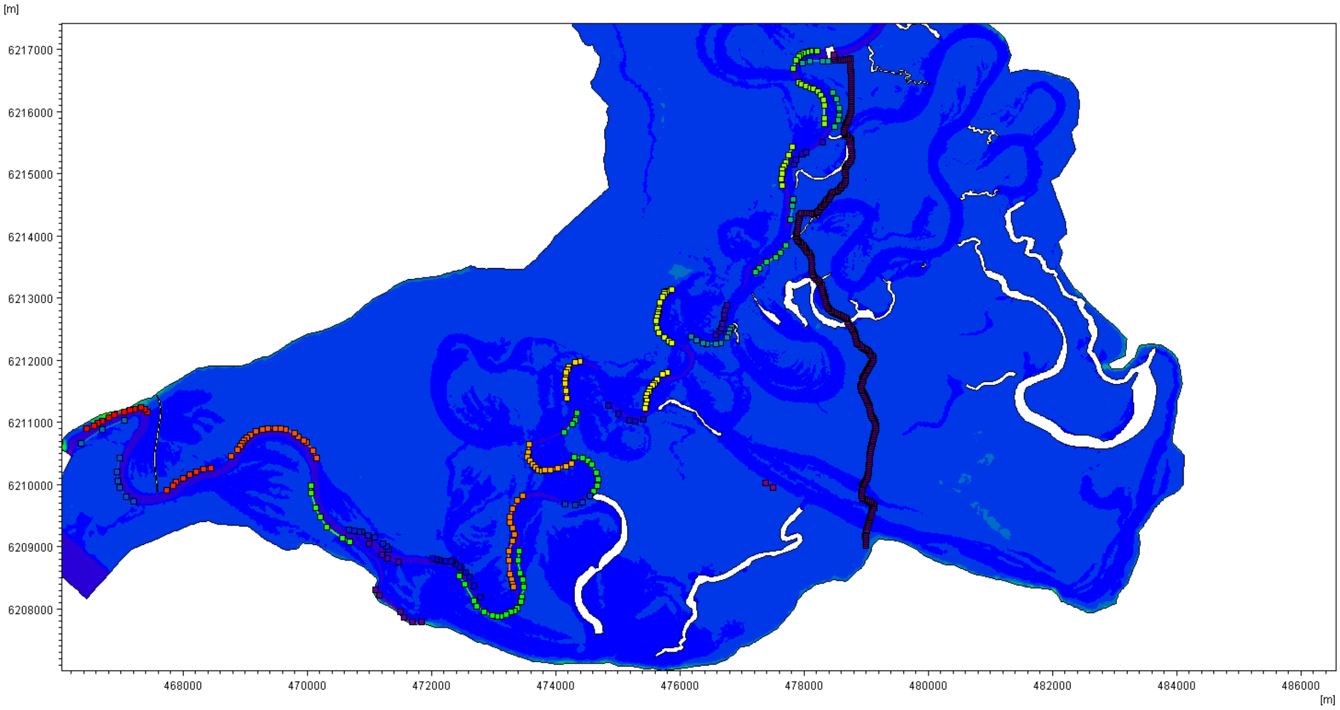
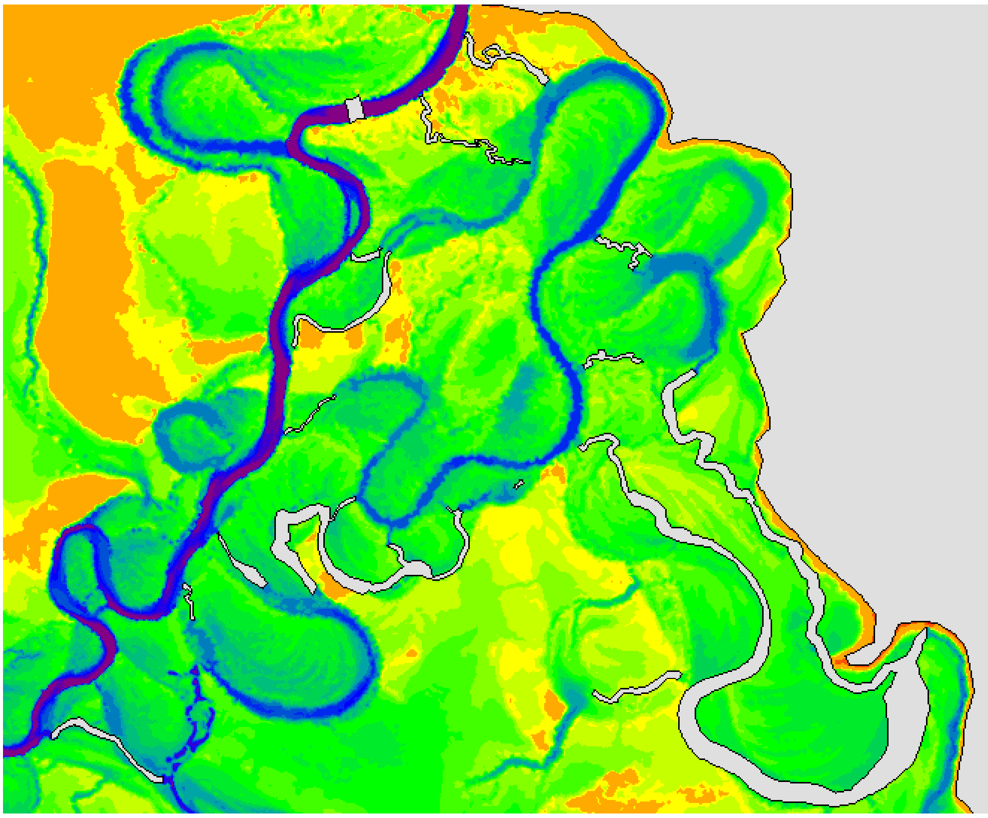


Figure 3.2. Dike structures (coloured dots), including the blocking alignment (purple dots spanning from Lock 5 to the Pike River), included in the Pike Floodplain model.

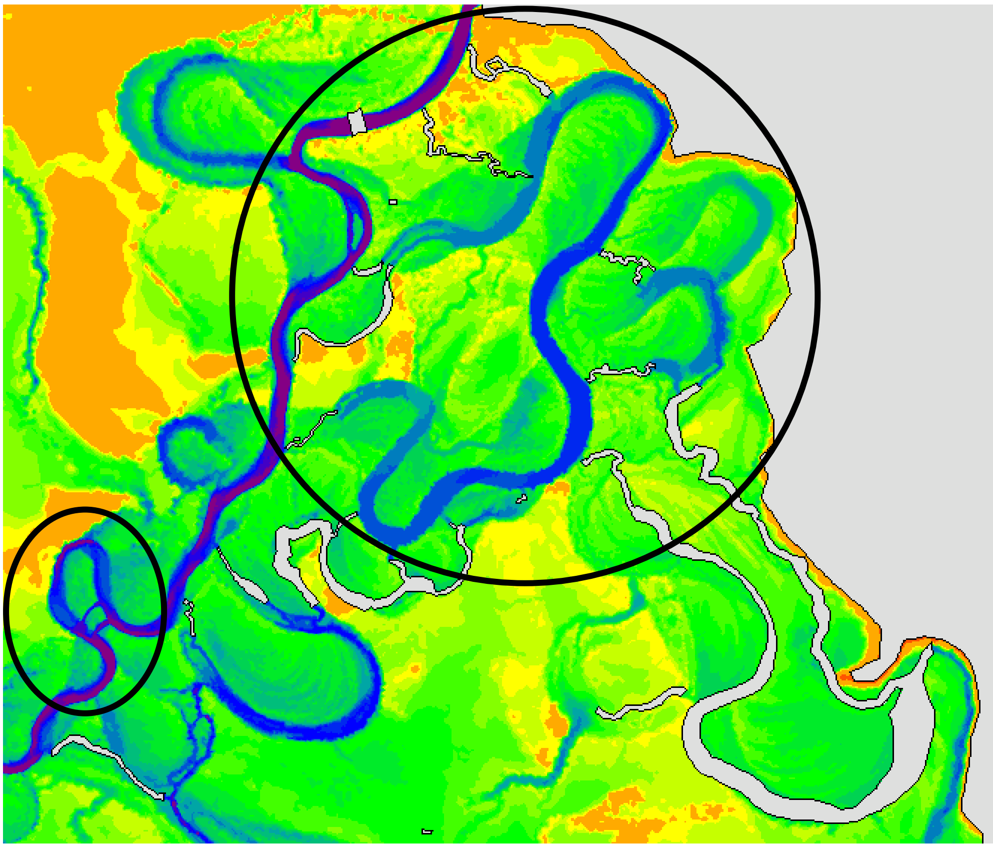
Element sizing was reduced within the floodplain area (i.e. to maximum element sizing of 500 m^2) to better resolve Mundic Creek and narrow flow paths compared to that possible using the default element sizing in the original Pike FM model conversion (i.e. maximum element area of 1000 m^2). Figure 3.3 shows a comparison of the mesh definition before and after modification.

Following mesh structure updates, specific edits were required on extracted elevations including:

- adjustment of elevations where the DEM incorrectly captured water surface as bed elevation, including:
    - parts of Mundic Creek in the vicinity of Banks B, B2 and C,
    - several narrow floodplain flow paths such as Mundic Creek outlets into Pike River,
    - at two bypass channels at Settler's Bend, which are typically flowing at normal pool levels (refer to circled area in south west corner of Figure 3.3), and
    - other narrow flow paths or floodplain depressions to ensure connection at various flows, based on inundation extent comparisons with satellite imagery.
- edits on bank elevations of the River Murray channel to avoid large changes in elevation over small horizontal distances parallel to flow (e.g. where elevations extracted from the DEM in adjacent vertices alternated between the top of bank and channel bed, as in Figure 3.4). Such differences created local water level instabilities that caused a rise in water level elevation with the main channel.



(a)



(b)

Figure 3.3. Comparison of (a) original mesh and (b) refined mesh for Pike Floodplain. Circled areas highlight examples of mesh refinement. Greyed areas represent flow paths represented in 1–D.

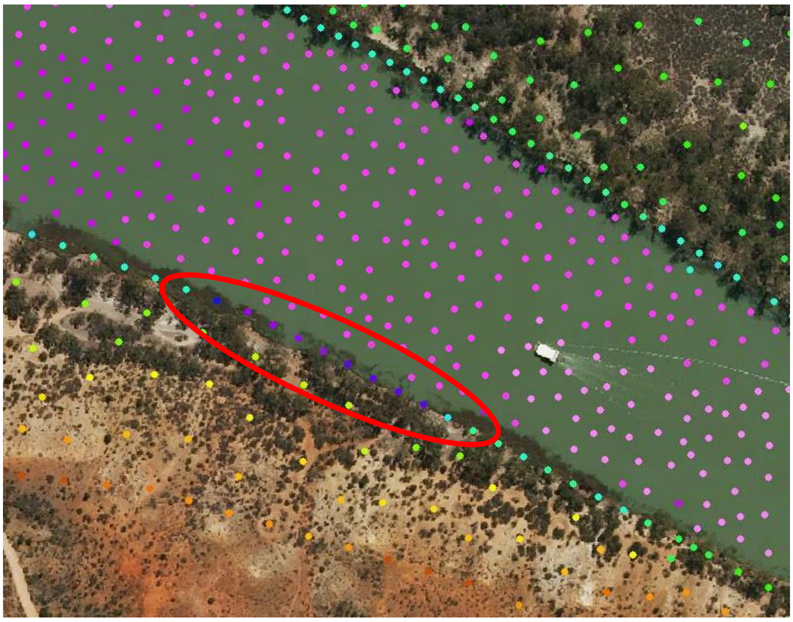


Figure 3.4. Scatter elevation variation along channel bank (purple/pink bed elevation, blue/green bank elevation).

The 2–D bed resistance values were largely maintained at those used during FM model conversion, with Manning's n value of 0.025 in the River Murray channel in the Lock 4 to 6 reach, matching the value used in the 1–D River Murray component in the grid-based model. One minor alteration was made to the resistance map upstream of Lock 4, namely in the channels at Settler's Bend, as shown in Figure 3.5 – bed resistance of these bypass channels was set to the same resistance factor as the River Murray, whereas the original bed resistance map set these resistance values similar to the surrounding land area.

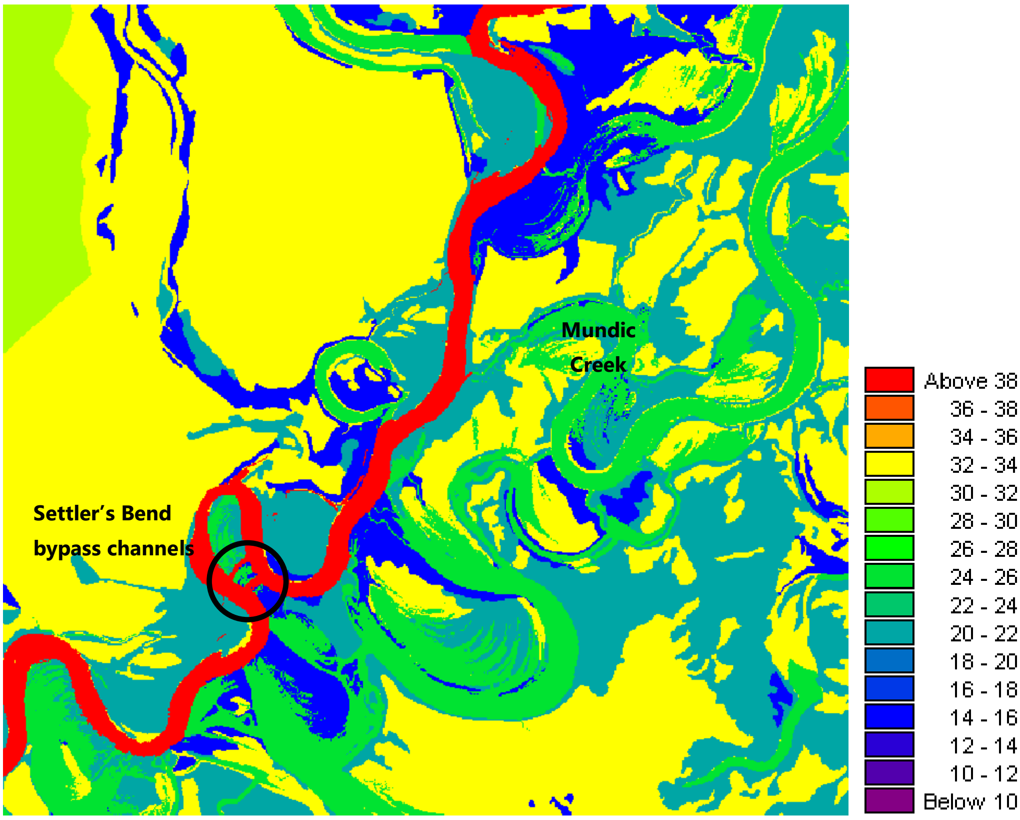


Figure 3.5. Location of Settler's Bend relative to Mundic Creek. Colours denote different Manning's roughness coefficients (M=1/n). Bypass channels at Settler's Bend circled in black.

The downstream 2–D water level boundary, representing the inlet to Gurra Gurra wetland in the model domain (see Figure 3.6), was found to be causing an artificial reduction in water levels in the modelled results when connected at higher flows (i.e. at simulations of 75 000 ML/d and above). This result was due to the wetland boundary diverting outflows from the model away from the 1–D River Murray component in increasing amounts with increasing river flows. Given this diversion does not reconnect to the river as it does in practice through Gurra Gurra prior to reaching Lock 4, this artificially lowers the levels in the 1–D River Murray component, resulting in reduced levels in the 2–D model component. The water level boundary was therefore changed to a land boundary, which prevents mass transfer at this location, thereby forcing all flow through the 1–D River Murray section, and providing more realistic levels through the system.

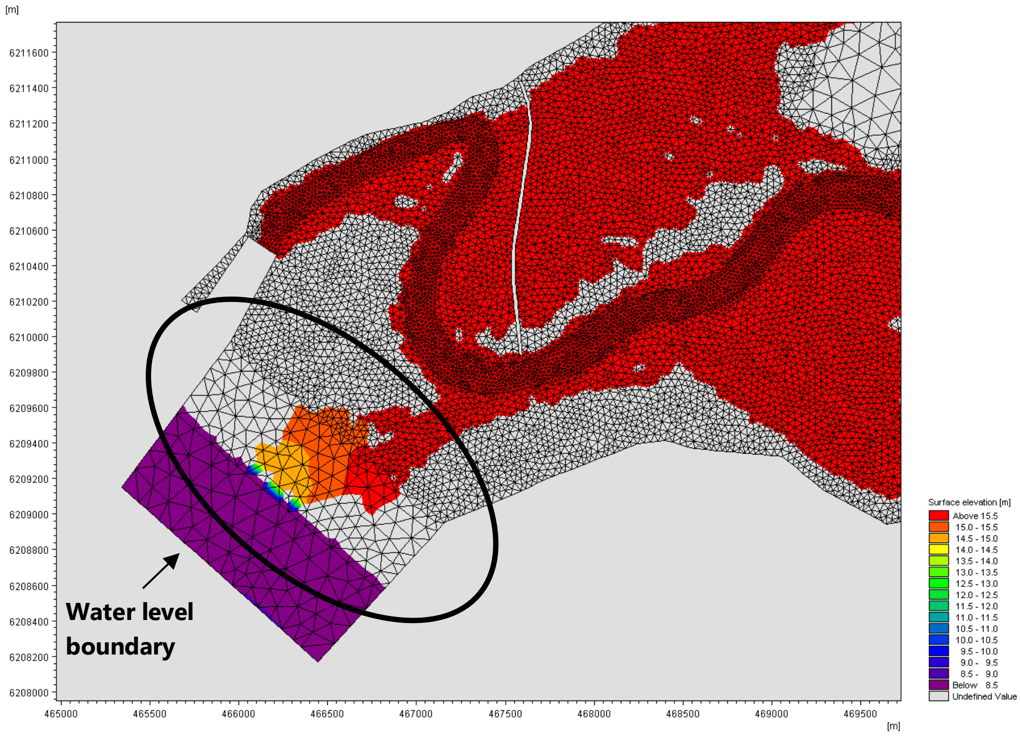


Figure 3.6. Downstream water level boundary and approximate Gurra Gurra inlet location (circled) at 90 000 ML/d.

3.2.3 1–D/2–D model linkages

A major instability at the Bank F branch lateral link location was identified within the floodplain in the uncalibrated model, as shown in Figure 3.7. This instability presented as a localised water level gradient that caused an overall reduction in water levels throughout the Lock 4 to 5 reach in the model under natural high flow and managed inundation conditions. This instability was particularly apparent under managed inundation conditions, as it prevented floodplain levels from reaching the full managed inundation height of 16.4 m AHD. Due to the small length of the branch, the lateral links could be removed to address the instability, with only the standard link at the start of the branch allowing transfer of water from 2–D to 1–D model components.

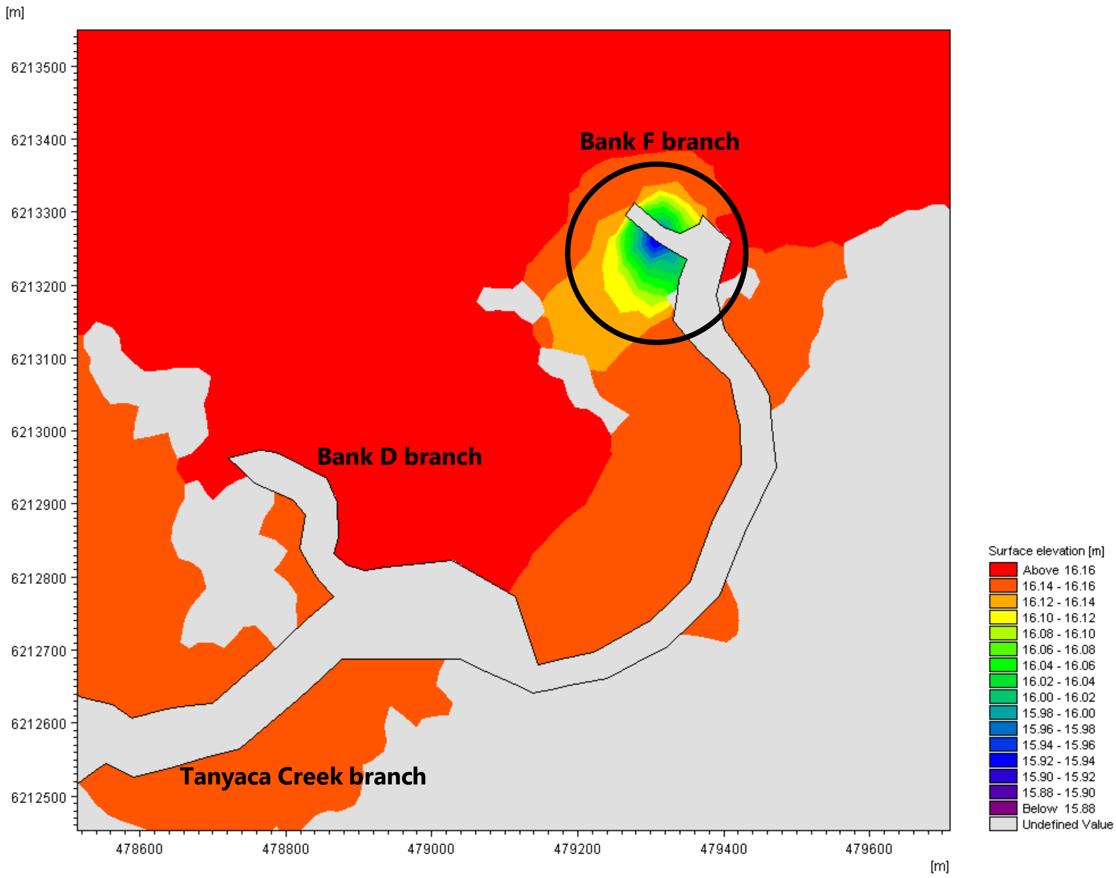


Figure 3.7. Instability at Bank F branch (circled) creating localised water level gradient.

3.3 Katarapko Floodplain specific refinements

3.3.1 1–D model component

Branches, and associated cross-sections, not included in the original Katarapko FM model conversion were added, including:

- eastern and western structures on the Lock 4 to Sawmill creek section of blocking bank,
- the Piggy Creek northern inlet flow path, and
- Gurra Gurra wetland inlet branch through the Lyrup forest.

For consistency purposes, the branch structure and cross-sections were imported directly from the standalone Gurra Gurra FM model, which was developed externally to the converted FM models (Nielsen, 2016).

Existing 1–D branches, associated cross-sections and structure dimensions/alignment were adjusted to match the latest designs and model requirements as included in the latest MIKE FLOOD grid-based model, including:

- at Sawmill creek east and west ancillaries,
- Car Park inlet and outlet branches, and
- the Splash in the reach section immediately upstream of the primary outlet regulator and adjacent to Car Park lagoon.

A 1–D branch representing a floodrunner on Katarapko Island, connecting Katarapko Creek and the River Murray between Solora and Loxton pump stations (designated as branch 'WETL_1541_CK'), was deleted from the model configuration to alternatively allow representation in the 2–D mesh given its low priority for hydraulic data extraction compared to locations within the floodplain itself.

3.3.2 2–D model component

The blocking bank alignment, present as a 2–D dike structure in the converted FM model, was redefined to match the latest design alignment and elevation (i.e. 13.7 m AHD crest height for the selected 13.5 m AHD maximum inundation option). Spillways were also included at a height of 0.1 m below the nominal bank crest (i.e. 13.6 m AHD spillway crest height). The blocking bank dike structure is presented in Figure 3.8 (red line).

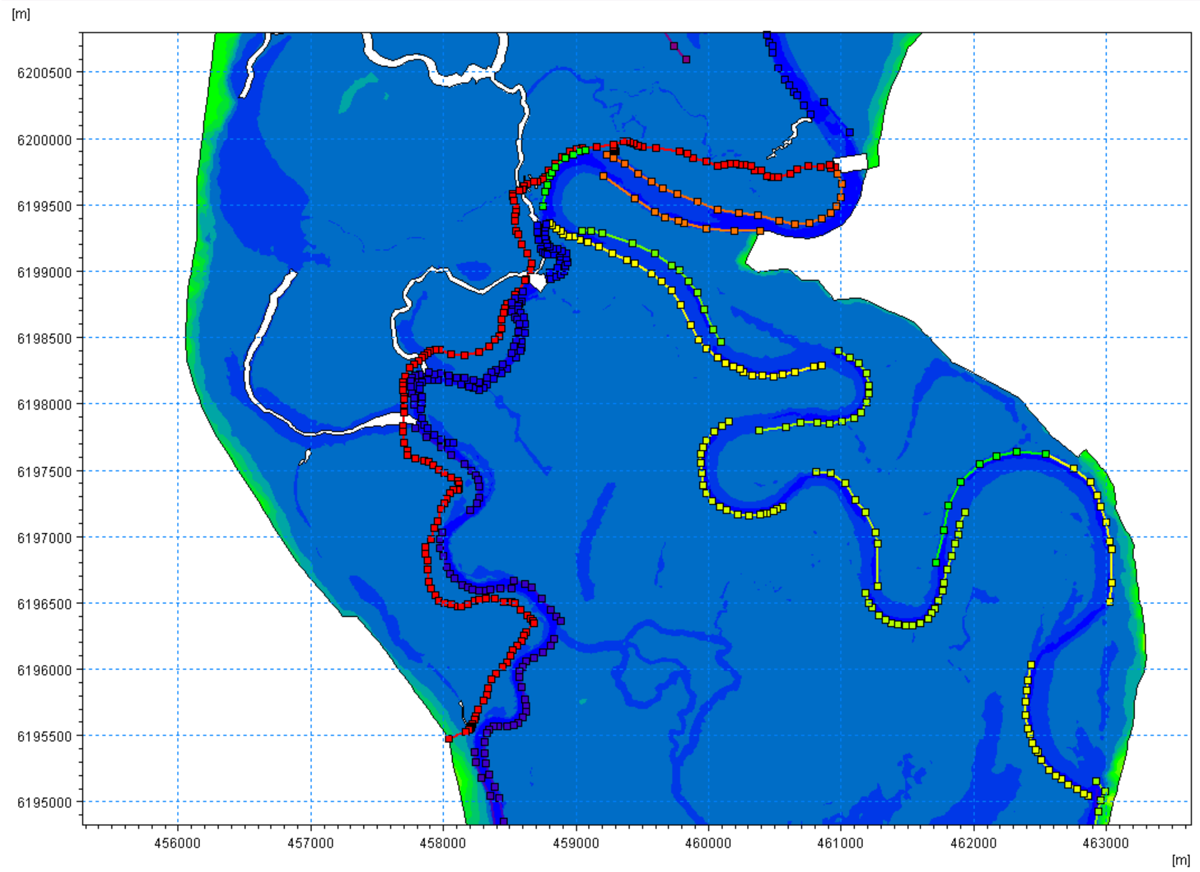
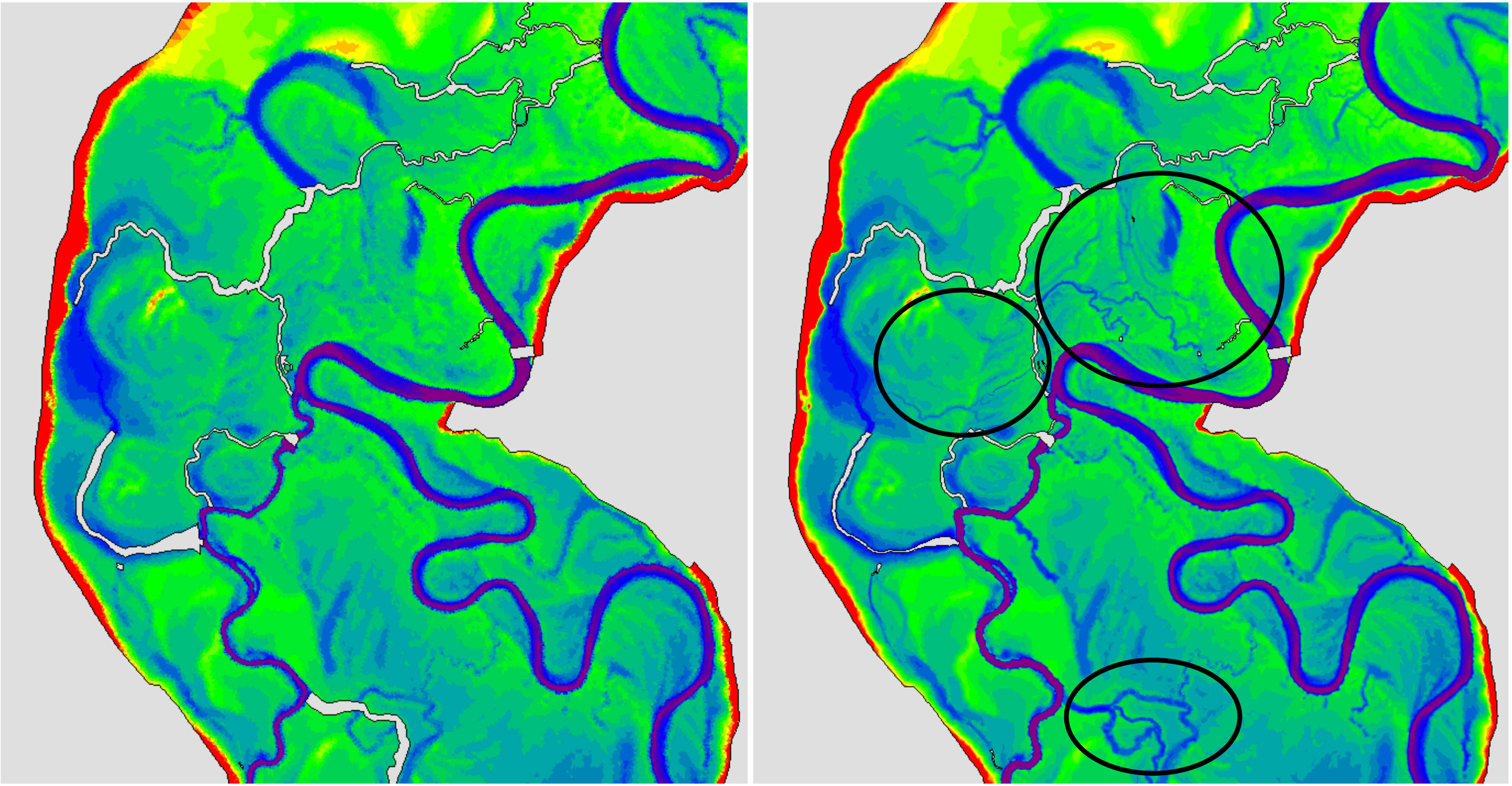


Figure 3.8. Dike structures, including the blocking alignment (red line), included in the Katarapko Floodplain model.

Element sizing was reduced within the upper floodplain and Car Park lagoon areas based on visual inspection of the mesh against the DEM, which indicated a number of minor flow paths and terrain features were present that were inadequately defined in the originally assigned mesh size. This was conducted in localised areas with a reduction in maximum element sizing from a typical value of 1000 m^2 to sizes ranging from 250 to 800 m^2, depending on the concentrations of minor flow paths or size of features in the area. Figure 3.9 shows a comparison of the mesh definition before and after modification in the main floodplain area.



(a) (b)

Figure 3.9. Close up of Katarapko Floodplain area detail refinement from (a) original mesh and (b) refined mesh. Circled areas highlight examples of refinement. Greyed areas represent excluded areas from mesh.

The Gurra Gurra wetland area in the north east of the model domain was replaced with the recent standalone Gurra Gurra FM model mesh in order to ensure consistency between the two models.

Following scatter data generation, edits were required on localised elevations to include:

- adjustment of elevations where the DEM incorrectly captured the water surface as bed elevation, including Lake Bonney, Yatco lagoon and other wetland areas upstream of Lock 3,
- edits on bank elevations of the River Murray and Katarapko Creek channels to avoid large changes in elevation over small horizontal distances parallel to flow, as conducted for Pike (see section 3.2.2)

In addition to dike structures defined along the banks of the main channels (refer to section 3.1.2), additional 2–D dike structures were added for purposes including:

- along roads in the model domain to ensure they can be overtopped at high flow conditions, which were prevented from doing so in the original FM model version due to being excluded from the mesh e.g. the Berri to Loxton road in the Gurra Gurra area is expected to overtop at River Murray flows in the order of approximately 120 000 ML/d.
- at bank locations upstream of Lock 4 that were not represented in the 1–D model component but associated with minor floodrunners.

Dike structures included in the Katarapko Floodplain model are shown in Figure 3.10.

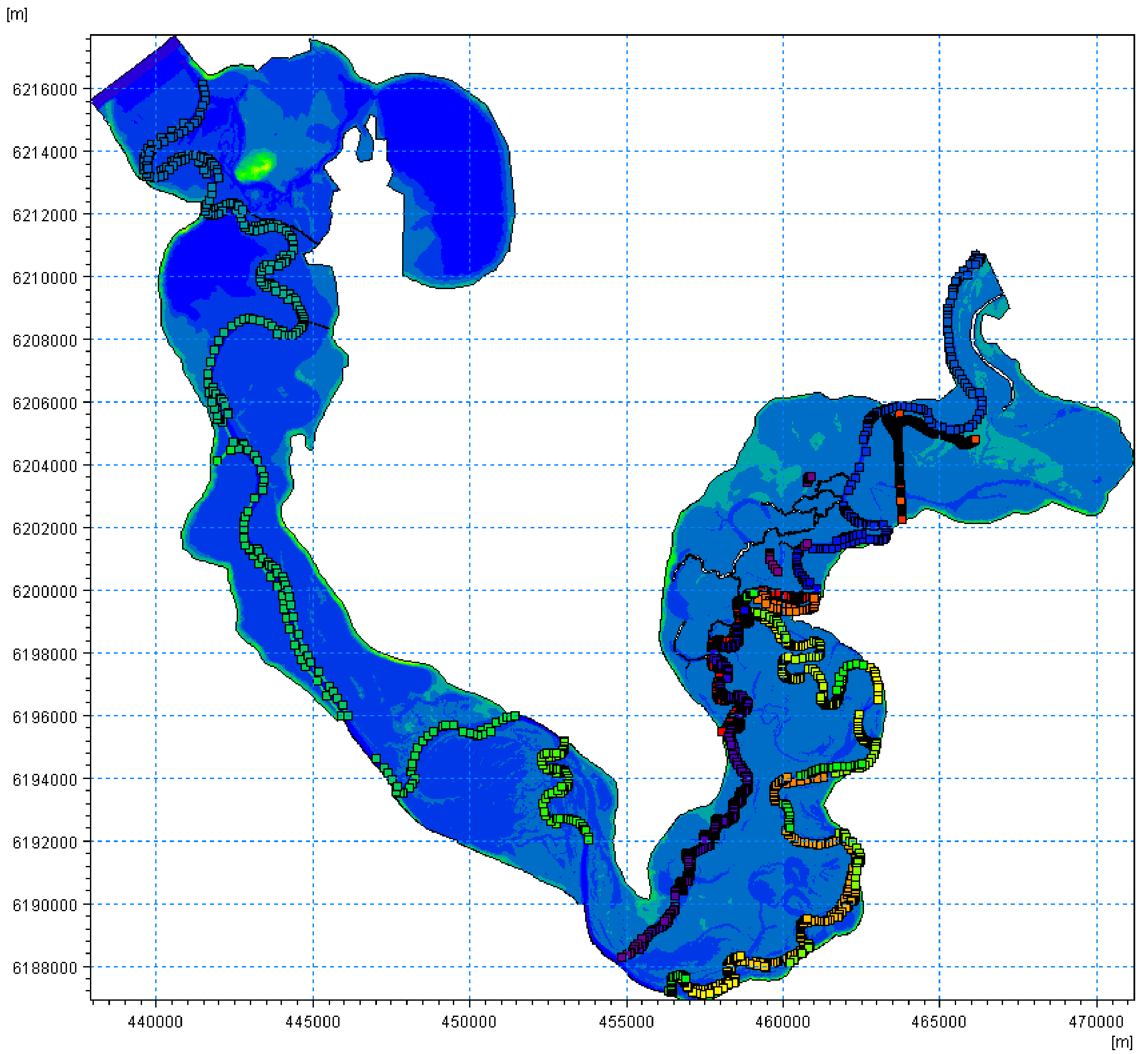


Figure 3.10. Dike structures included in the Katarapko Floodplain model.

The 2–D bed resistance values used during the model conversion process were largely retained, except for in Katarapko Creek and the River Murray between Locks 3 and 4, which were adjusted as follows:

- reducing Katarapko Creek Manning's n value from 0.040 to 0.025
- reducing River Murray Manning's n value from 0.025 to 0.024

These adjustments were made based on comparison of calibration simulation results with observed data for flows throughout the range tested. Figure 3.11 shows the adjusted roughness map used in the Katarapko Floodplain model.

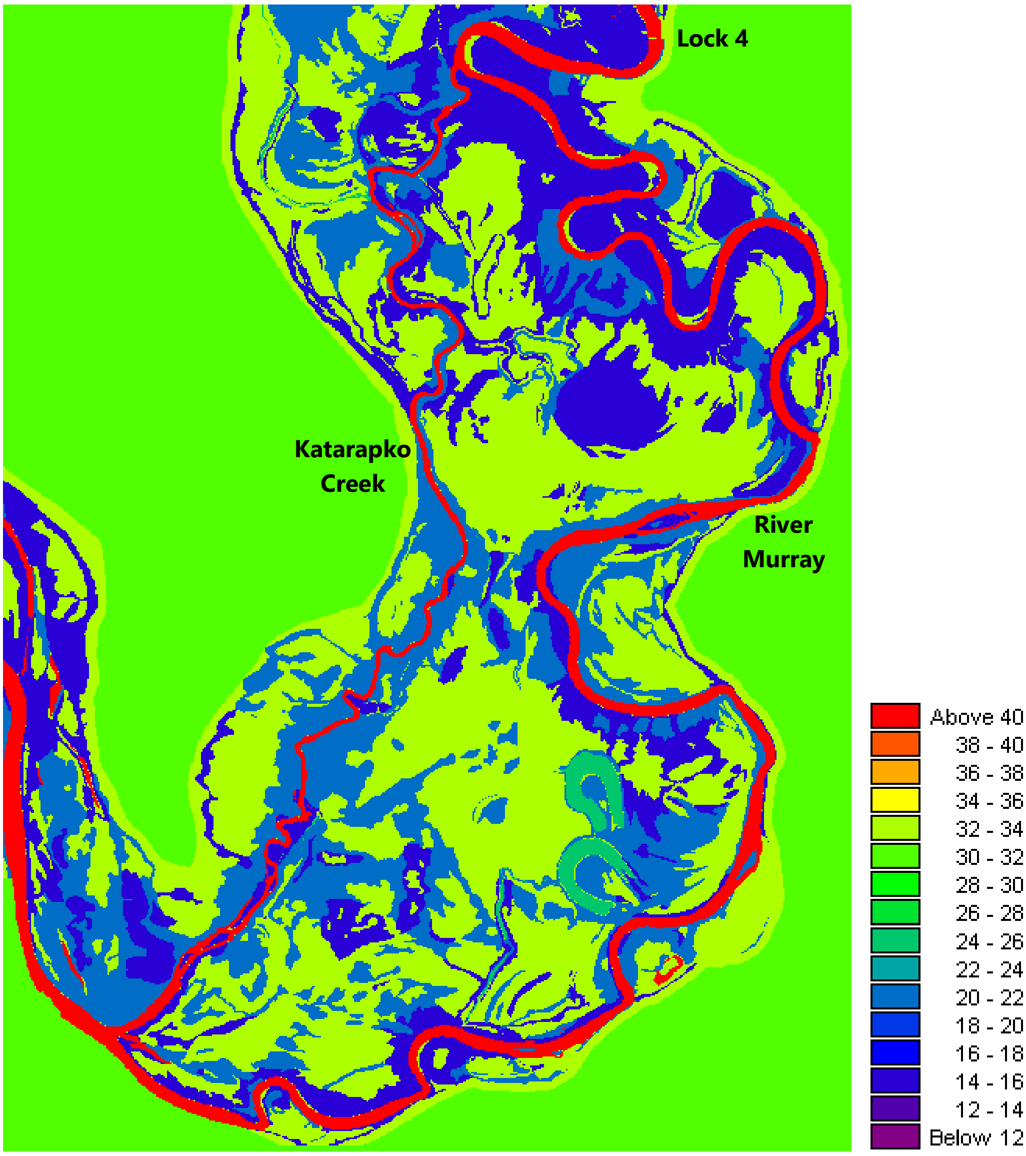


Figure 3.11. Adjusted Manning's roughness map for Katarapko Floodplain model. Colours denote different Manning's roughness coefficients (M=1/n).

4 Calibration results and discussion

4.1 Pike Floodplain

Modelled levels in the River Murray at Lock 5 downstream (A4260513) and Lyrup gauging station (A4260663) for 10 000, 40 000, 60 000, 75 000 and 90 000 ML/d flows are compared to observed data over a similar range of flows in Figure 4.1. The modelled levels for both Lock 5 downstream and Lyrup pump station are within the scatter of observed levels to flow at each flow, suggesting the model is representing river levels at these locations adequately. Note that all observed data in the period of record are included in the plot, which incorporates both rising and falling limbs of high flow events. From this scatter data, the steady state level for a given flow is assumed to fall at the approximate mid-point of the data for the purposes of calibration and validation of each model.

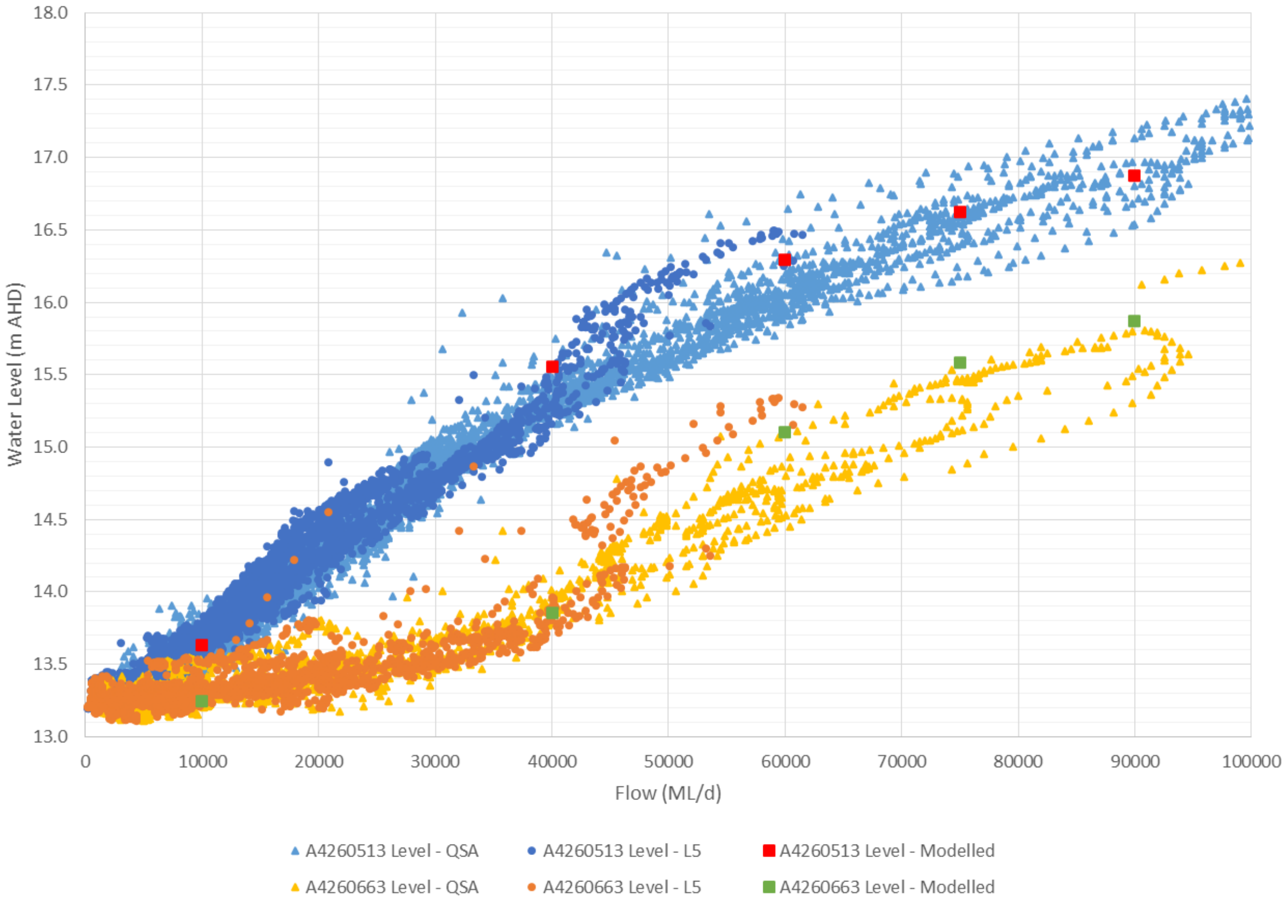


Figure 4.1. Comparison of modelled River Murray water levels to observed data in the Lock 4 to 5 reach.

Modelled levels within the floodplain at various monitoring site locations are compared to observed data and presented in Figure 4.2 to Figure 4.11. Note that the recent monitoring sites installed in 2016 have a relatively small sample of data to reference compared to the more established sites, and thus may present a higher level of uncertainty when comparing modelled to the observed data at these sites. Despite this, in general the modelled water levels fall within the available scatter data at each monitoring site.

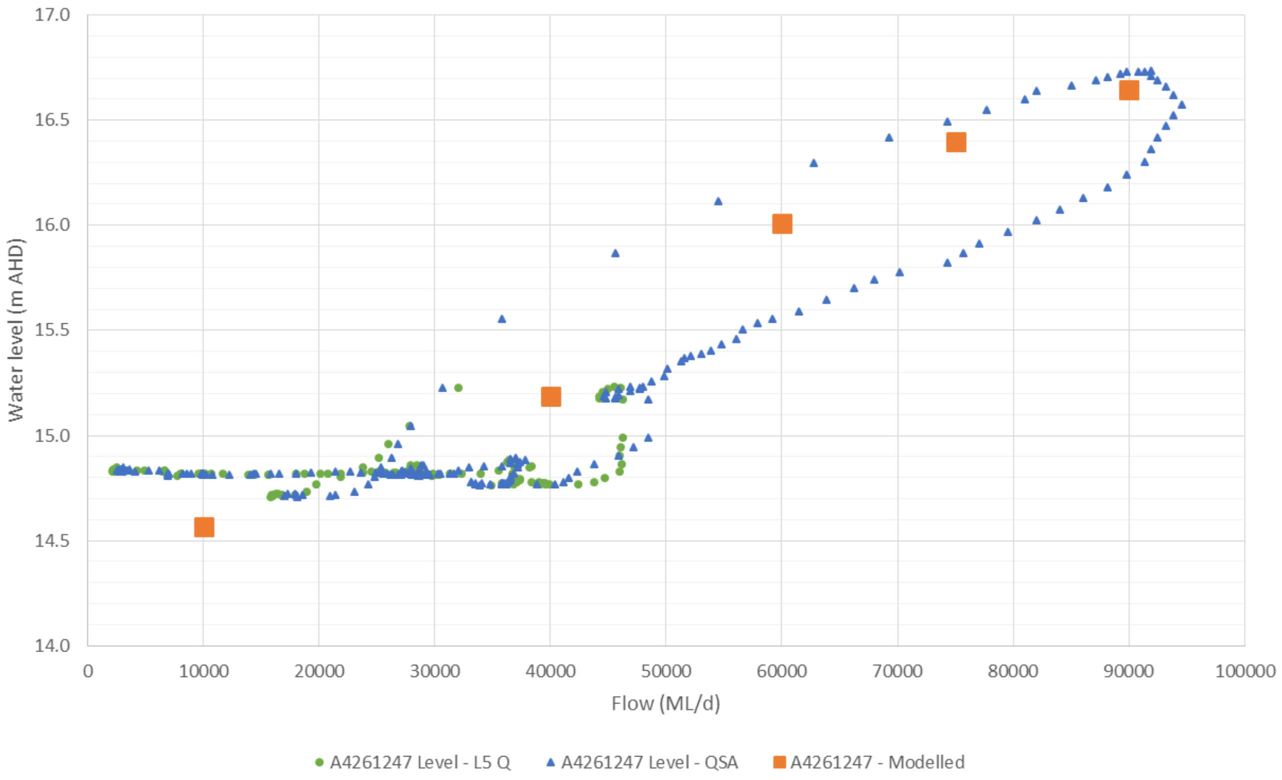


Figure 4.2. Comparison of modelled to observed water level at Bank B2 (Mundic Creek) monitoring site (A4261247).

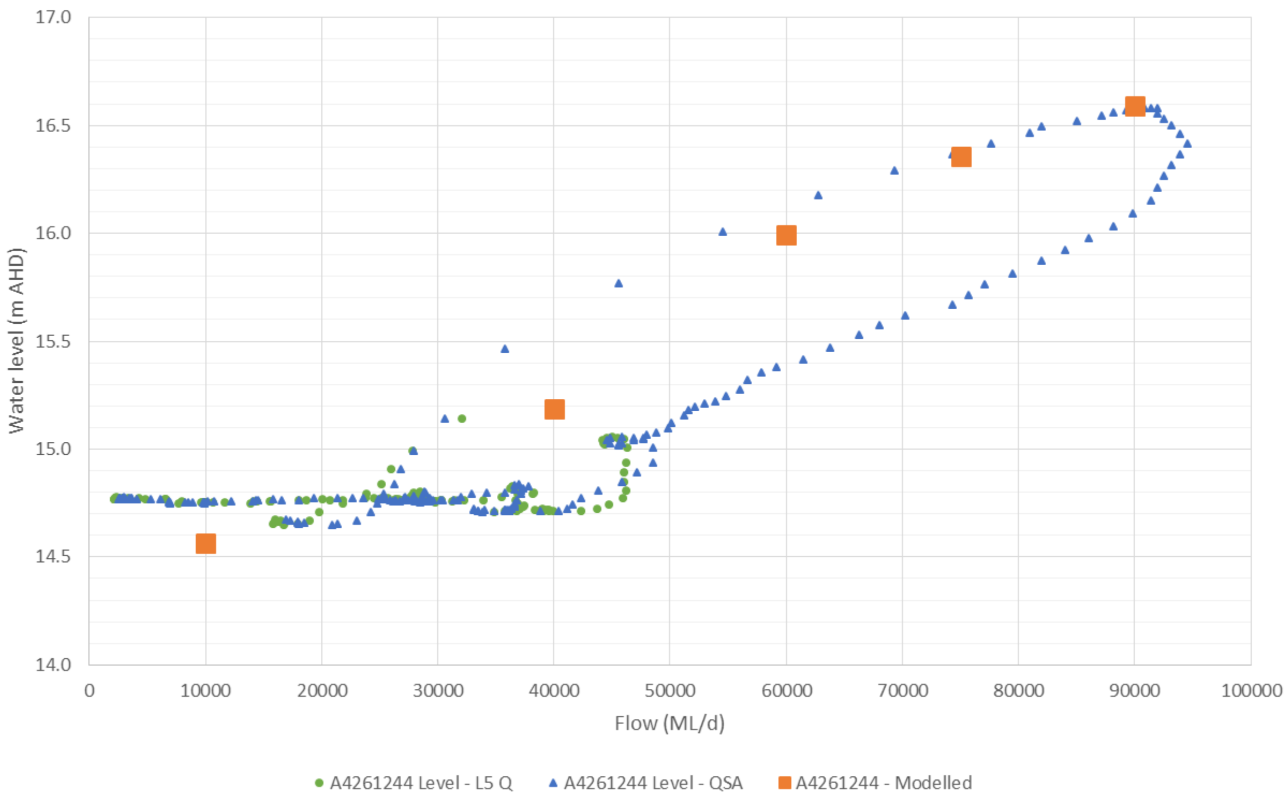


Figure 4.3. Comparison of modelled to observed water level at Bank C (Mundic Creek) monitoring site (A4261244).

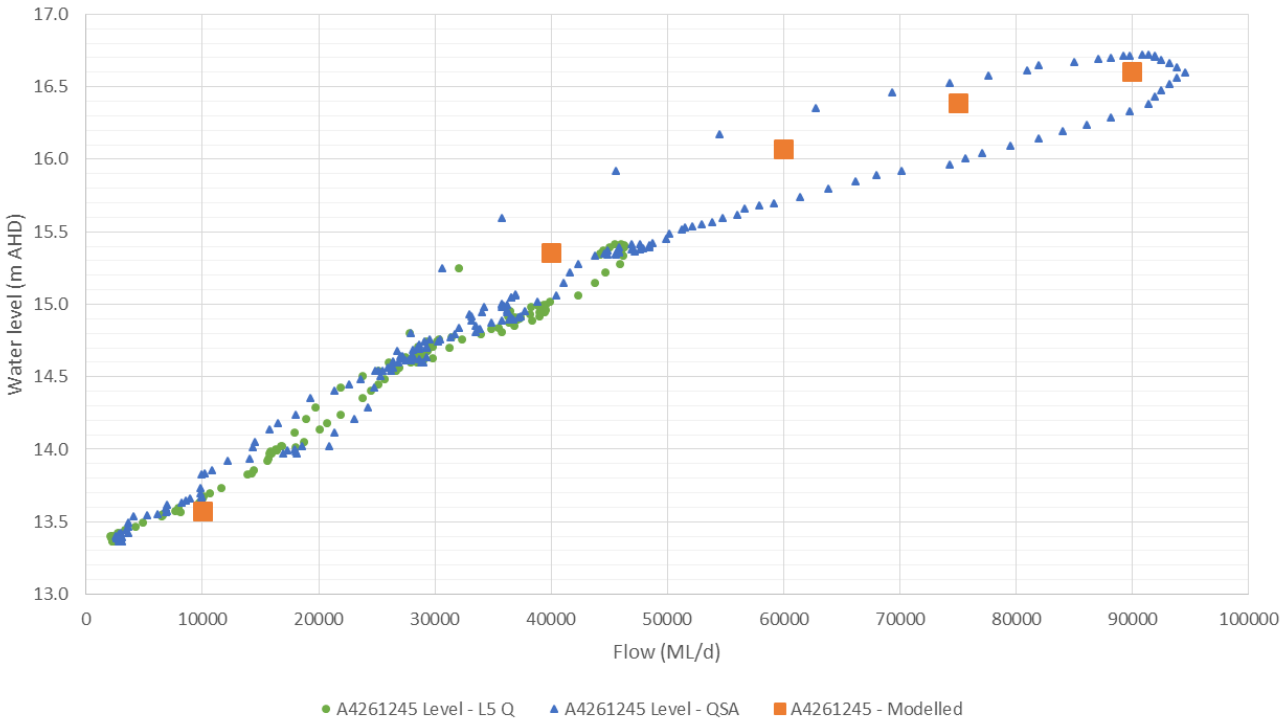


Figure 4.4. Comparison of modelled to observed water level at Bank C (River Murray) monitoring site (A4261245).

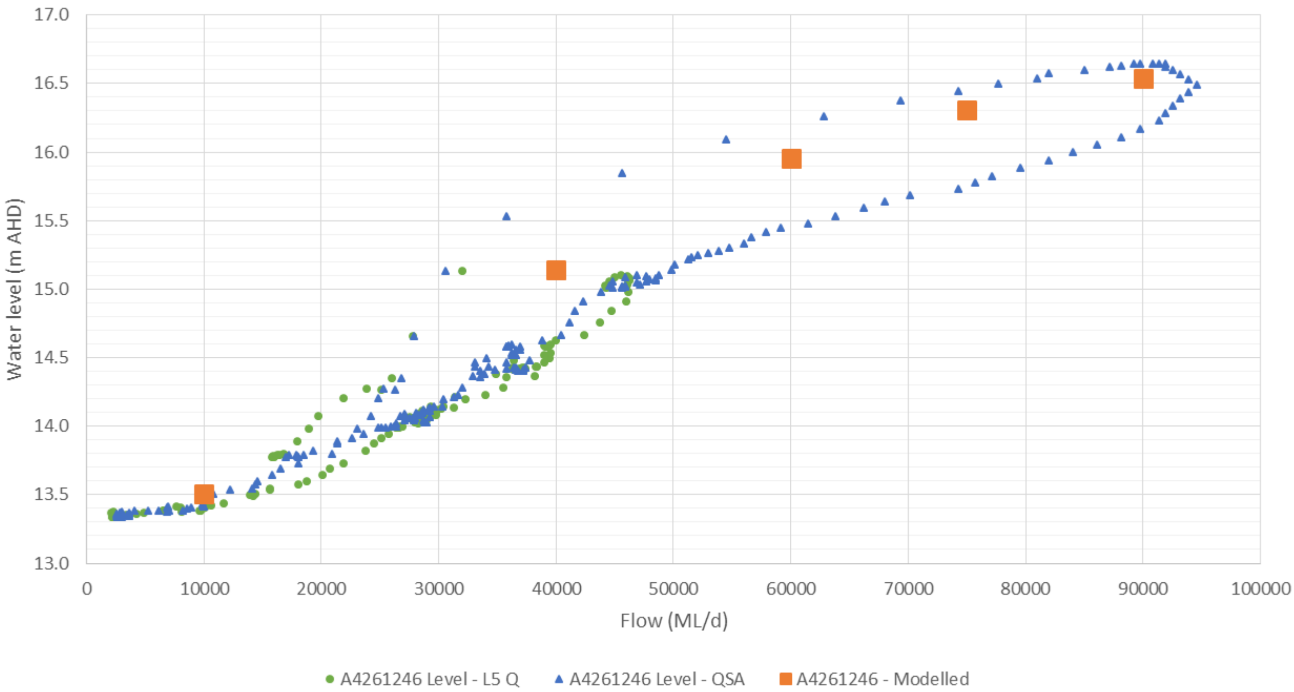


Figure 4.5. Comparison of modelled to observed water level at Tanyaca Creek monitoring site (A4261246).

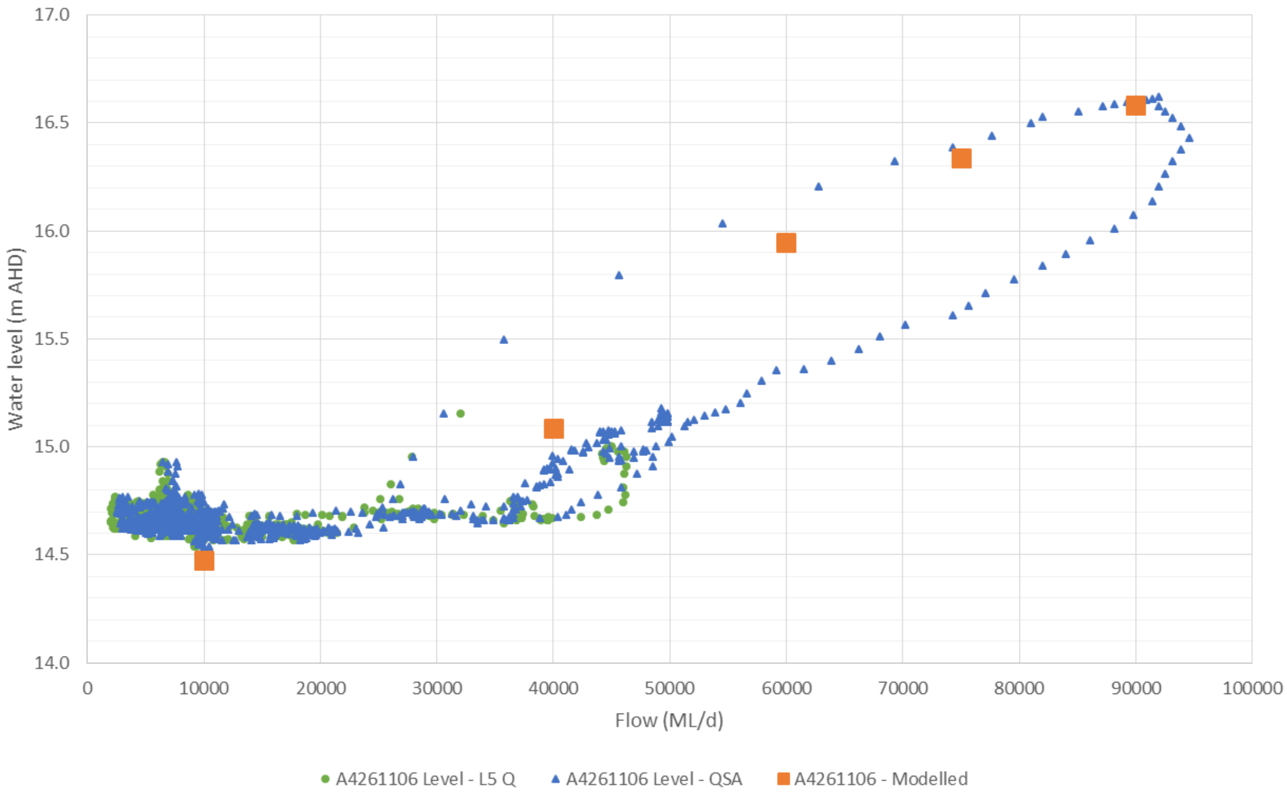


Figure 4.6. Comparison of modelled to observed water level at North Pike Lagoon monitoring site (A4261106).

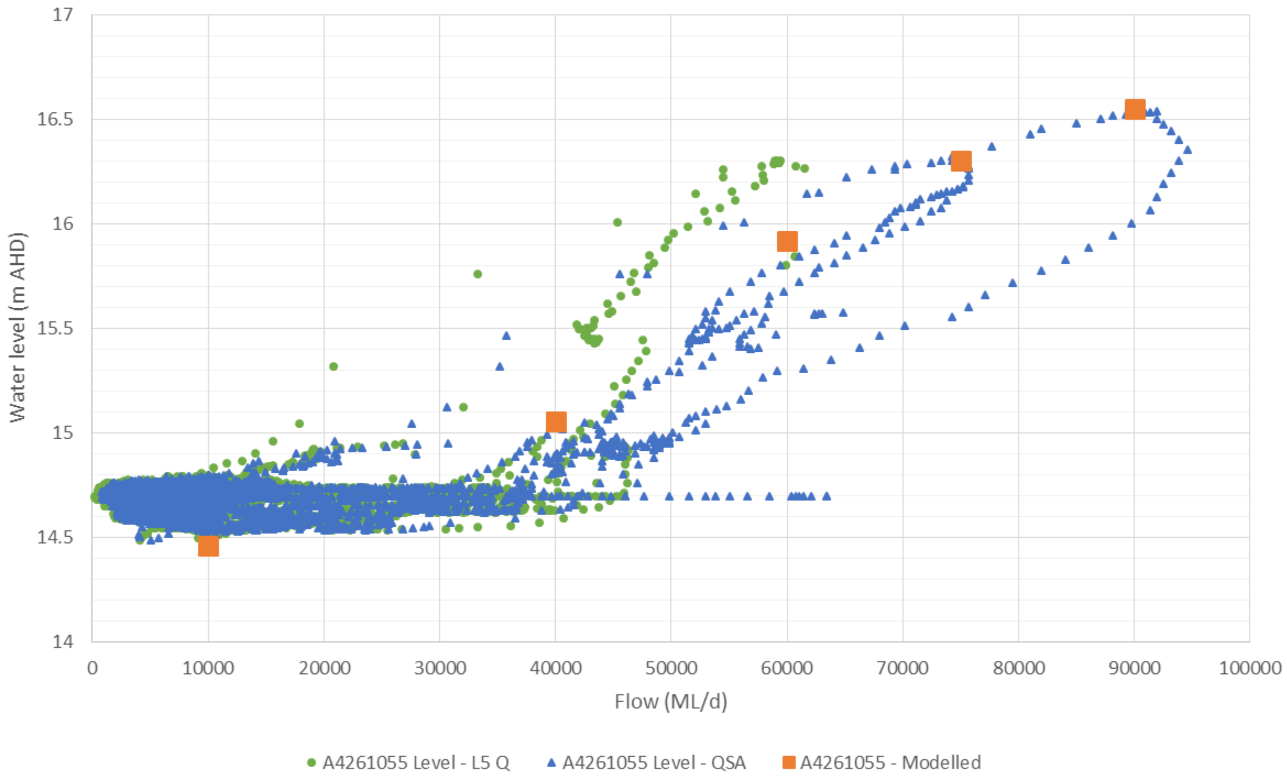


Figure 4.7. Comparison of modelled to observed water level at ex-Coombs bridge monitoring site (A4261055).

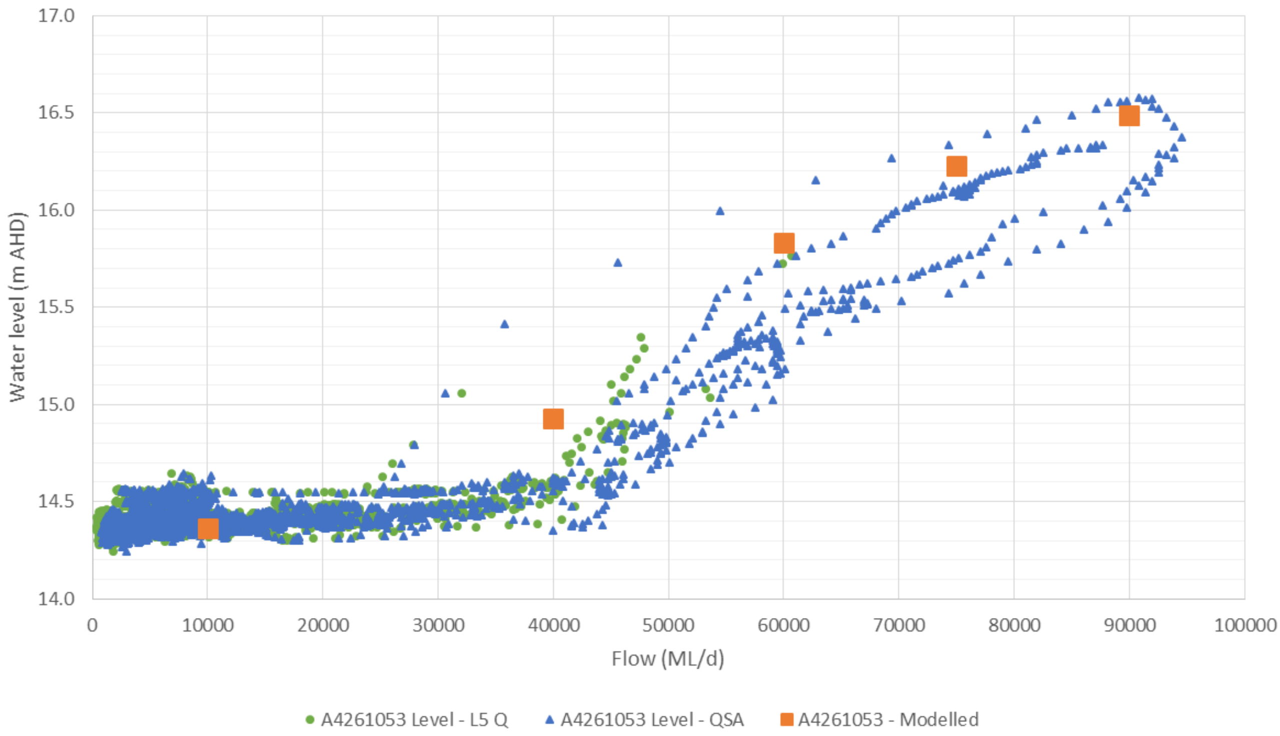


Figure 4.8. Comparison of modelled to observed water level at Col Col bank upstream monitoring site (A4261053).

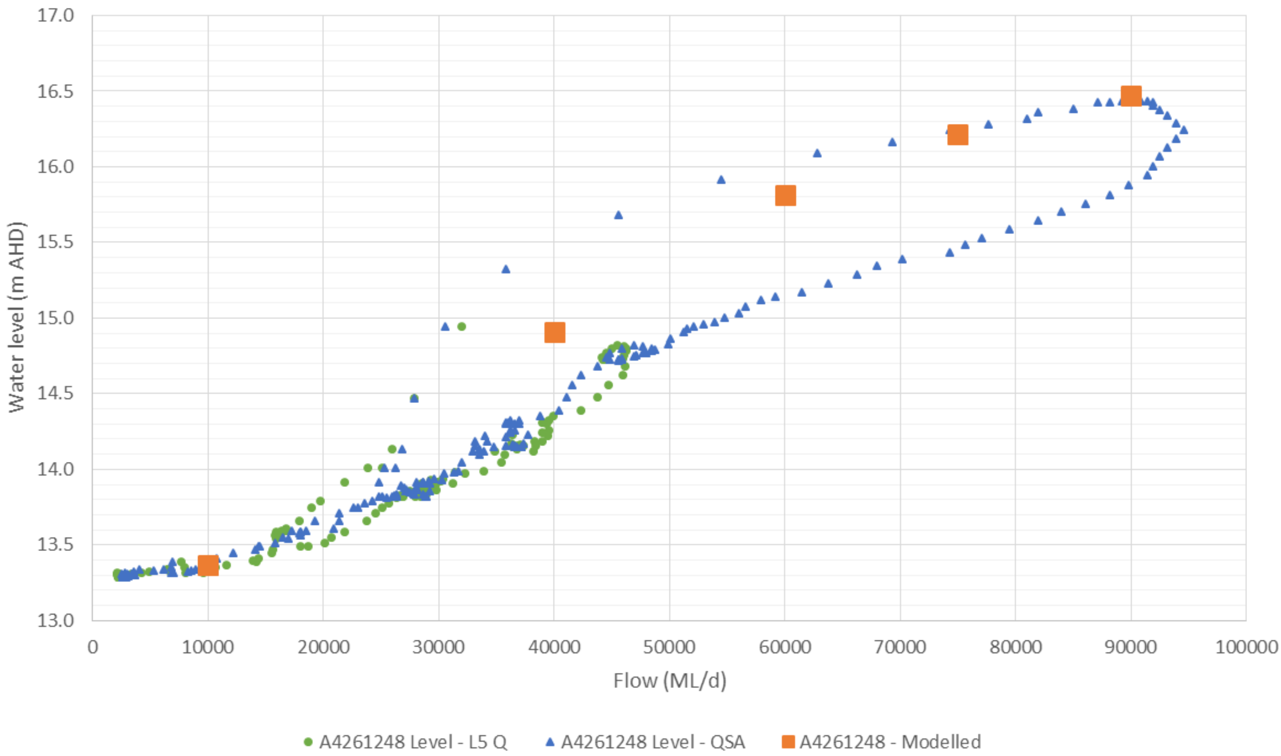


Figure 4.9. Comparison of modelled to observed water level at Pike River D/S regulator monitoring site (A4261248).

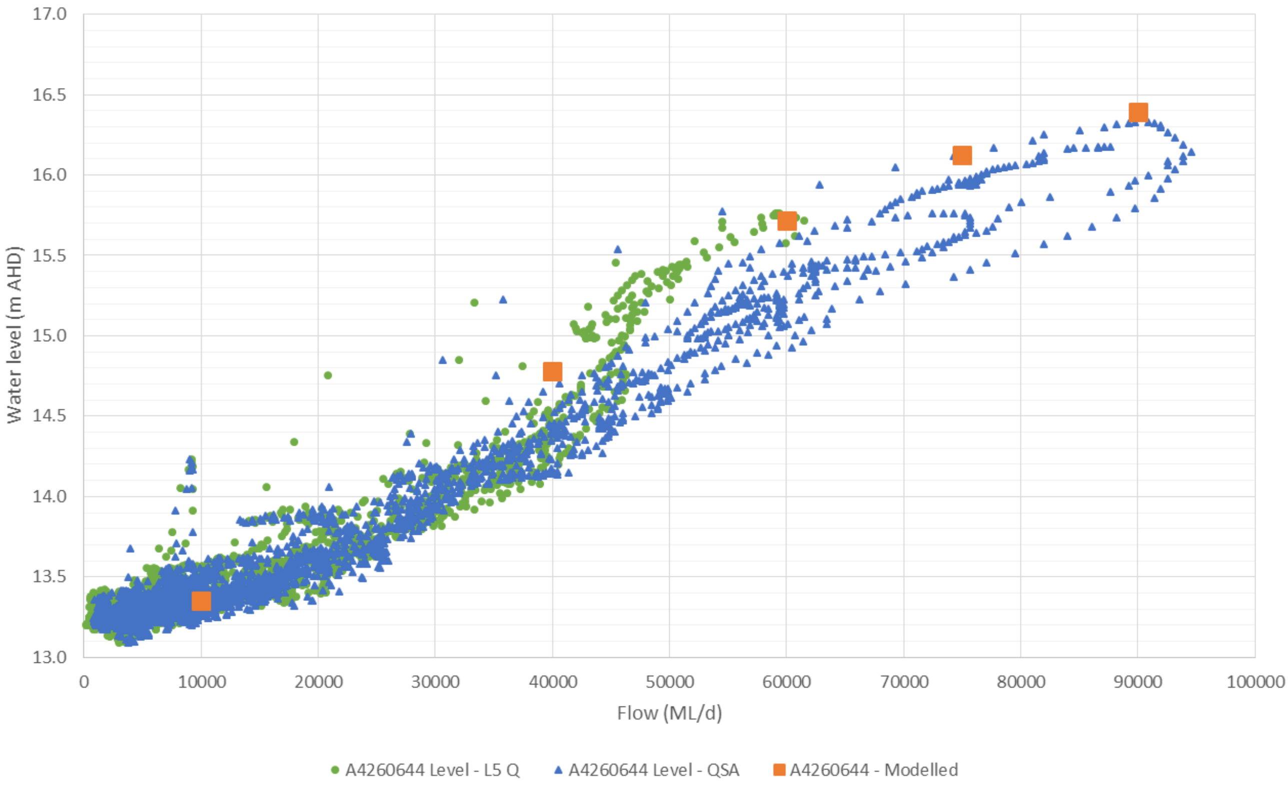


Figure 4.10. Comparison of modelled to observed water level at Pike River at Letton's monitoring site (A4260644).

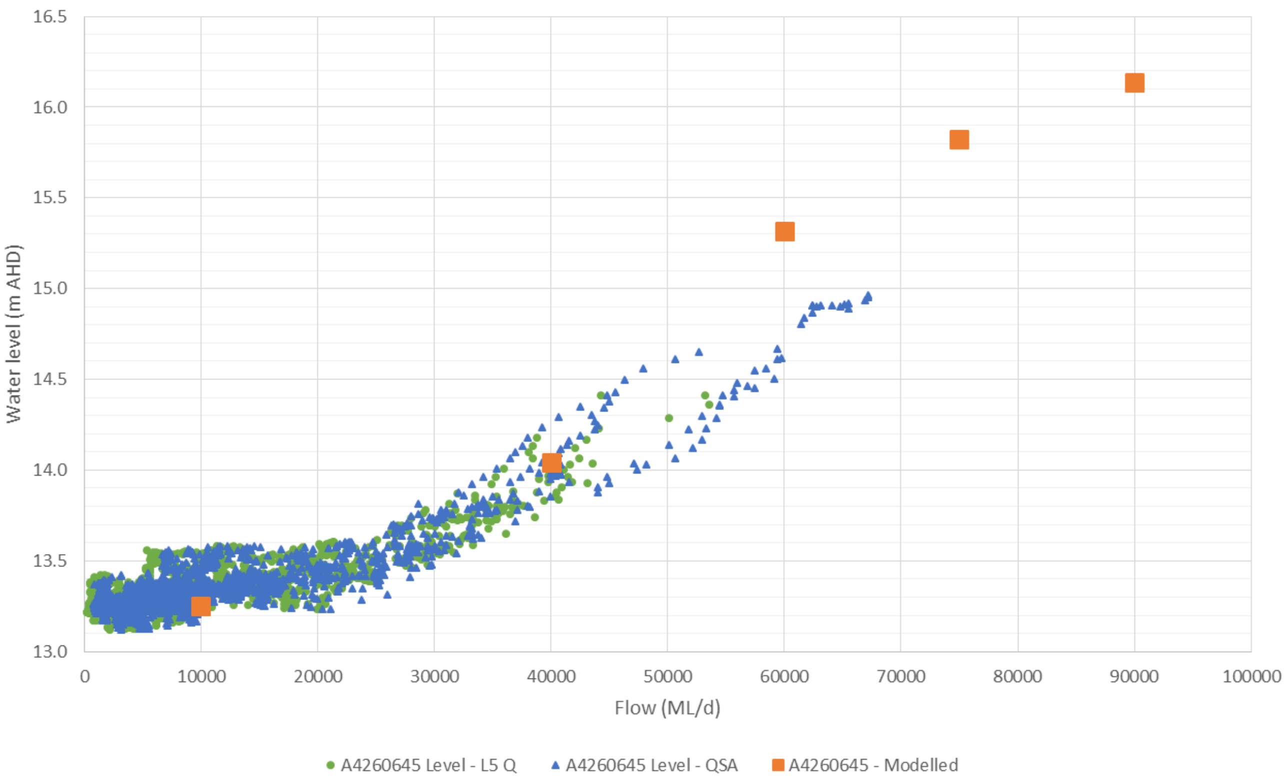


Figure 4.11. Comparison of modelled to observed water level at Pike River Picnic Ground monitoring site (A4260645).

At 10 000 ML/d, some of the monitoring locations upstream of Tanyaca Creek and Pike River regulators present water levels that are marginally lower than the observed data at historical floodplain inflows of approximately 300 ML/d combined through Margaret Dowling and Deep Creeks. This is particularly the case in the two Mundic Creek sites at Banks B2 and C (i.e. A4261247 – Figure 4.2 and A4261244 – Figure 4.3, respectively), which are approximately 10-15 cm lower than the typical historical Mundic level of approximately 14.75 m AHD. This difference however corresponds to a recent discovery relating to the elevation reference at upstream of Col Col bank under normal flows, which indicated the historical reference used at the water level monitoring site was approximately 15-20 cm below the resurveyed value. This therefore changed the previously understood water level operational setting upstream of Col Col Bank of 14.35 m AHD to approximately 14.50-14.55 m AHD at the new reference height. As such, the modelling within the floodplain was understating the water level setting upstream of Col Col Bank at 10 000 ML/d. It should also be noted that the FM model excludes some historical structures, such as Bank G and Coombs Bridge, which have previously acted to raise water levels in Mundic Creek. These factors combined account for the lower modelled levels in Mundic Creek at 10 000 ML/d. Water levels upstream of Col Col Bank at higher flows are not affected by this set point value however due to a rise in level above the resurveyed operational set point, while levels downstream of Col Col Bank and in the River Murray are also unaffected by this difference.

Modelled water level profiles along the Lock 4 to 5 reach are presented in Figure 4.12 to Figure 4.16, which includes comparisons with observed data limits and the modelled profiles from the uncalibrated FM model evaluation simulation outputs (at baseflow – 10 000 ML/d and natural high flow – 75 000 ML/d conditions) for a demonstration of the impact of calibration. 2–D outputs from the Katarapko Floodplain model upstream of Lock 5 (refer to section 4.2 for outputs downstream of Lock 4) are also presented alongside the same section of river in the Pike Floodplain model generated from 1–D for an additional comparison. Historical backwater curves at similar river flows to those modelled are also shown in the figures for reference. However it should be noted that these curves (which are based on modelling themselves below 60 000 ML/d) are linked to QSA rather than flow upstream of Lock 5 as used in the FM model, and hence comparisons with the modelled data may be affected by losses between Pike Floodplain and the border, and also QSA travel times from Lock 7 to Pike Floodplain, which may vary depending on the flow event.

Although there is limited observed data, the water level profiles of the calibrated model at each flow simulated are shown to fall within the observed limits in each case. The water level profiles above Lock 4 from the 1–D section of model also generally compare favourably with the outputs from the Katarapko model at each flow, with the main exceptions being at 60 000 and 75 000 ML/d, at which the levels are shown to be marginally higher in the Katarapko model outputs (i.e. Figure 4.14 and Figure 4.15, respectively). This can be attributed to the difference in flows between the two models in these sections of river due to losses through the Pike Floodplain model, as shown in Table 4.1. The percentage differences between Pike model outflows and Katarapko model inflows are approximately 5 and 9% at 60 000 and 75 000 ML/d, respectively, while the differences are lower for Pike inflows of 10 000, 40 000 and 90 000 ML/d, at 2.0, 2.5 and 3.7%, respectively. Note that in the validation case of the 2016 event, inflows into each model were set at the actual peak flows of the event at each relevant location in the river (refer to section 2.2), and thus the losses between Pike and Katarapko are accounted for in the validation scenario configurations.

Table 4.1. Comparison of Pike Floodplain model outflows and Katarapko Floodplain model inflows. A percentage difference is calculated between the Pike model outflow and Katarapko model inflow.

Pike model inflow ML/d	Pike model outflow ML/d	Katarapko model inflow ML/d	Difference %
10 000	9800	10 000	2.0
40 000	39 000	40 000	2.5
60 000	57 000	60 000	5.0
75 000	68 000	75 000	9.3
90 000	79 000	82 000	3.7

Comparison of the modelled results to the backwater curves shows general agreement in the lower half of the channel at 10 000 (Figure 4.12) and 40 000 ML/d (Figure 4.13), but a departure in the upper half of the channel with modelled results increasing above the backwater curves – note however that the backwater curves at these flows fall below even the observed limits downstream of Lock 5. Under flows of 60 000 to 90 000 ML/d (i.e. Figure 4.14 to Figure 4.16), the modelled results are generally higher than those in the backwater curves but with a similar gradient. This difference may however be attributed to the downstream water level boundary condition in the model at Lock 4 used in each simulation, which are based on data from the modelled events but lie at the upper end of the observed range. These levels are higher than those used for the backwater curves, and as such, reducing these boundary levels in the Pike model configuration would also be expected to lower the water level profiles within the Lock 4 to 5 reach.

Comparing the uncalibrated model results with those from the calibrated model, at 10 000 ML/d (Figure 4.12) the uncalibrated model water level profile shows a sudden jump in River Murray level at approximately 554 km, which contributes to an over-estimation in level of approximately 30 cm downstream of Lock 5 when compared to the calibrated model results. This is a result of the bypass streams at Settler's Bend being adequately defined in the calibrated model, ensuring that the gradient in the river at this location is reduced to more realistic levels. At 75 000 ML/d (Figure 4.15), the uncalibrated results are actually lower than those of the calibrated model runs. This difference can be primarily attributed to the instabilities identified within the floodplain in the uncalibrated model (refer to section 3.2) that were artificially reducing the water levels within the Lock 4 to 5 reach under overbank flow conditions.

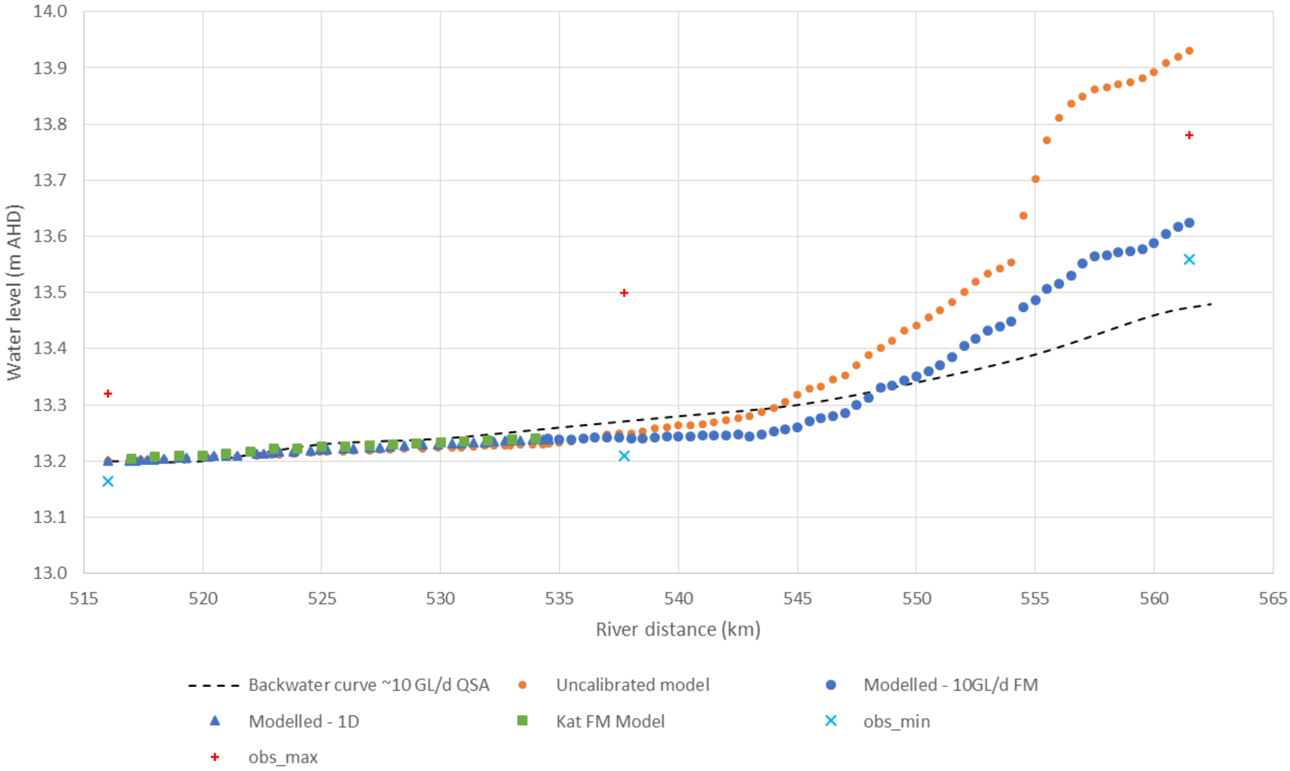


Figure 4.12. Modelled water level profile in Lock 4 to 5 reach at 10 000 ML/d U/S Lock 5 compared to uncalibrated model result, observed water level data limits, Katarapko FM model result and backwater curve at 10 000 ML/d QSA.

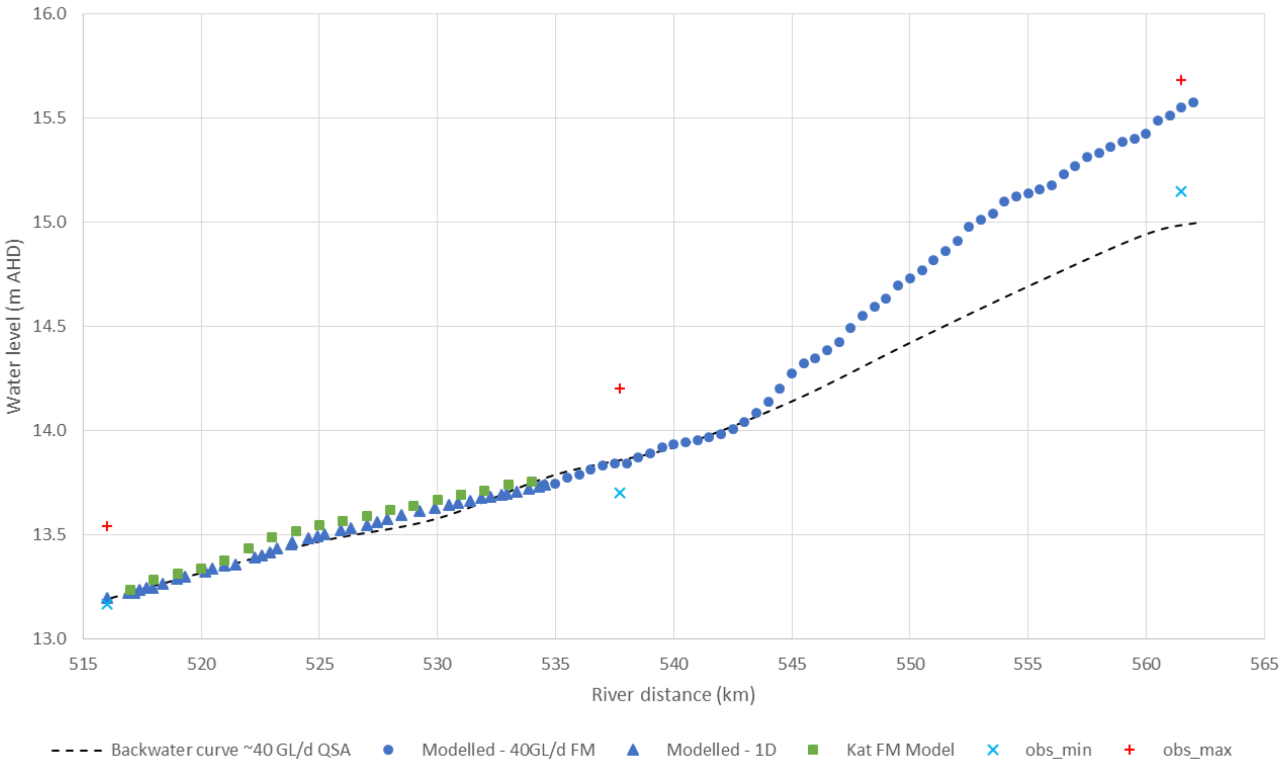


Figure 4.13. Modelled water level profile in Lock 4 to 5 reach at 40 000 ML/d U/S Lock 5 compared to observed water level data limits, Katarapko FM model result and backwater curve at 40 000 ML/d QSA.

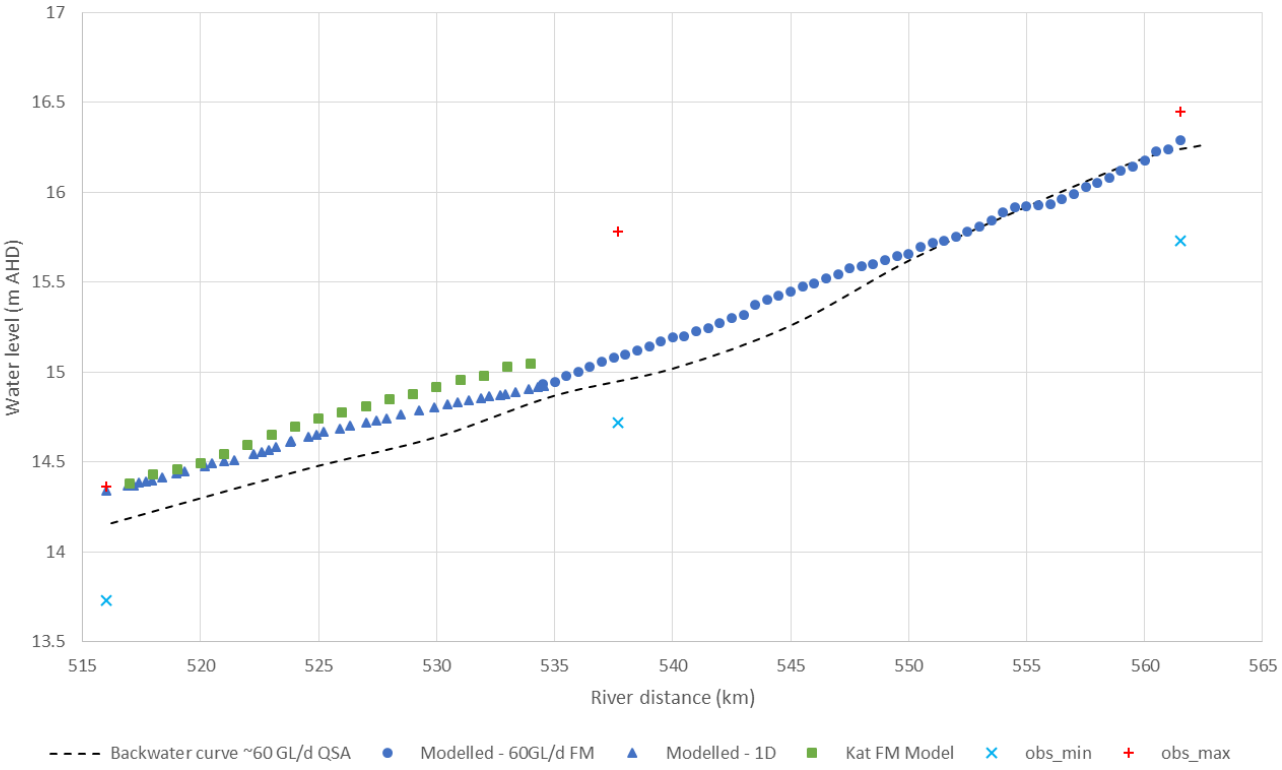


Figure 4.14. Modelled water level profile in Lock 4 to 5 reach at 60 000 ML/d U/S Lock 5 compared to observed water level data limits, Katarapko FM model result and backwater curve at 60 000 ML/d QSA.

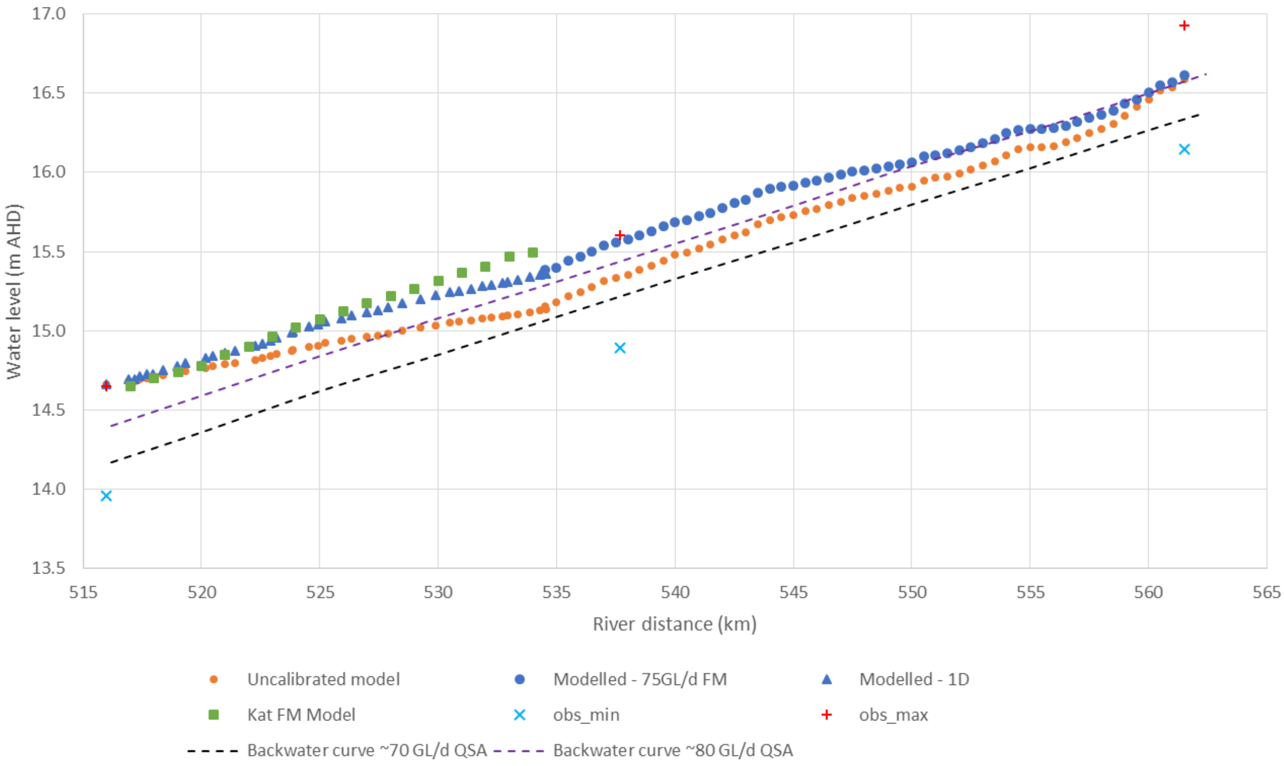


Figure 4.15. Modelled water level profile in Lock 4 to 5 reach at 75 000 ML/d U/S Lock 5 compared to uncalibrated model result observed water level data limits, Katarapko FM model result and backwater curves at 70 000 and 80 000 ML/d QSA.

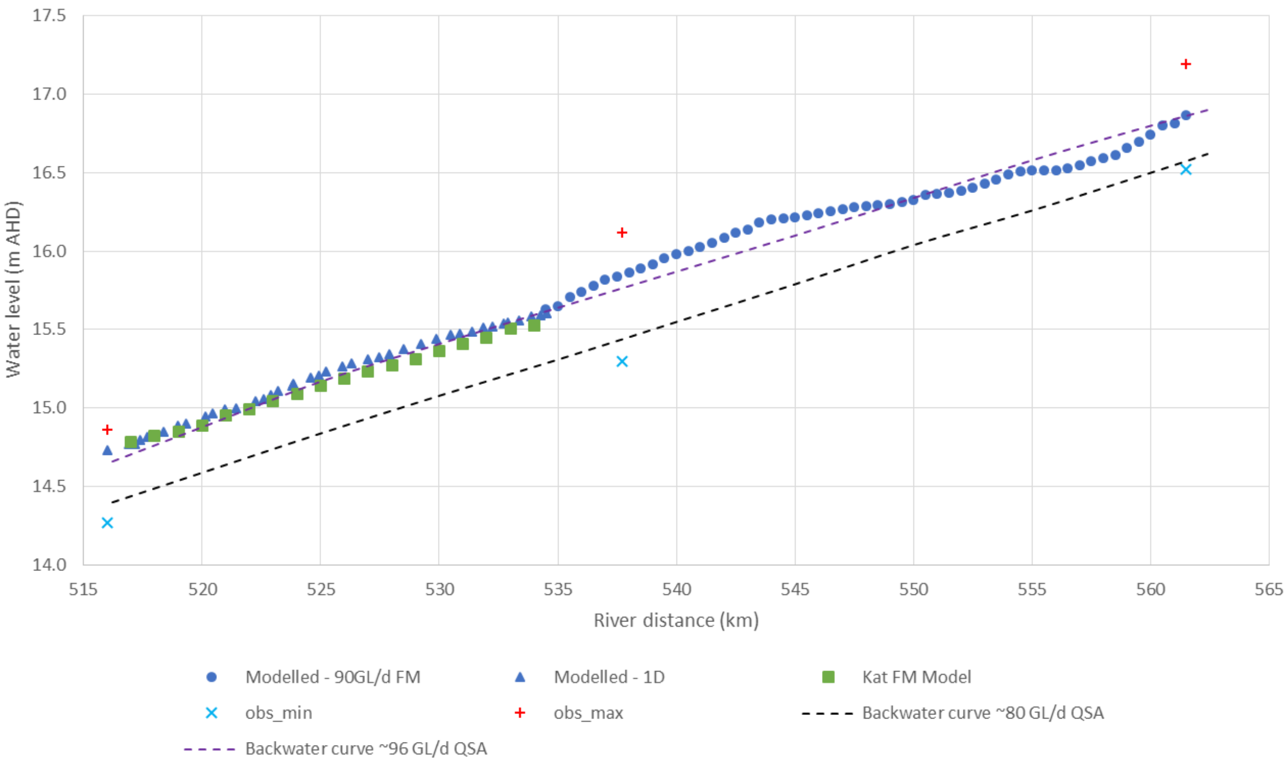


Figure 4.16. Modelled water level profile in Lock 4 to 5 reach at 90 000 ML/d U/S Lock 5 compared to observed water level data limits, Katarapko FM model result and backwater curves at 80 000 and 96 000 ML/d QSA.

Modelled inundation extents are compared to observed data (Landsat imagery) for flows of 40 000, 60 000, 75 000 and 90 000 ML/d in Figure 4.17 to Figure 4.20, respectively. Note that satellite imagery is selected as close to the corresponding simulated flow as possible, but may differ slightly as indicated. The comparisons indicate the modelled extents provide an appropriate representation of observed extents for all flows simulated. Note that at 40 000 ML/d (Figure 4.17), the imagery indicates Snake Lagoon is inundated while the modelled extent shows this area as dry. However, this is potentially a result of another mechanism of filling (e.g. exfiltration through the soil), as there is no obvious connection with Snake Creek in the imagery. In comparison, the same area does appear connected under the 60 000 ML/d scenario (Figure 4.18), and yet indicates a smaller area of inundation in Snake Lagoon.

A comparison of managed inundation extent in the Pike FM model to the modelled extent produced in the gridded model version is shown in Figure 4.21. Note that the comparison gridded model scenario was operated at a comparatively higher River Murray flow of 30 000 ML/d than that of the FM model scenario (10 000 ML/d), creating a greater level of inundation downstream of the blocking alignment. The area between Tanyaca Horseshoe and the blocking bank was also flooded in the gridded model using the Snake Lagoon north ancillary structure, while this structure was not operated for the purposes of the FM model scenario and hence the area remained dry. Despite these differences, the inundation extent upstream of the blocking alignment compares favourably with the previous gridded model version.

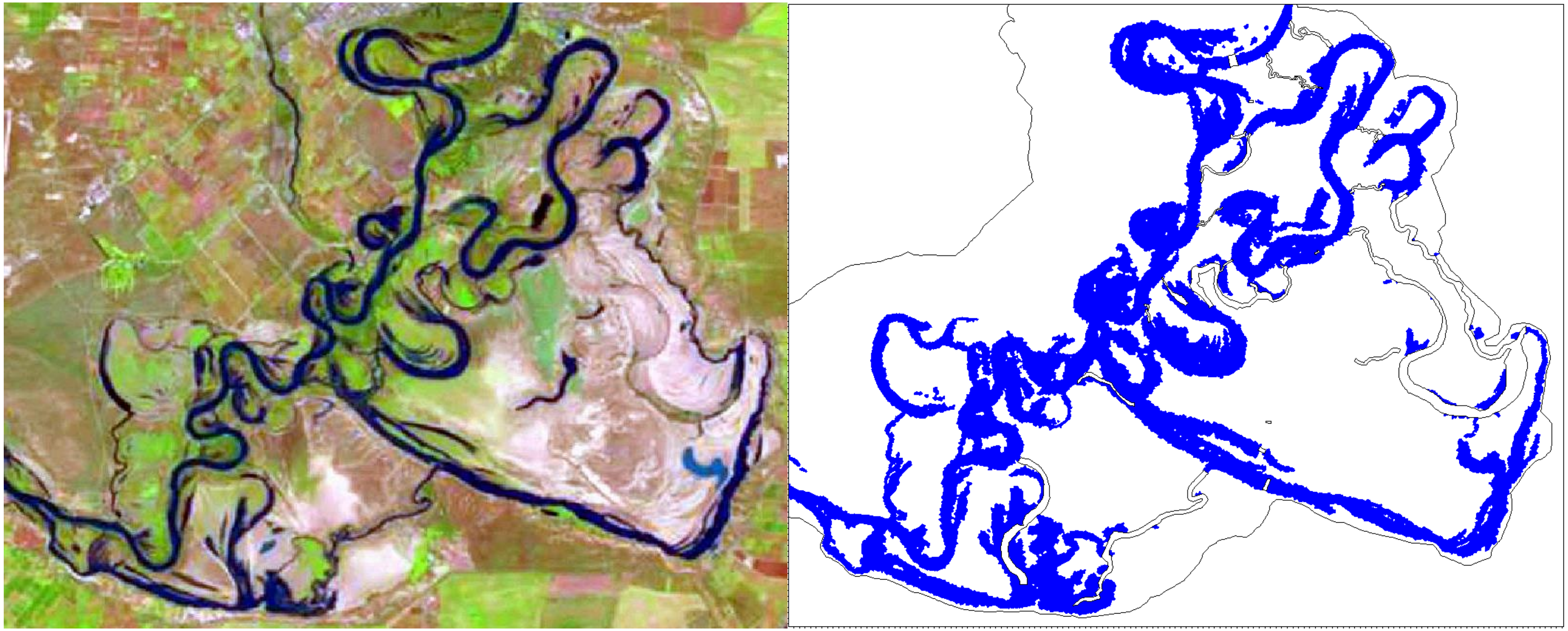


Figure 4.17. Comparison of (a) observed to (b) modelled inundation extents in Pike Floodplain for a flow of approximately 40 000 ML/d (imagery dated 30 August 2011, ~40 200 ML/d Lock 5 flow).

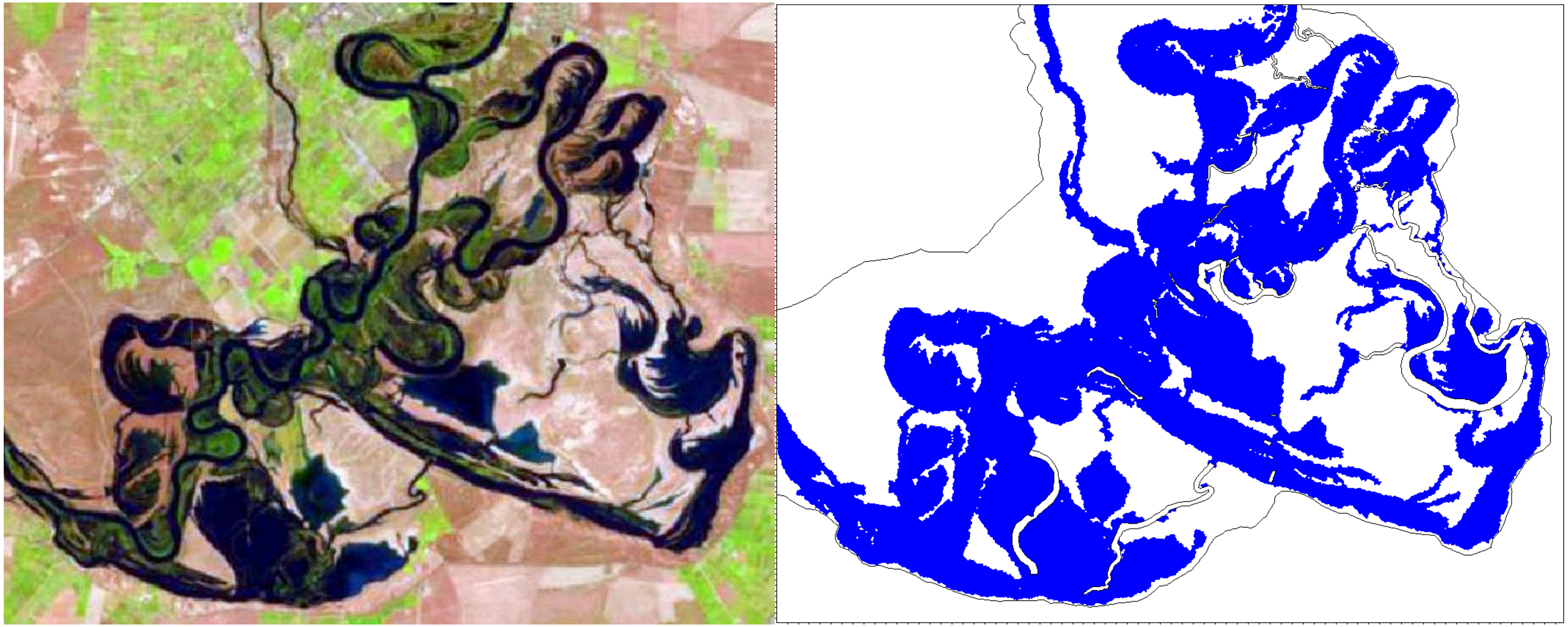


Figure 4.18. Comparison of (a) observed to (b) modelled inundation extents in Pike Floodplain for a flow of approximately 60 000 ML/d (imagery dated 9 December 1996, ~59 700 ML/d Lock 5 flow estimated).

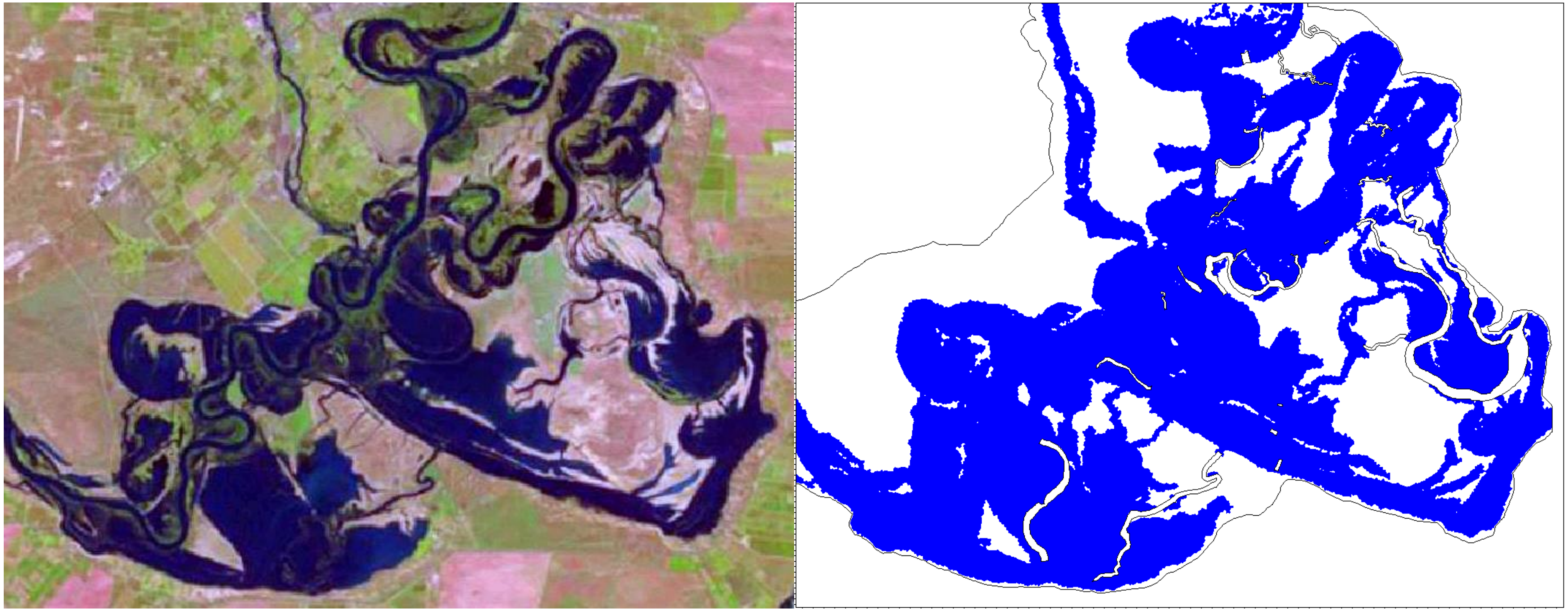


Figure 4.19. Comparison of (a) observed to (b) modelled inundation extents in Pike Floodplain for a flow of approximately 75 000 ML/d (imagery dated 7 March 2011, ~74 800 ML/d Lock 5 flow estimated).

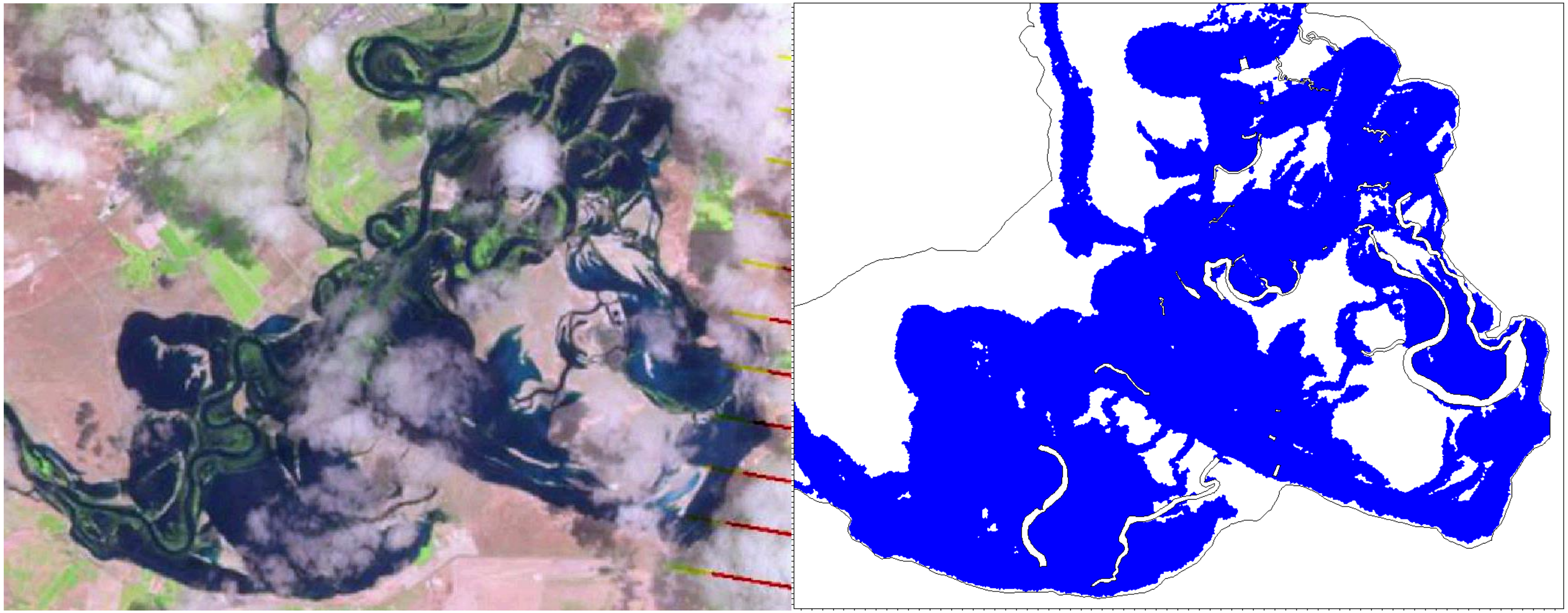
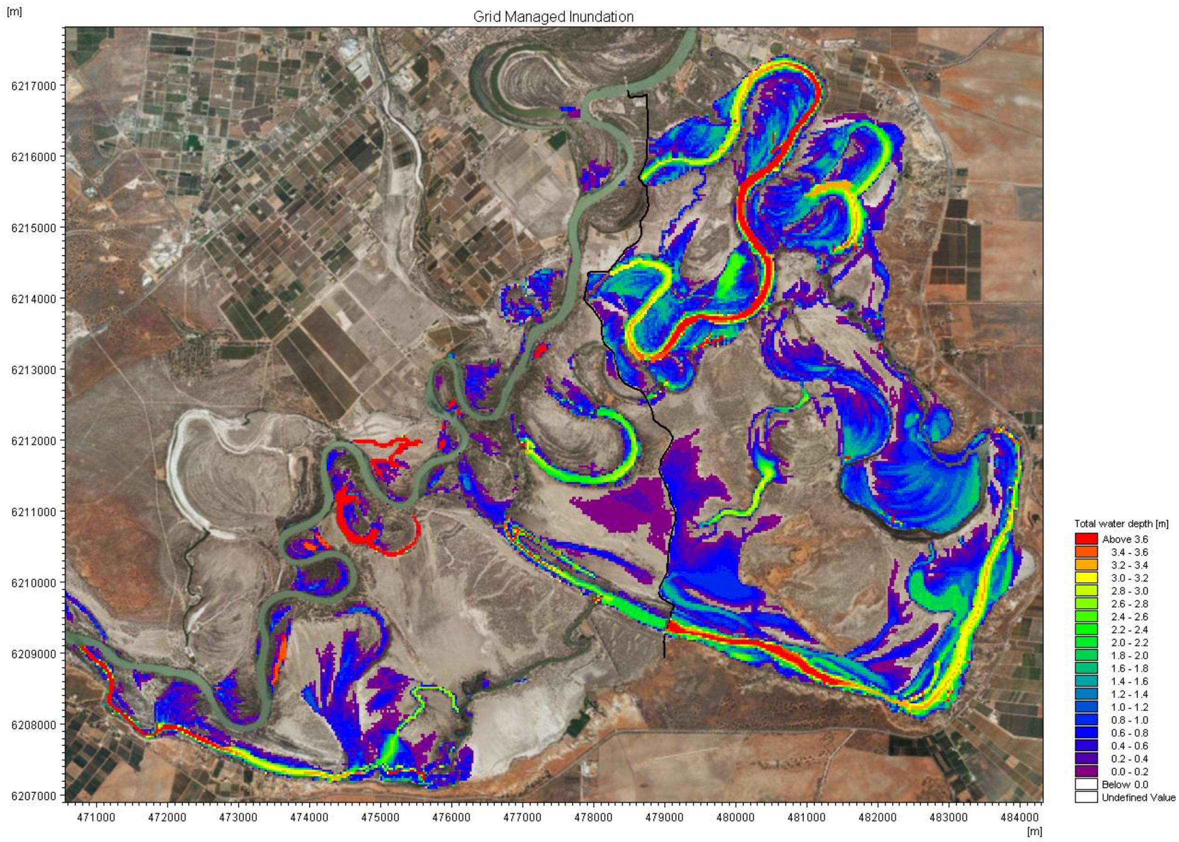
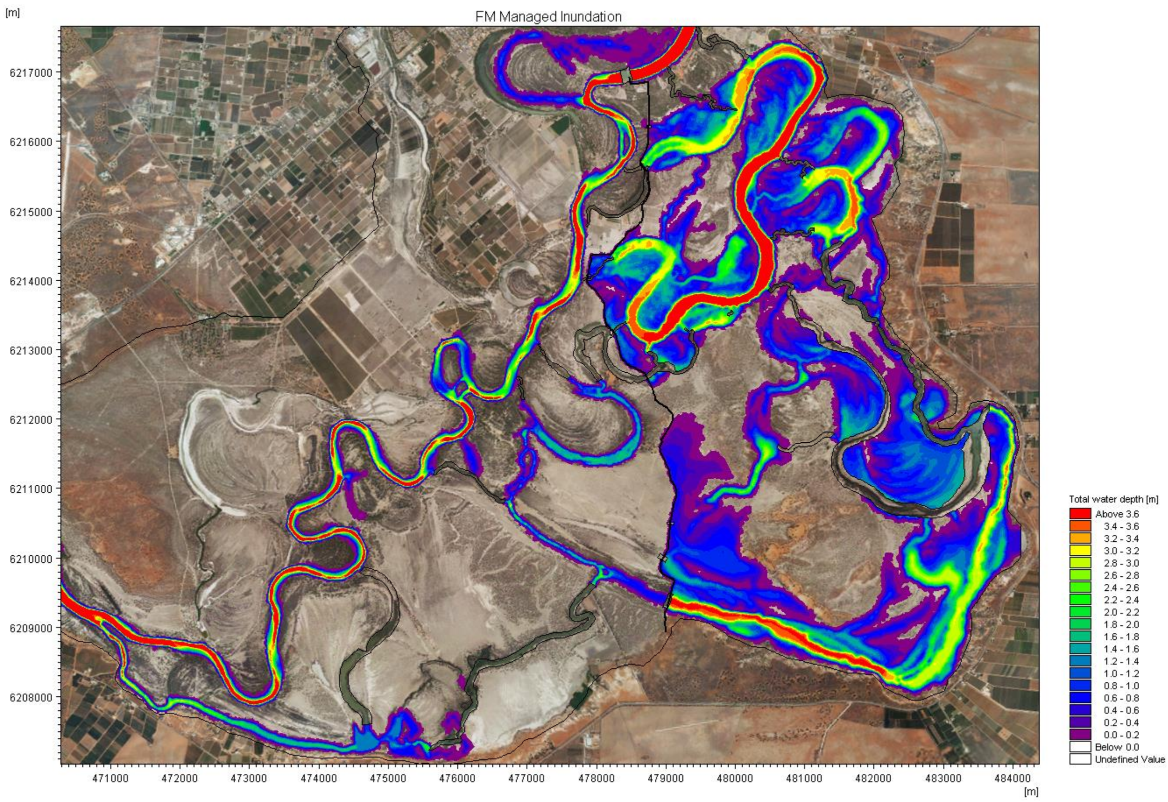


Figure 4.20. Comparison of (a) observed to (b) modelled inundation extents in Pike Floodplain for a flow of approximately 90 000 ML/d (imagery dated 9 December 2016, ~90 000 ML/d Lock 5 flow estimated).



(a)



(b)

Figure 4.21. Comparison of modelled Pike Floodplain managed inundation at 16.4 m AHD under (a) gridded and (b) FM models.

4.2 Katarapko Floodplain

Modelled levels in the River Murray are compared to observed data for 10 000, 40 000, 45 000, 60 000, 75 000 and 82 000 ML/d in Figure 4.22. Unlike under the Pike calibration runs, an additional 45 000 ML/d run was completed based on a medium flow event in 2000 as tested in McCullough (2016a); however, 40 000 ML/d was still used to match the same run completed in the Pike model calibration set.

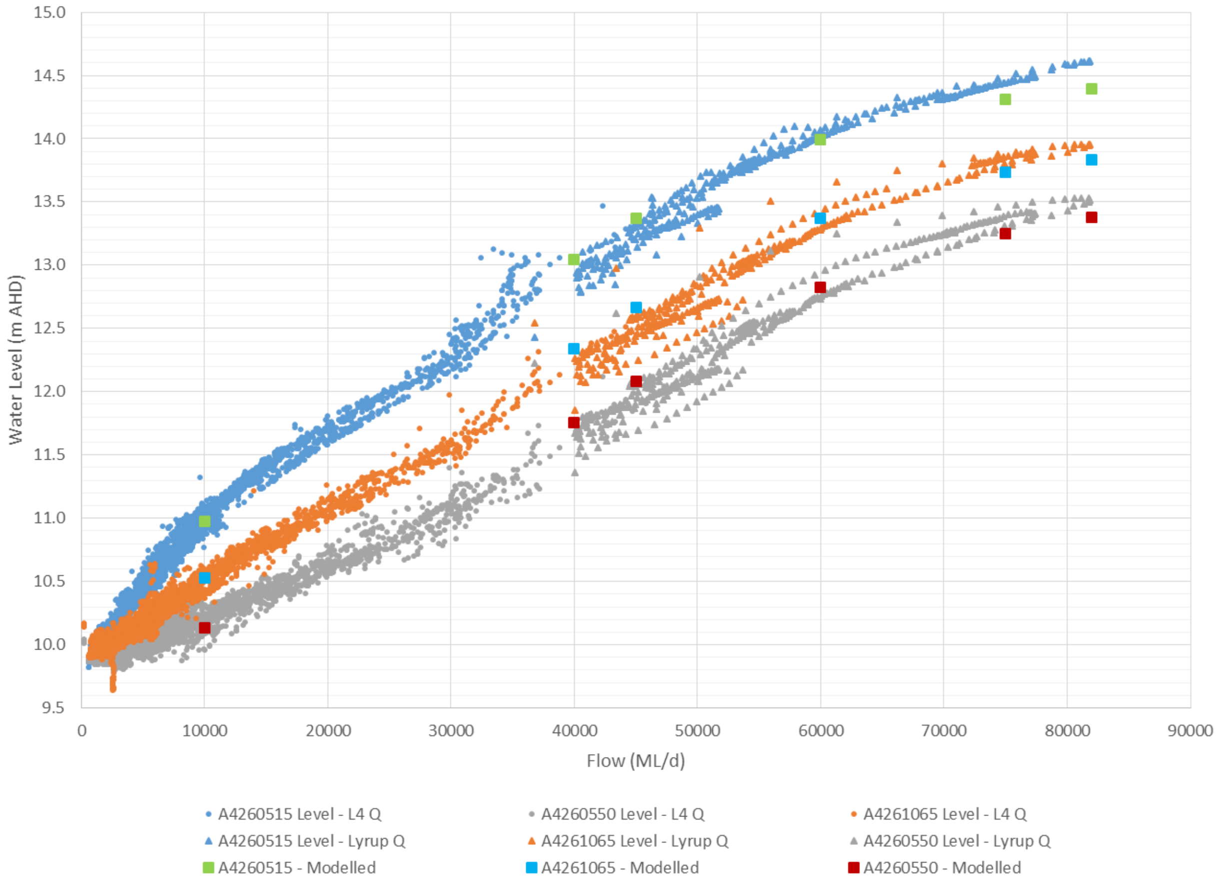


Figure 4.22. Comparison of modelled water level to observed data in the River Murray downstream of Lock 4.

Note that the observed data correlates water level with Lock 4 flow up to the rated limit of the lock (i.e. approximately 40 000 ML/d) while rated flows at Lyrup gauging station (A4260663) are used for river flows exceeding 40 000 ML/d. Note that the rated flows at the Lyrup gauging station incorporate flows greater than approximately 40 000 ML/d since late 2000, with only two events (2011 and 2016) contributing to the observed data range at the high flow end of the presented data.

In general, the modelled levels fall within the observed range of values at all river monitoring sites below Lock 4, particularly at simulated flows between 10 000 and 60 000 ML/d. At 75 000 ML/d and 82 000 ML/d simulations, there is a minor underestimation of Lock 4 downstream water level (site A4260515) when compared to observed data i.e. at 75 000 ML/d, modelled level is approximately 14.3 m AHD, compared to approximately 14.4 m AHD at the lower observed range, while at 82 000 ML/d modelled level is approximately 14.4 m AHD compared to 14.6 m AHD observed. The level of underestimation of simulated to observed levels is reduced however at downstream monitoring sites at Solora (A4261065) and Loxton (A4260550) pump stations, with only the levels for the 82 000 ML/d showing noticeable underestimation – i.e. approximately 0.1 m underestimation at both sites – while for 75 000 ML/d the simulated levels approximately match the lower end of the observed range. These underestimations may be partly attributable to the low concentration of observed data at the high flow end of the observed range, with future high flow events potentially expanding this range. There may also be some impact arising from differences between the steady state simulations and the dynamic nature of the actual flow events, in particular for the 2016 high flow event (82 000 ML/d), which was a relatively short event and a greater loss over the floodplain areas (due to drier antecedent conditions) experienced in comparison to historical high flow events.

A comparison of modelled to observed water level in Katarapko Creek (i.e. at site A4261225, 1.7 km downstream of The Splash outlet) is shown in Figure 4.23. As the monitoring site was only installed in 2013, there is a reduced concentration of data available at raised flows, with only the most recent high flow event in 2016 providing comparison data above approximately 40 000 ML/d. However, the modelled levels in Katarapko Creek are shown to correspond well with the available observed data at all flows simulated, matching the levels at 10 000 ML/d well, and falling approximately half way between the levels recorded on the rising and receding flood limbs of the 2016 event at flows exceeding 40 000 ML/d.

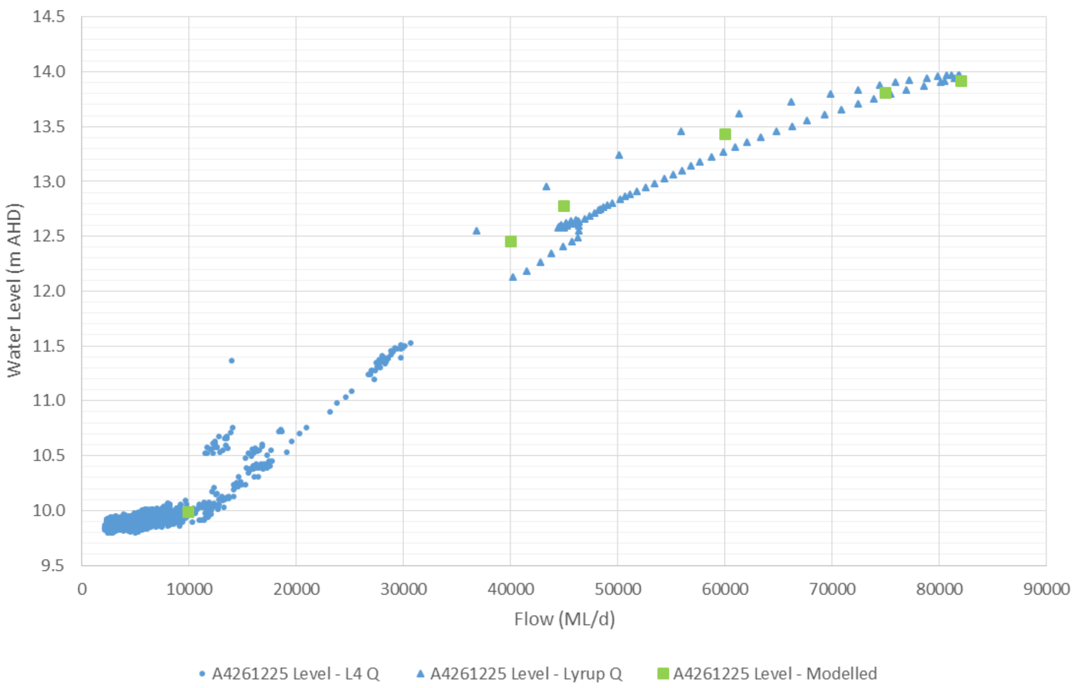


Figure 4.23. Comparison of modelled water level to observed data in Katarapko Creek downstream of The Splash.

Modelled water level profiles along the Lock 3 to 4 reach, and along the length of Katarapko Creek, are presented in Figure 4.24 to Figure 4.35, which include comparisons with observed data limits and the modelled profiles from the uncalibrated FM model evaluation runs (at baseflow – 10 000 ML/d and natural high flow – 75 000 ML/d conditions) for a demonstration of the impact of calibration. Historical backwater curves for the River Murray are additionally shown at approximately equivalent flows for reference only, as these curves are based on Flow to SA rather than flow above Lock 4 as used in the FM model (which may differ due to upstream losses), and are also derived from a combination of modelled data below 50 000 ML/d and actual historical events at higher flows, and thus is only an indicative guide of expected water level profile within the reach.

At 10 000 ML/d the modelled profiles in both River Murray (Figure 4.24) and Katarapko Creek (Figure 4.25) are in reasonable agreement with the observed limits at the various monitoring station locations. In comparison, the River Murray water level profile arising from the uncalibrated model is greater than the upper observed range at all monitoring sites, with the greatest difference being directly downstream of Lock 4 at approximately 0.4 m higher than the upper observed range. The Katarapko Creek water level profile from the uncalibrated model is substantially greater than the observed range, being almost 0.9 m above the upper observed level downstream of the Splash. This difference can be attributed to a greater flow passing through Katarapko Creek due to the higher level at the creek inlet and changes implemented to the mesh as part of the calibration process.

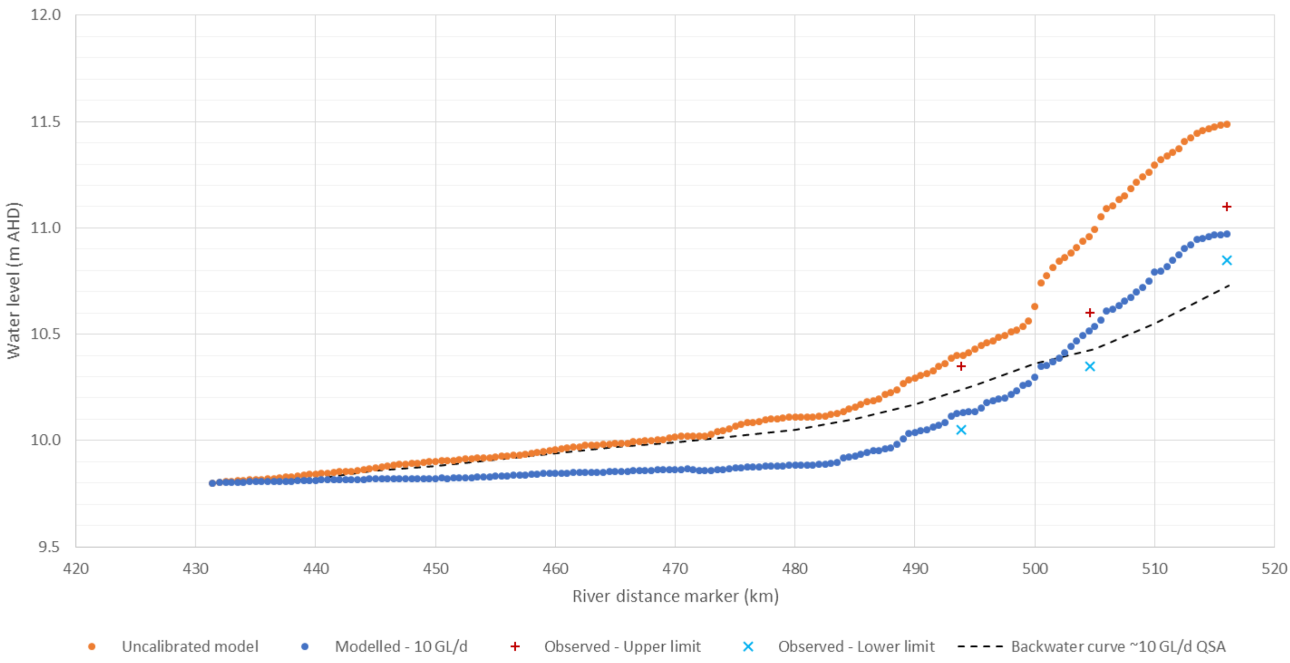


Figure 4.24. Modelled water level profile in Lock 3 to 4 reach at 10 000 ML/d U/S Lock 4 compared to uncalibrated model result, observed water level data limits and backwater curve at 10 000 ML/d QSA.

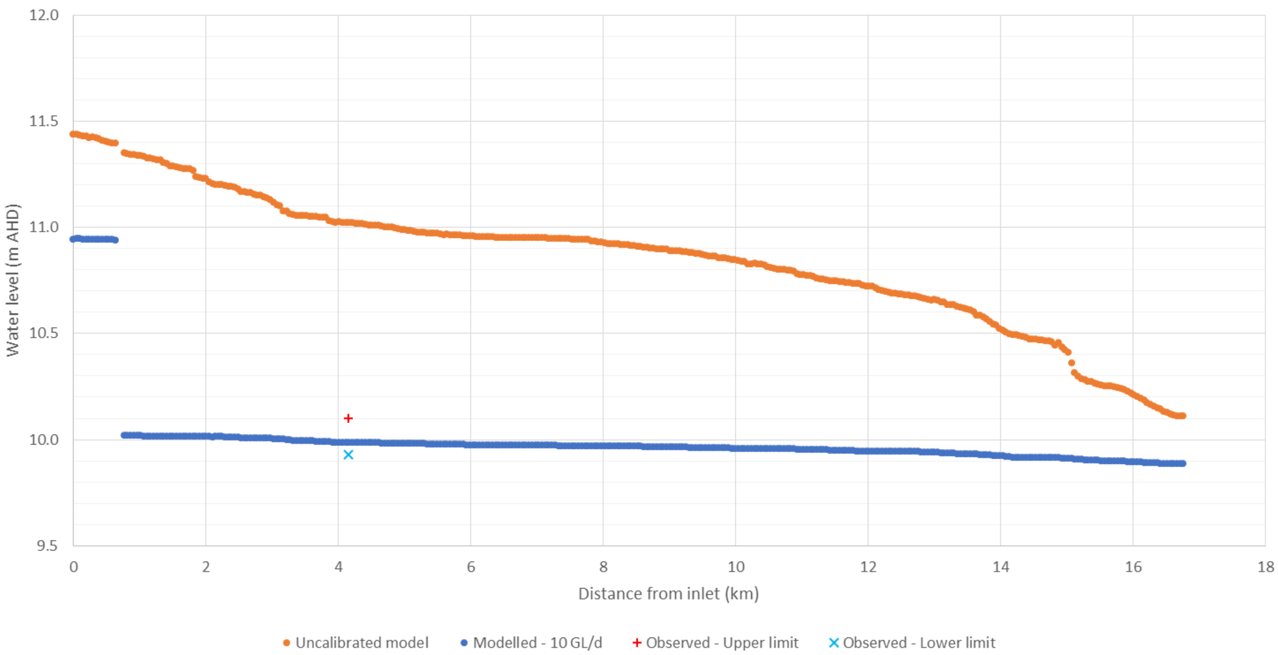


Figure 4.25. Modelled water level profile in Katarapko Creek at 10 000 ML/d U/S Lock 4 compared to uncalibrated model result and observed water level data limits.

For modelled flows of 40 000 and 45 000 ML/d, River Murray water level profiles (Figure 4.26 and Figure 4.28, respectively) fall at the upper limit of the observed ranges for the monitoring station locations, while in Katarapko Creek the water level is approximately half way between the upper and lower observed range (downstream of the Splash) for both flows (Figure 4.27 and Figure 4.29, respectively).

At 60 000 ML/d, the water level profiles of both the River Murray (Figure 4.30) and Katarapko Creek (Figure 4.31) fall within the observed ranges at the various monitoring locations. At 75 000 ML/d, the modelled River Murray levels (Figure 4.32) are at or marginally below the lower observed range at the various monitoring stations. Katarapko Creek level downstream of the Splash is also only marginally greater than the lower observed limit (Figure 4.33), noting that a reduced number of data points are currently available around this river flow.

Under the verification run at 82 000 ML/d, the observed ranges at each station are relatively narrow due to data taken at the peak of the 2016 flow event, and result in the calibrated profile falling marginally below these observations (Figure 4.34). In Katarapko Creek however (Figure 4.35), the water level downstream of the Splash is modelled within the observed range, falling marginally above the lower observed limit.

The above results from simulated flows between 10 000 and 82 000 ML/d indicate that the calibrated Manning's n values are most appropriate throughout the entire flow range, as variation of these values may marginally improve correlation at certain flows, but will consequently exacerbate water level discrepancies at other flows.

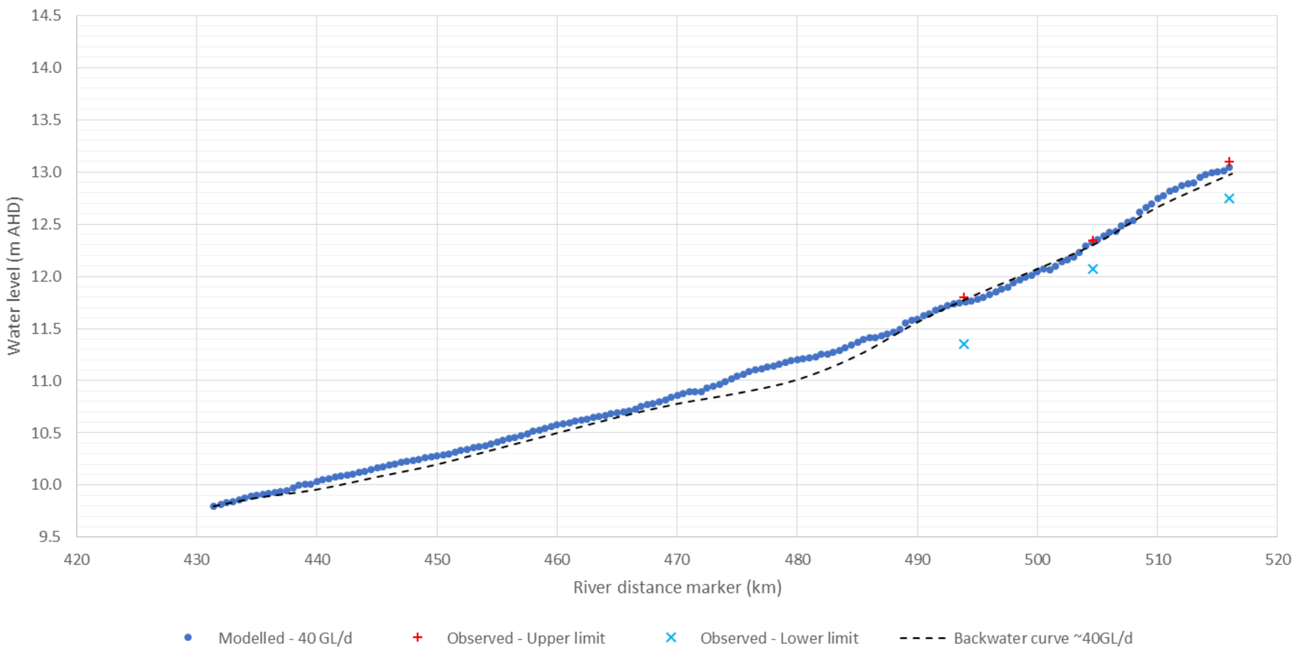


Figure 4.26. Modelled water level profile in Lock 3 to 4 reach at 40 000 ML/d U/S Lock 4 compared to observed water level data limits and backwater curve at ~40 000 ML/d QSA.

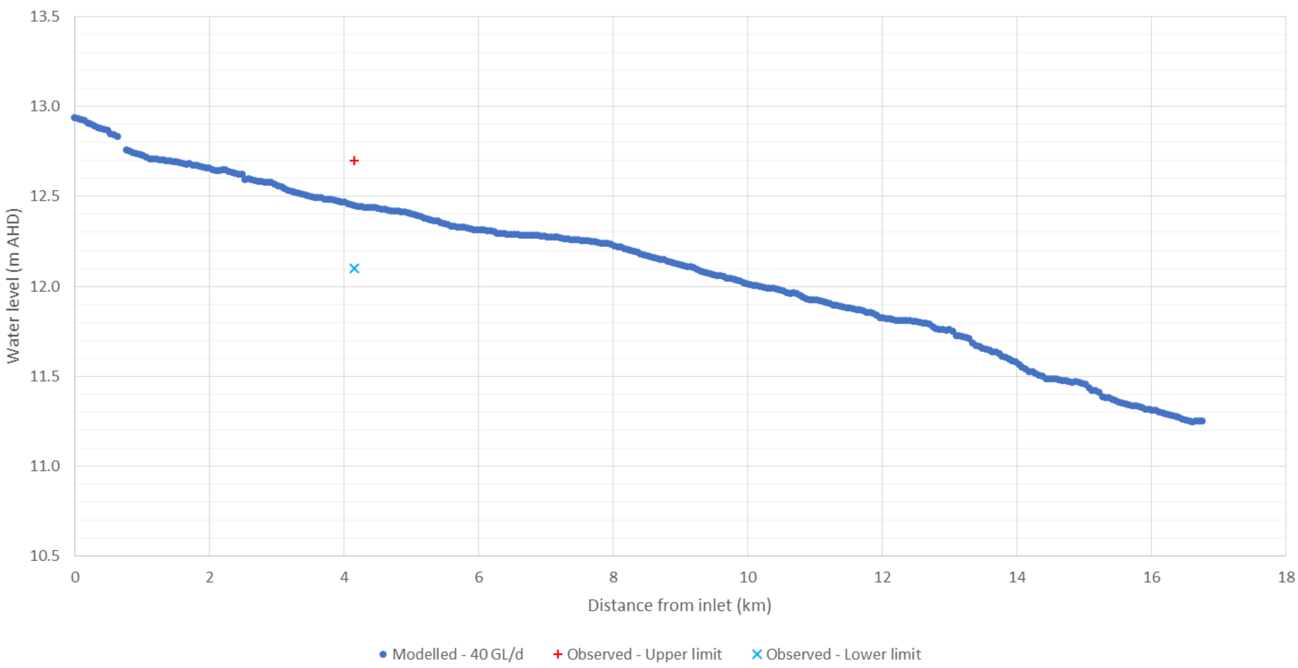


Figure 4.27. Modelled water level profile in Katarapko Creek at 40 000 ML/d U/S Lock 4 compared to observed water level data limits.

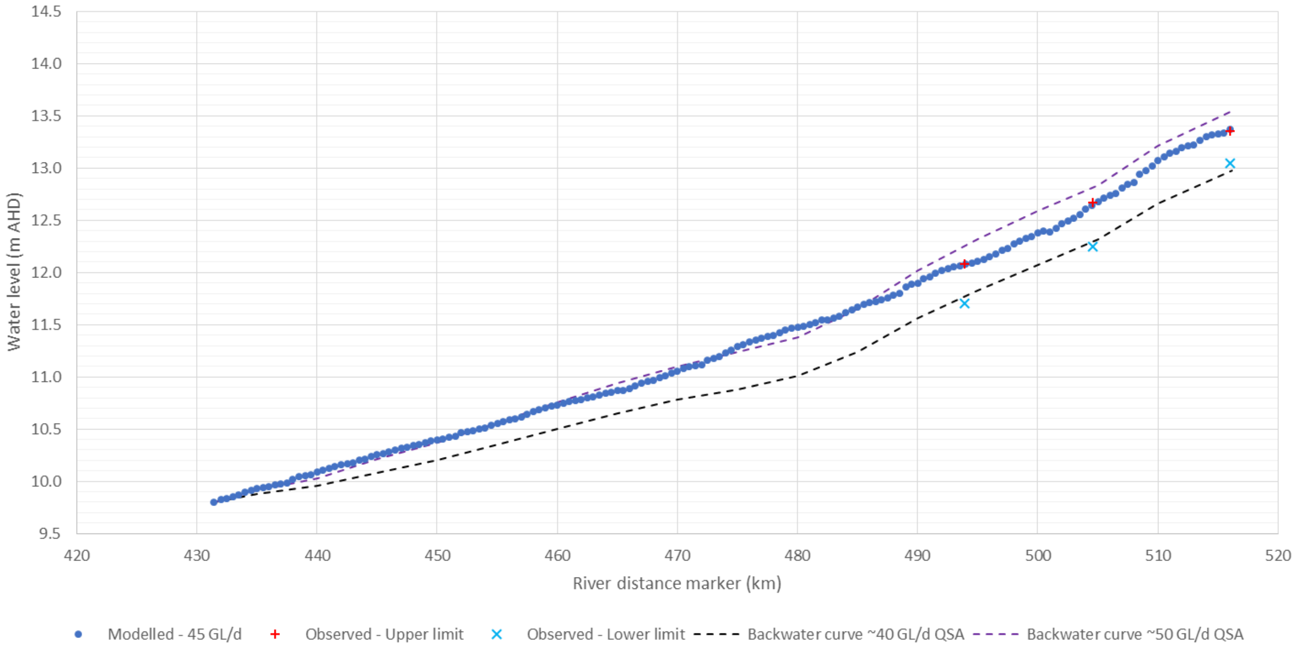


Figure 4.28. Modelled water level profile in Lock 3 to 4 reach at 45 000 ML/d U/S Lock 4 compared to observed water level data limits and backwater curves at ~40 000 and 50 000 ML/d QSA.

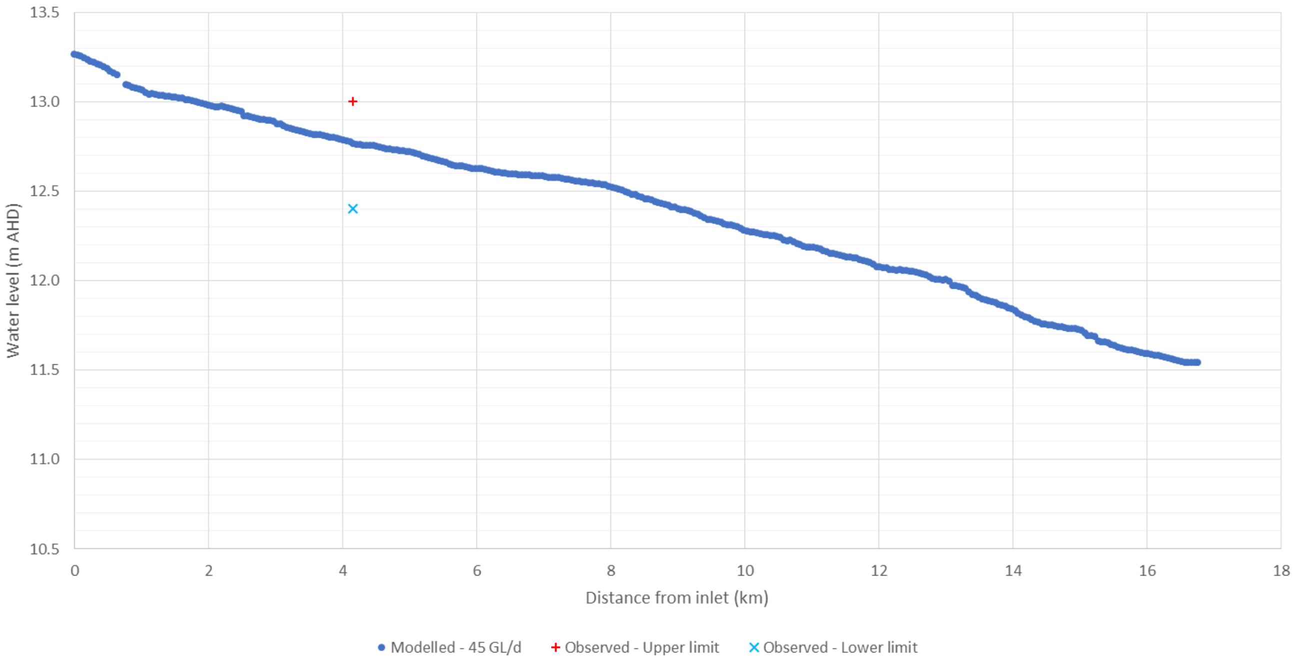


Figure 4.29. Modelled water level profile in Katarapko Creek at 45 000 ML/d U/S Lock 4 compared to observed water level data limits.

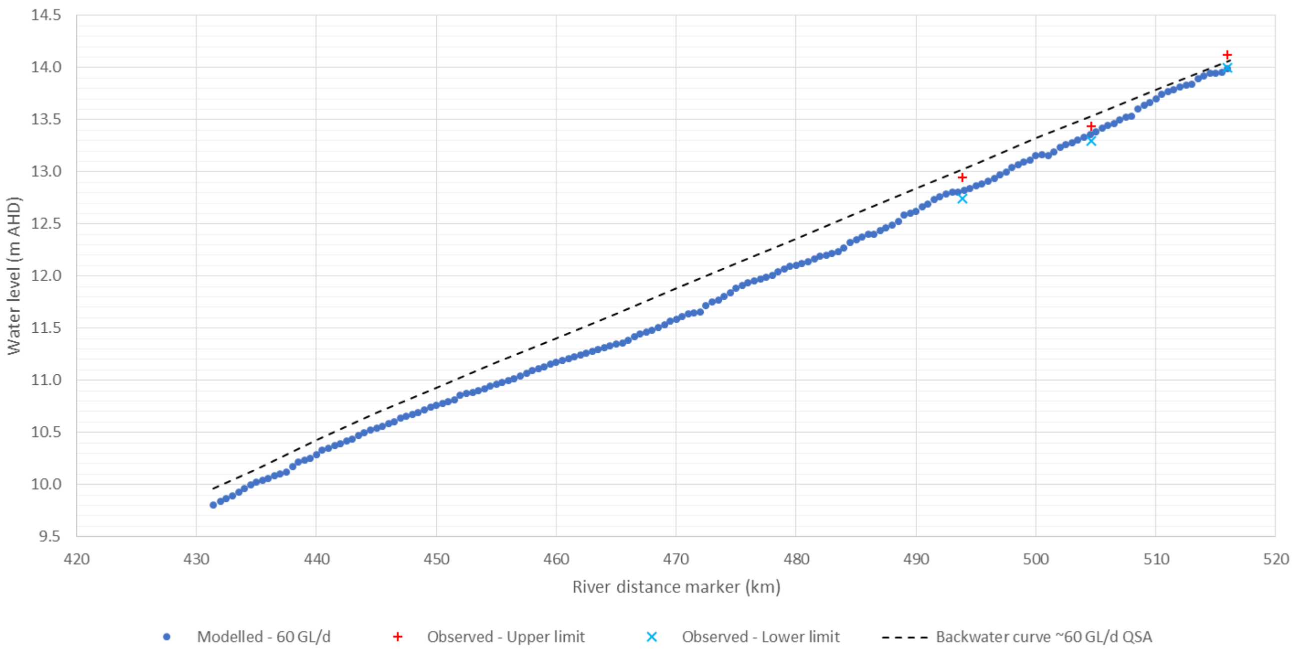


Figure 4.30. Modelled water level profile in Lock 3 to 4 reach at 60 000 ML/d U/S Lock 4 compared to observed water level data limits and backwater curve at ~60 000 ML/d QSA.

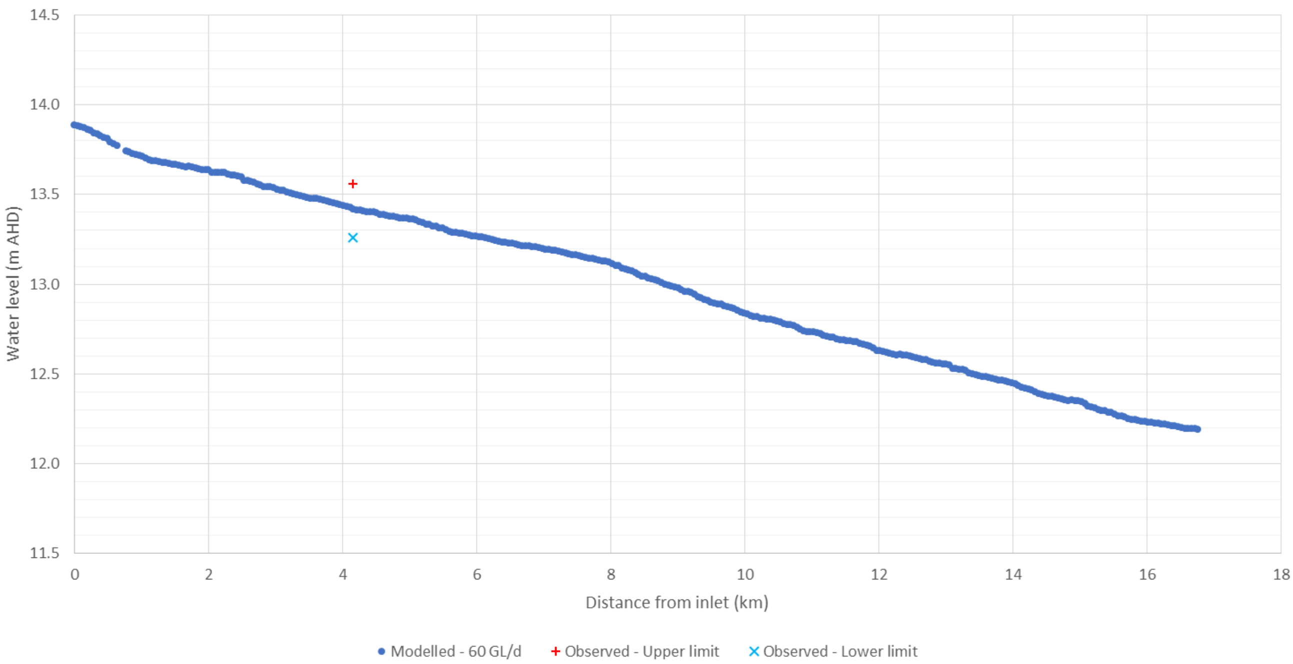


Figure 4.31. Modelled water level profile in Katarapko Creek at 60 000 ML/d U/S Lock 4 compared to observed water level data limits.

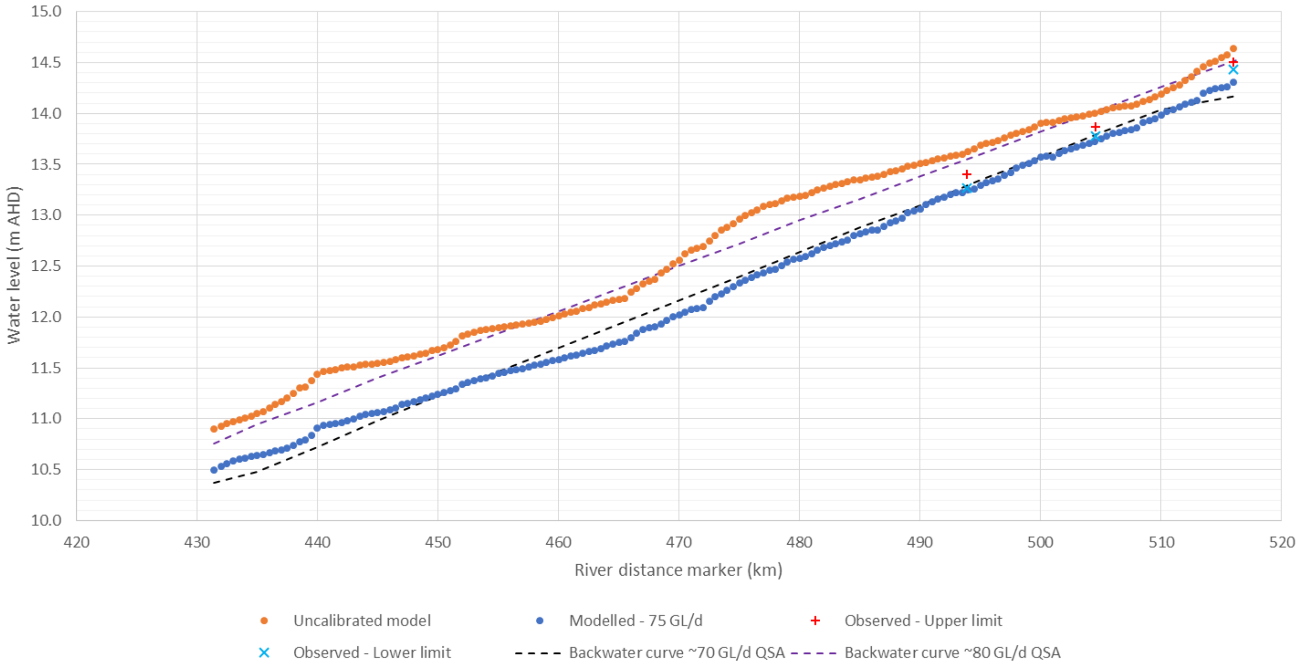


Figure 4.32. Modelled water level profile in Lock 3 to 4 reach at 75 000 ML/d U/S Lock 4 compared to observed water level data limits and backwater curves at ~70 000 and 80 000 ML/d QSA.

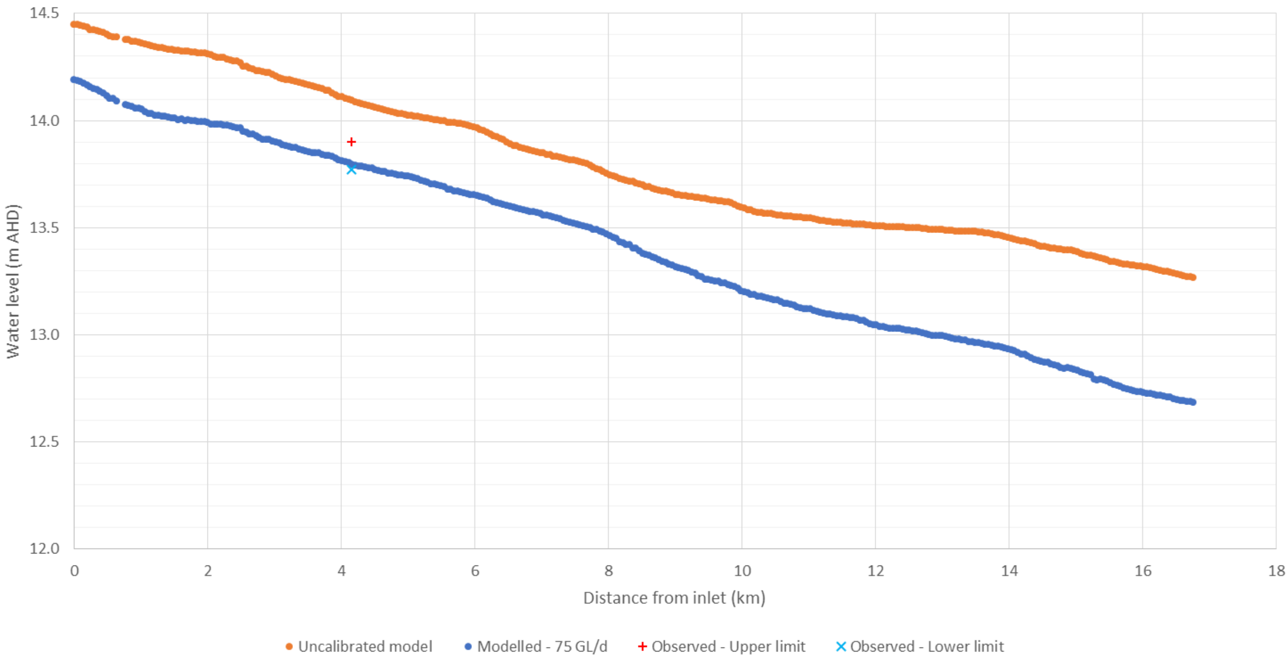


Figure 4.33. Modelled water level profile in Katarapko Creek at 75 000 ML/d U/S Lock 4 compared to uncalibrated model result and observed water level data limits.

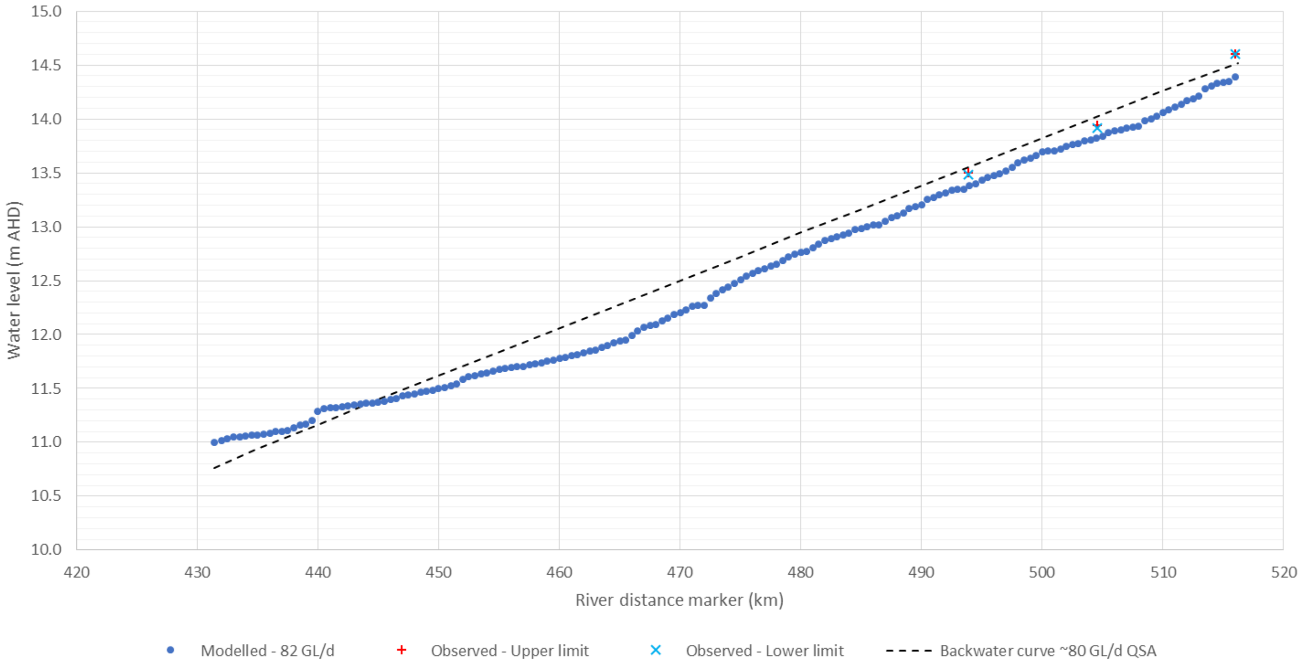


Figure 4.34. Modelled water level profile in Lock 3 to 4 reach at 82 000 ML/d U/S Lock 4 compared to observed water level data limits and backwater curve at ~ 80 000 ML/d QSA.

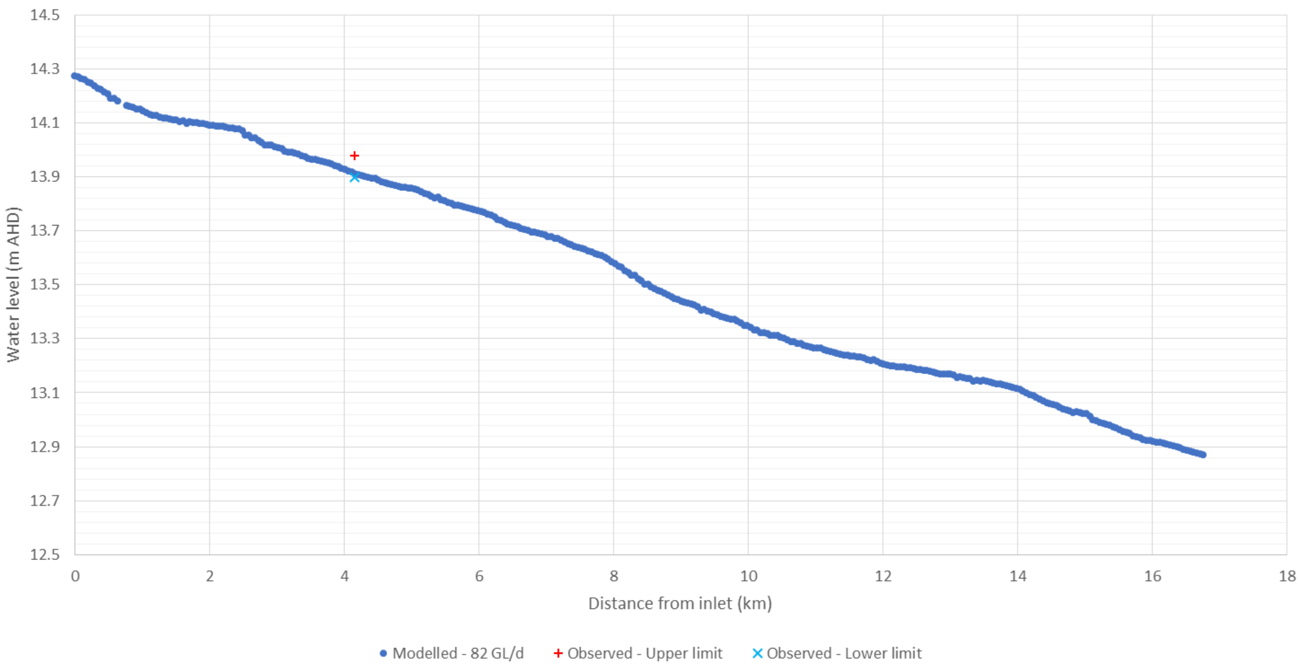
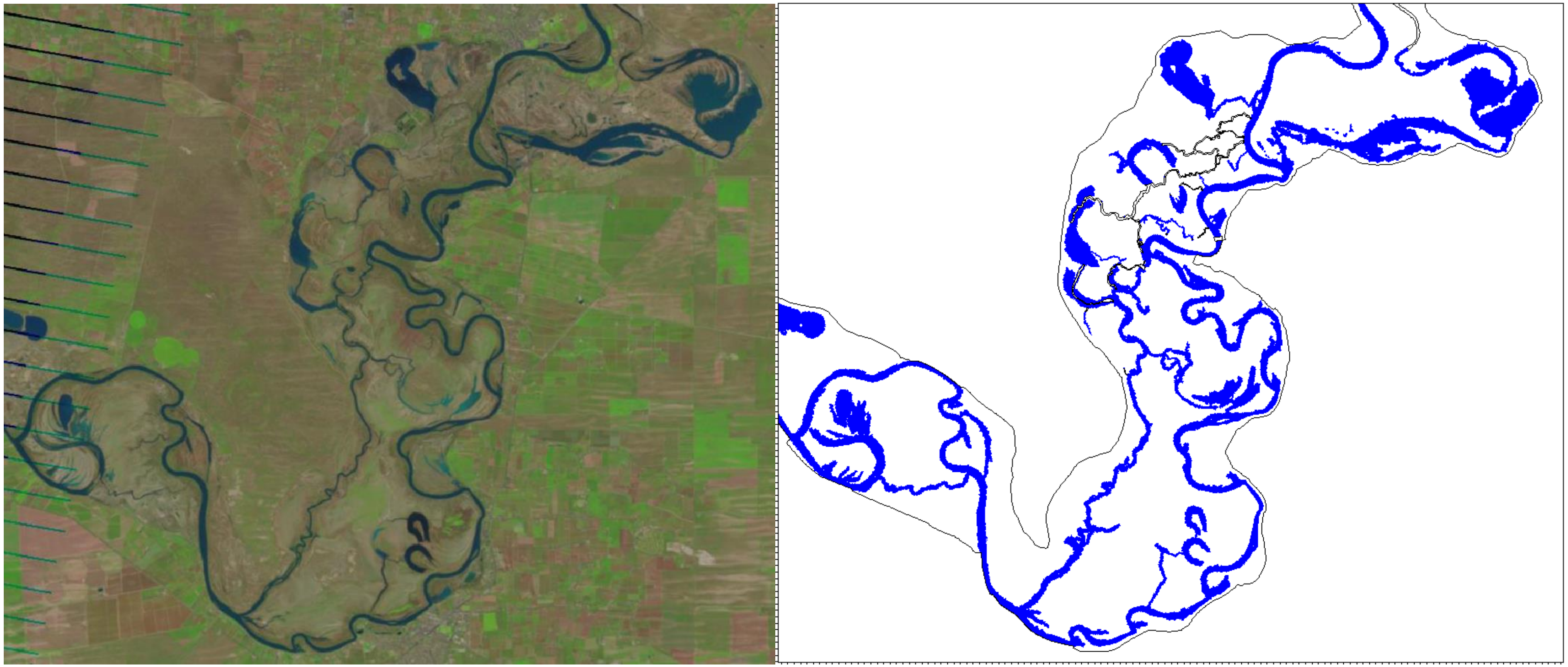


Figure 4.35. Modelled water level profile in Katarapko Creek at 82 000 ML/d U/S Lock 4 compared to observed water level data limits.

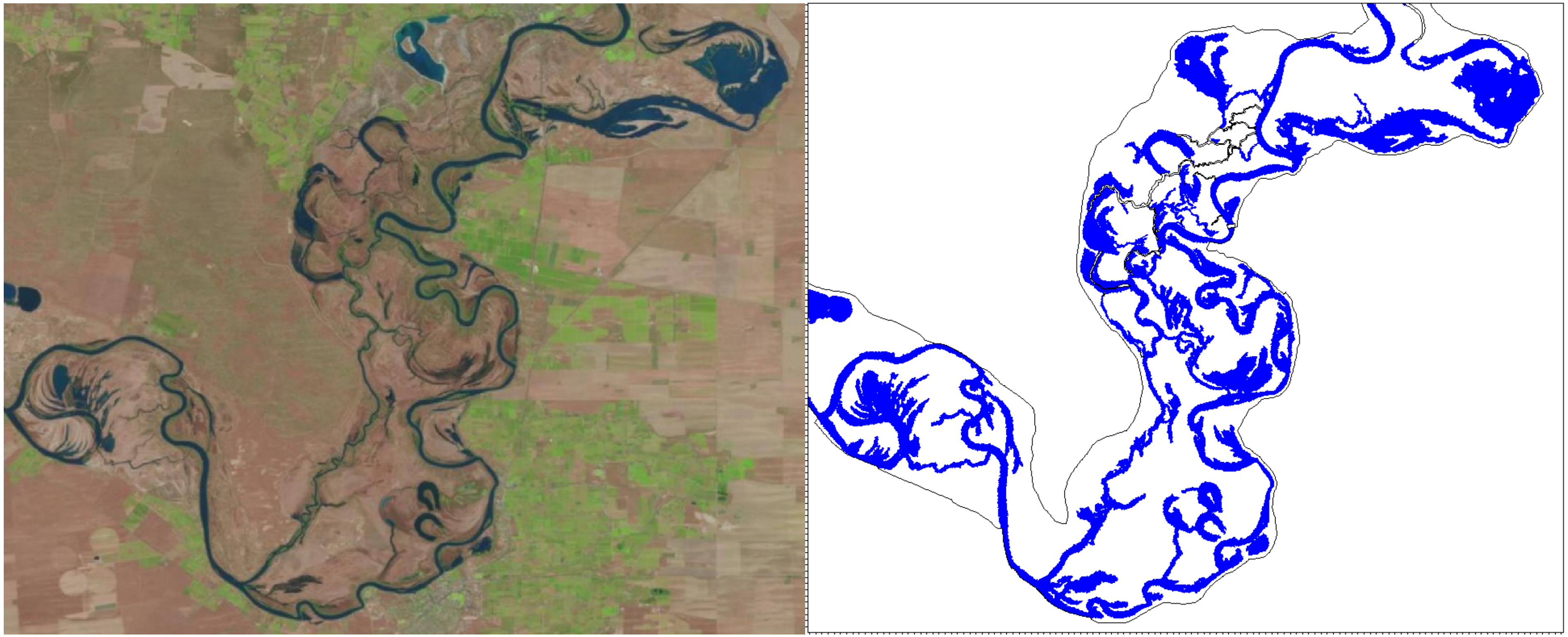
Modelled inundation extents are compared to observed data (Landsat imagery) for flows of 40 000, 45 000, 60 000, 75 000 and 82 000 ML/d in Figure 4.36 to Figure 4.40, respectively. Note that satellite imagery is selected as close to the corresponding simulated flow, but may differ slightly as indicated. The comparisons indicate an adequate representation of modelled extents for all flows simulated, matching the findings of the water level comparisons presented above.

A comparison of managed inundation extent in the Katarapko FM model to the modelled extent produced in the latest gridded model version is shown in Figure 4.41. The inundation extent upstream of the blocking alignment under the FM model version appears to show a marginally larger extent of inundation compared to the gridded model, despite being at the same inundation height at the Splash regulator of 13.5 m AHD. The additional inundation extent is modelled at the fringes of the inundation at the lowest depth category (0 to 0.2 m). One potential reason for this difference may be a result of the additional representation of flow paths upstream of Lock 4 that were not effectively represented in the previous modelling, as highlighted in Figure 4.41. Comparison of modelled Katarapko Floodplain managed inundation at 13.5 m AHD under (a) gridded and (b) FM models. Additional flow paths not captured in gridded model are circled in (b).. The additional inflows that these flow paths create cause a rise in water level gradient from Lock 4 to Katarapko Creek, thereby creating an additional area of inundation. This suggests that the FM model may provide an improved representation of inundation extent under raised Lock 4 weir pool level than the previous model.



(a) (b)

Figure 4.36. Comparison of (a) observed to (b) modelled inundation extents in Katarapko Floodplain and Gurra Gurra wetlands for a flow of approximately 40 000 ML/d (imagery dated 6 October 2016, ~38 000 ML/d at Lyrup gauging station).

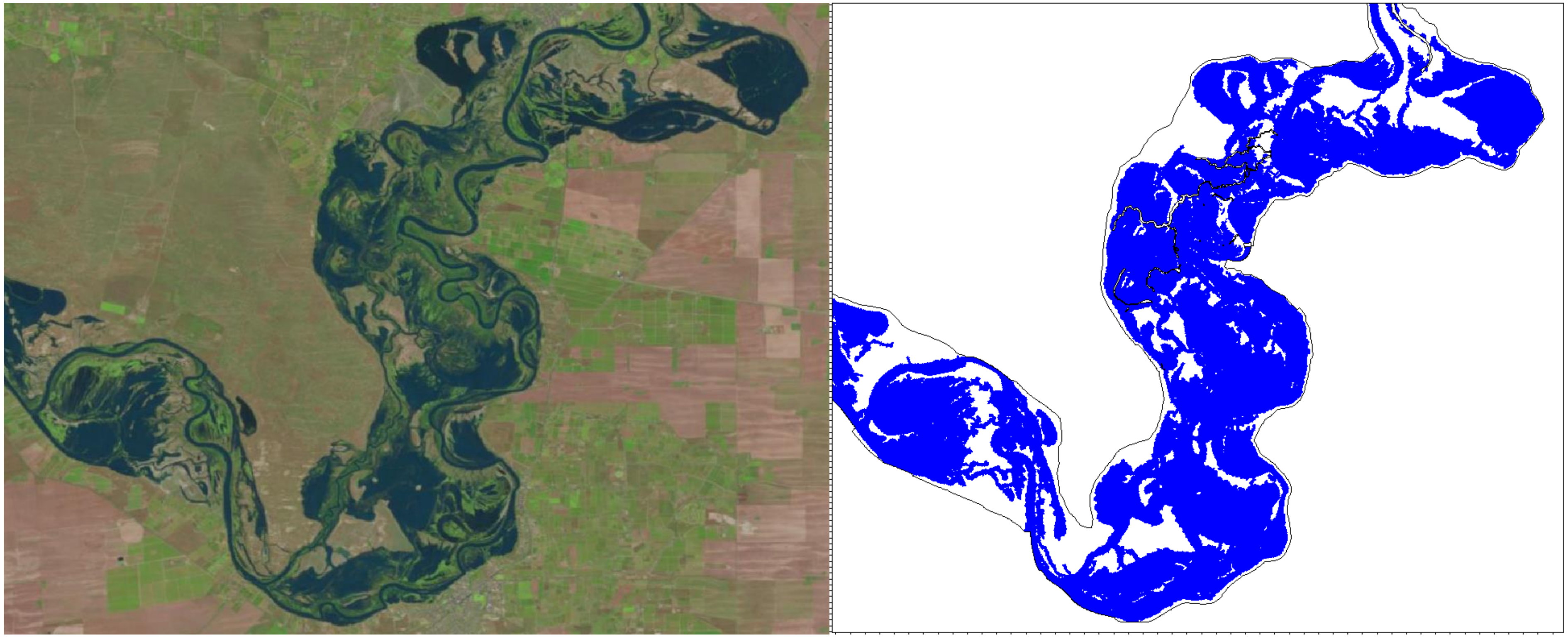


(a) (b)

Figure 4.37. Comparison of (a) observed to (b) modelled inundation extents in Katarapko Floodplain and Gurra Gurra wetlands for a flow of approximately 45 000 ML/d (imagery dated 13 December 2000, ~46 500 ML/d at Lyrup gauging station).

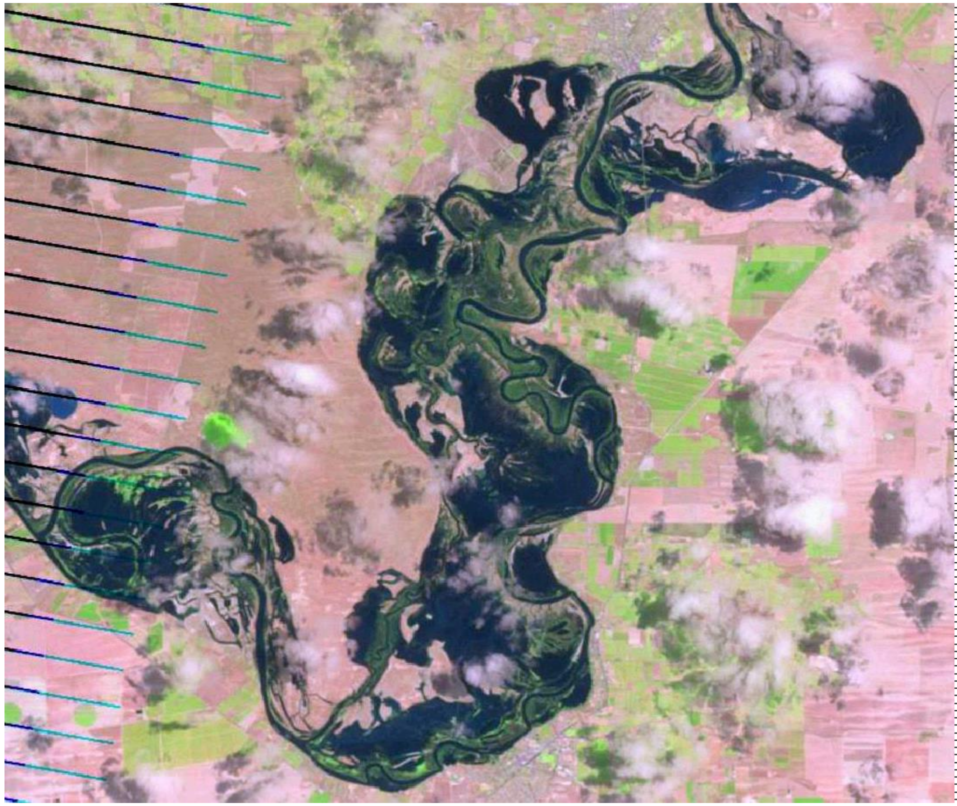
(a) (b)

Figure 4.38. Comparison of (a) observed to (b) modelled inundation extents in Katarapko Floodplain and Gurra Gurra wetlands for a flow of approximately 60 000 ML/d (imagery dated 18 January 2011, ~59 000 ML/d at Lyrup gauging station).

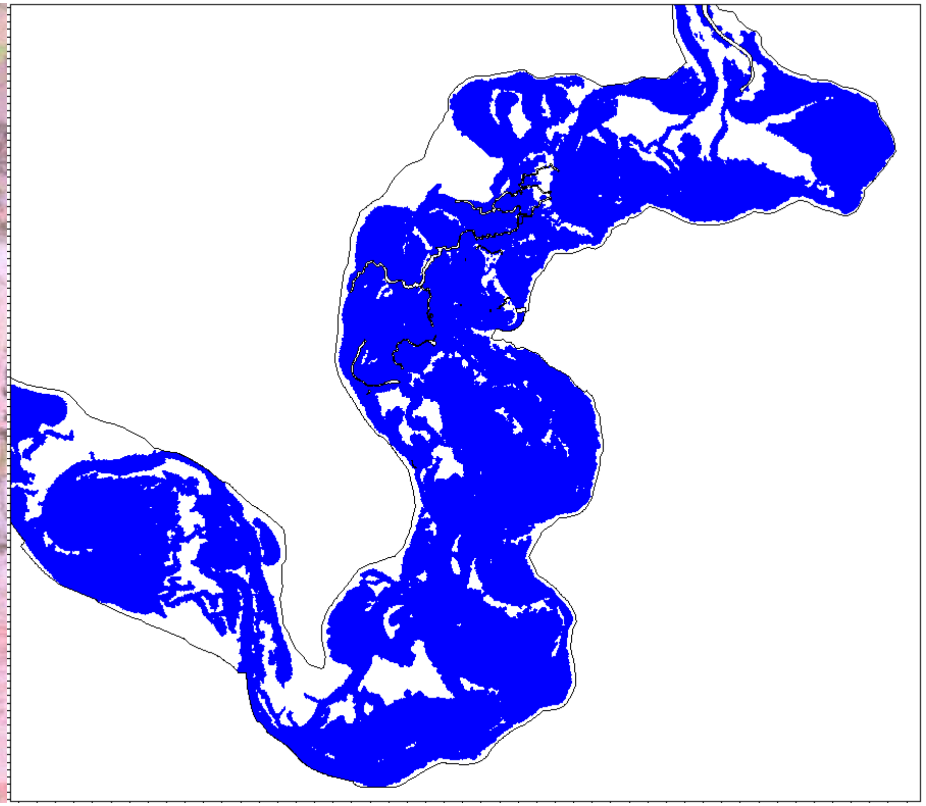


(a) (b)

Figure 4.39. Comparison of (a) observed to (b) modelled inundation extents in Katarapko Floodplain and Gurra Gurra wetlands for a flow of approximately 75 000 ML/d (imagery dated 7 March 2011, ~73 600 ML/d at Lyrup gauging station).



(a)



(b)

Figure 4.40. Comparison of (a) observed to (b) modelled inundation extents in Katarapko Floodplain and Gurra Gurra wetlands for a flow of approximately 82 000 ML/d (imagery dated 9 December 2016, ~80 500 ML/d at Lyrup gauging station).

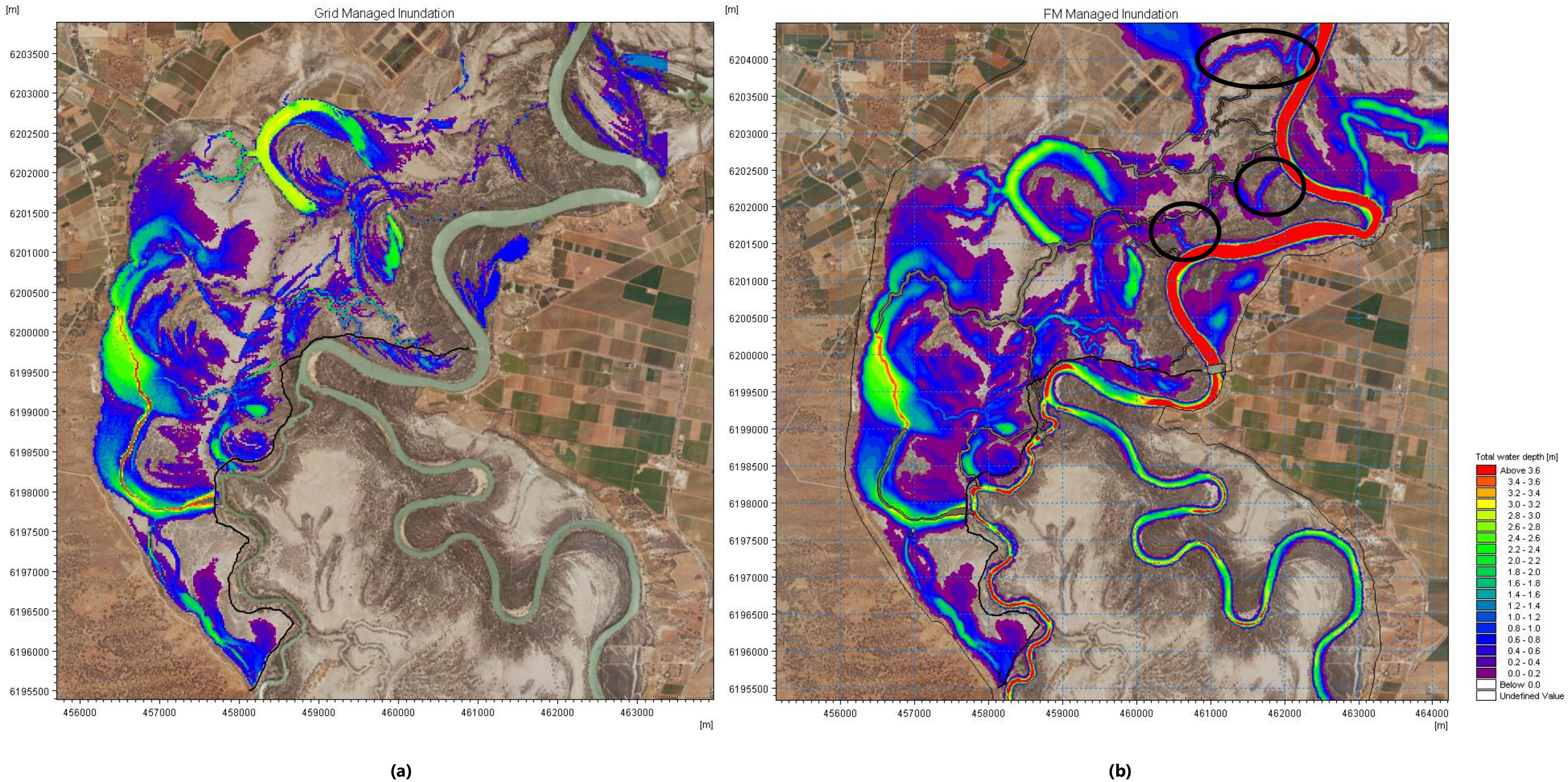


Figure 4.41. Comparison of modelled Katarapko Floodplain managed inundation at 13.5 m AHD under (a) gridded and (b) FM models. Additional flow paths not captured in gridded model are circled in (b).

5 Conclusions

Existing MIKE FLOOD grid-based models of Pike and Katarapko floodplains that were converted to Flexible Mesh versions were refined, calibrated and verified against historical and recent observations.

Model updates involved incorporating changes to the grid-based models that were conducted after the conversions had been implemented, and refining the mesh resolution to best represent each floodplain. Updates included modifications to 1–D model components and structures, blocking alignment changes, and adjusting the mesh and 1–D/2–D coupling links accordingly.

Calibration was conducted in an iterative fashion, simulating flows of 10 000 to 75 000 ML/d and comparing outputs to observed data for similar flow conditions. Differences were investigated and adjustments made before rerunning subsequent simulations. Adjustments were typically made to remove instabilities, which caused an over- or under-estimation of water levels, or removing localised artificial high points in the mesh that may have prevented flow at certain flows. Measures implemented included:

- introducing dike structures parallel to the flow in the main channels at points where large elevation changes were occurring over small perpendicular differences and creating instabilities
- adjusting lateral coupling links that were causing instabilities under certain flow conditions, or causing issues with model functionality such as preventing full managed inundation from being reached
- reducing down point elevations in the scatter data to ensure flow paths were fully connected as represented in the DEM

Overall, comparisons of calibrated modelled results to available data including observed water levels and satellite imagery of flood extents showed a reliable representation of conditions across all flows simulated, providing confidence for modelling future SARFIIP management scenarios.

6 Recommendations

A number of recommendations were made in the original internal technical note on which this publication is based, which included:

- It is recommended that initial scenarios with the FM models are duplicated in the MIKE FLOOD grid-based model versions in order to provide further confidence in the results produced.
- Continue to refine the models into the future as further data becomes available and/or as future requirements change. This may include further refinement of flow paths and wetland areas outside the Pike and Katarapko floodplains (e.g. for weir pool manipulation investigations).
- Include dynamic simulations of high flow events for future model refinements and verifications.
- Investigate more quantitative evaluations of modelled inundation extent against observed data where alternative, higher resolution satellite imagery may be obtained.

Note that these recommendations have since been addressed in subsequent modelling work, and are included here for completeness.

7 Appendices

A. Model simulation configurations

Pike Floodplain

Model config. type	Description	Units	Flow event					
			10 000 ML/d	40 000 ML/d	60 000 ML/d	75 000 ML/d	90 000 ML/d	Managed Inundation 16.4 m AHD
Boundary conditions	U/S flow boundary	m3/s	115.741	462.960	694.444	868.056	1041.66	115.741
	D/S level boundary (i.e. Lock 4 level)	m	13.2	13.2	14.34	14.66	14.73	13.2
Control settings	Lock 5 weir U/S level	m	16.3	16.3	16.85	16.95	17.05	16.8
	Deep Creek flow[1]	ML/d	300	300	300	300	Fully open	600
	Margaret Dowling Creek flow[1]	ML/d	300	300	300	300	Closed	600
	Pike River regulator U/S level[1]	m	14.35	14.35	14.35	14.35	14.35	16.4
	Tanyaca Creek regulator U/S level[1]	m	14.75	14.75	14.75	14.75	14.75	16.4
	Bank B	-	Closed	Closed	Fully open	Fully open	Fully open	Closed
	Bank B2	-	Closed	Closed	Fully open	Fully open	Fully open	Closed
	Bank C	-	Closed	Closed	Fully open	Fully open	Fully open	Closed
	Ancillary structures	-	None	None	None	None	None	Closed
	Blocking alignment	m	None	None	None	None	None	16.6

[1] Minimum setting – model calculates final value based on hydraulic conditions

Katarapko Floodplain

Model config. type	Description	Units	Flow event						
			10 000 ML/d	40 000 ML/d	45 000 ML/d	60 000 ML/d	75 000 ML/d	82 000 ML/d	Managed Inundation 13.5 m AHD
Boundary conditions	U/S flow boundary	m3/s	115.741	462.960	520.833	694.444	868.056	949.074	115.741
	D/S level boundary (i.e. Lock 3 level)	m	9.8	9.8	9.8	9.8	10.5	11.0	9.8
Control settings	Lock 4 weir U/S level	m	13.2	13.2	13.4	14.34	14.6	14.75	13.8
	Bank J flow[1]	ML/d	100	100	100	100	100	100	Fully open
	Log crossing[1]	m	11.1	11.1	11.1	11.1	11.1	11.1	Fully open
	The Splash regulator	m	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	13.5
	Sawmill regulator	ML/d	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	100
	Piggy Creek outlet	ML/d	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	10
	Car Park outlet	ML/d	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	10
	Piggy Creek northern inlet	-	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	Closed
	Piggy Creek southern inlet	-	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	Closed
	Ancillary structures (Lock 4 alignment)	-	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open
	Ancillary structures (Sawmill Creek)	-	Fully open	Fully open	Fully open	Fully open	Fully open	Fully open	Closed
	Blocking alignment	m	None	None	None	None	None	None	13.7

[1] Minimum setting – model calculates final value based on hydraulic conditions

B. Model update logs

Pike Floodplain

Model Version	Model Details	Model Updates	Additional Update Details	Relevant Updated File
FM V1_3	Un-calibrated FM model converted from grid model version at time of conversion	DHI upgraded Pike FM model, directly from MIKE FLOOD gridded version, with SARFIIP infrastructure included. Used as base model for updates to be applied (i.e. MIKE FLOOD grid version was modified since FM upgrade was applied)		
MIKE FLOOD grid (MFG)	Latest version of gridded model	Use as base model to update v2 FM model with latest changes applied since DHI upgraded to FM.		
FM V2		Replaced nwk11 file in FM V1_3 with nwk11 from MFG. Used nwk11 file from FM V1 to guide modification of MFG nwk11 file, including deleting ancillary culverts and spillway structures (to be added to blocking bank dike structure in m21fm). Modified points at other existing branches where adjusted or deleted from the FM V2 conversion.	Added ancilary culverts based on the recent updates. Culv_B, Culv_C1, Culv_K, Culv_L Adjusted existing branches: Mundic outlet (branch 10) and Tanyaca (branch 4_1) restructured to extend branch to include flood runner sections (ensure minimum elevation in mesh not compromised by small width of these runners).	Pike_V2_Managed.nwk11
		Replaced xns11 file V5_6 with xns11 file from MFG. Cross-checked new xns11 file with that from FM V2 model to ensure adjustments made to cross-sections for integrating with FM were captured (e.g. new cross-sections for updated branch 10).		Pike_V2.xns11
		Edit mesh using MDF file from FM V1_3 to incorporate new/adjusted nwk11 branches (exclude area from mesh), covering Mundic Outlet and four ancilary culverts. Steps: extract xyz data from res11 file for markers 1 and 3 (LB and RB); import boundary file from xyz file, which presents as arcs in MDF file; edit arcs as appropriate to ensure that surrounding elements are not too small, or no crossing over of other arcs, etc., and join into a single polygon; add polygon marker inside the area and select 'exclude from mesh' in properties.		Pike_V3_0.mdf

Model Version	Model Details	Model Updates	Additional Update Details	Relevant Updated File
		MDF file: Added additional polygons around floodplain to define smaller flow paths along centrelines, also covered sections that require more detail than the default element sizing used by DHI in their development (edits mainly within the floodplain section that contain higher numbers of small flow paths). Regenerated mesh around changes, exported to zero bathymetry mesh file, and created point shape file of mesh elements to use in ArcGIS. Extracted values to the point shape file using the updated DEM as the elevation file. Deleted points where elevations were -9999 m (i.e. gaps in DEM), and created xyz file from resultant points.		Pike_V3_1.mdf
		Bathymetry assignment to mesh: In MDF file, use the following scatter data - scatter from: xyz file created from the previous step; DHI version of the mesh (for the gaps only); Use prioritisation with the latest xyz data for the global floodplain area, DHI scatter data for filling in gaps (generally permanent water bodies that don't need high density of points given they don't vary much).		Pike_V3_2.mdf
		Adjust links or create new ones as applicable in couple file: for standard links, create as normal and manually locate the start and end coordinates of the links as does not always fall where expected; for lateral links, export the arc coordinates selected from the left and right banks of each excluded area, create link as normal, then replace those coordinates with the ones just extracted (plus ensure left or right bank is selected as applicable - default is left bank). Break lateral links that span the blocking alignment into two sections to avoid bypassing the bank when managed inundation occurring (i.e. link ends with a 1-2 element spacing to bank, and starts on other side with another 1-2 element spacing from the bank)		Pike_V3_Managed.couple
		Create water level boundaries for the standard links in the bnd11 file for newly generated links (or adjust existing boundary chainages as applicable).		Pike_V3_Managed.couple

Model Version	Model Details	Model Updates	Additional Update Details	Relevant Updated File
		Adjust elevations at standard links to avoid differences between 1D and 2D - run couple file, then refer to log file to determine where differences lie. Inspect the differences and either: edit scatter points around link location to better match cross-section, then regenerate mesh using new bathy elevations; or adjust the elevation in the cross-section itself. Repeat iteratively until all elevations match. Also edit scatter points where flow path elevations on the floodplain may not adequately be represented (i.e. too high in elevation).		Pike_V3_2.mesh
		Create new scatter file based on mesh above (V3), and adjust elevations that have been biased high and create instability error. Added arcs and adjusted point elevations at minor floodrunners and floodplain area around Mundic creek, snake creek, Tanyaca horseshoe and Pike lagoon, to ensure connection above appropriate flows.		Pike_V3_3.mesh
		Modify element size at selected sections (e.g. Settler's bend bypass creeks) to improve resolution for appropriate representation of bathymetry. Reduce point elevations at wetland areas where DEM shows water surface elevation at these locations rather than bed elevations.	Reduce elevation of creeks in lower pike section to ~13 m AHD to allow wetting of area at normal pool.	Pike_V3_4.mesh
		Adjust edge elevations of main channel (River Murray) to avoid large changes in elevations parallel to flow, which create local instabilities e.g. point elevations extracted from flow sometimes captured top of bank and sometimes bottom of channel depending on location of arcs defining banks - make adjacent elevations consistent.		Pike_V4_0.mesh
		Adjusted lateral links at start/end of branches (where applicable) to move back 1-2 elements from standard link to reduce local instabilities.	Adjustments of lateral links includes 4_1 branch (N.B. delete lateral link section on creek side of blocking bank), Branch 5, 7, 10, 11_1, 15, 19	Pike_V5.couple

Model Version	Model Details	Model Updates	Additional Update Details	Relevant Updated File
		Creation of dike structures (2D) along the main channel at River Murray at targeted locations where large elevations changes occur perpendicular to flow, including: deep sections of river, usually on outside of bends, and/or where high cliffs are present adjacent to the river. N.B. instabilities may result where large elevation changes occur over small distance. Also, added further 2D dikes to represent couple of minor existing structures/banks. Adjustment of Manning's n value for sensitivity in order to better match observed levels at flows of 10 and 40 GL/d as main effort.	Dikes created in 2D along bank arcs at the selected locations on outside of bends, at edges of in-stream islands and/or adjacent to cliffs. N.B. adding dikes along full length of channels was not favourable as it caused considerable increase in run times.	Iterations up to V5_4
		Testing of different Manning's n values for M11 section of River Murray at downstream end of model domain to address underestimation of water level and inundation extents at higher flows.	Tried n = 0.04 and 0.035 to observe changes in inundation extent (previously set to default of 0.028). Also used Katarapko floodplain modelling outputs to compare water level at upstream end of the Katarapko FM model with the downstream end of the Pike FM model. Comparisons indicated that a value of 0.035 for M11 River Murray section was sufficient to address the water level underestimation issue at high flows.	V6
		Further instability discovered at Bank E lateral links that were impacting on levels at overbank flow conditions. Downstream water level boundary was also found to be actual cause of the level underestimation issue identified above, which was diverting flow away from M11 model and artificially reducing water levels. Other connectivity issues were identified in the mesh at various flows.	Adjusted Bank E lateral links to remove instability. Changed downstream water level boundary to a land boundary to better reflect levels in the M11 model at high flows. Adjusted M11 Manning's n value back to original default value, reversing change above. Adjusted local elevations to improve connectivity.	V7

Katarapko Floodplain

Model Version	Model Details	Update Summary	Additional Details	Updated File
FM V2_2	Un-calibrated FM model version	DHI upgraded Kat FM model, directly from MIKE FLOOD gridded version, with SARFIIP infrastructure included (see link under Model Version column). Used as base model for updates to be applied (i.e. MIKE FLOOD grid version was modified since FM upgrade was applied)		
MIKE FLOOD grid model (MFG)	Current version of gridded model	Use as base model to update v2_2 FM model with latest changes applied since DHI upgraded to FM. Same model used for Kat Lateral Connectivity study (see link under Model Version Column)		
FM V3_0 to 28 (iterative)	Various iterations of the model during the update and calibration process	Replaced nwk11 file in FM V2_2 with that from MFG. Used nwk11 file from FM V2_2 to guide modification of MFG nwk11 file, including deleting superfluous sections of River Murray and Kat Creek, and adding branch for Lock 4 updated during FM conversion. Also deleted spillway structures (to be added to blocking bank dike structure in m21fm). Modified points at other existing branches where adjusted or deleted from the FM V2_2 conversion. Added Gurra Gurra model branches for wetland inlets to the nwk11 file.	Branch edits - Added Piggy Ck Northern inlet, Lock 4 flood runner E and W culverts, Gurra Gurra inlets that were cut off from mesh; Adjusted existing branches: lower Splash section around regulator (narrower 1D section to allow more of floodplain captured in 2D), Sawmill ancillary structures (restructured runners to incorporate more of 2D floodplain), Car Park inlet and outlets restructured to extend branch to include flood runner sections (ensure minimum elevation in mesh not compromised by small width of these runners); Deleted branch WETL 1541 on Kat island to instead represent in 2D only - is wide enough to do this and no apparent advantage in maintaining in 1–D.	1–D Network file (.nwk11)
		Replaced xns11 file V1_6 with xns11 file from MFG. Cross-checked new xns11 file with that from FM V2_2 model to ensure adjustments made to cross-sections for integrating with FM were captured (e.g. new cross-sections for updated Lock 4 branch), while preserving any updates to cross-sections applied in MFG. Added cross-sections used in Gurra Gurra file to match the inlet creeks.		1–D cross-section file (.xns11)
		Edit mesh using MDF file from FM V2_2 to incorporate new/adjusted nwk11 branches (exclude area from mesh),	Steps: extract xyz data from res11 file for markers 1 and 3 (LB and RB); import boundary file from xyz file, which presents as arcs in MDF file; edit arcs as appropriate to	2–D mesh generation file (.mdf)

Model Version	Model Details	Update Summary	Additional Details	Updated File
		covering Piggy Ck northern inlet, Sawmill ancillaries, Splash outlet and Car Park inlet and outlets.	ensure that surrounding elements are not too small, or no crossing over of other arcs, etc., and join into a single polygon; add polygon marker inside the area and select 'exclude from mesh' in properties.	
		Adjusted arcs along blocking line to match latest alignment, which differs from that used by DHI - further north alignment between Lock 4 and Sawmill Ck. Extracted arc coordinates to adjust dike alignment to match new one - changed elevation to a constant value of 13.7 m AHD to a varying in space elevation at 14.1 m AHD, except for the location of spillways which were lowered to 14.0 m AHD for those specific sections.		2–D mesh generation file (.mdf)
		MDF file: Added additional polygons around floodplain to define smaller flow paths along centrelines, also covered sections that require more detail than the default element sizing used by DHI in their development (edits mainly within the floodplain section that contain higher numbers of small flow paths). Also imported polygons and arcs into mesh that were used in the Gurra Gurra model for consistency.	Replaced excluded areas in Gurra Gurra area, representing the Loxton-Berri and Lyrup roads, with single arcs, and exported the arc coordinates to add additional dike structures in the m21fm file - allows overtopping of the road at high flows, rather than being blocked altogether.	2–D mesh generation file (.mdf)
		Regenerated mesh around changes, exported to zero bathymetry mesh file, and created point shape file of mesh elements to use in ArcGIS. Extracted values to the point shape file using the updated DEM as the elevation file. Deleted points where elevations were -9999 m (i.e. gaps in DEM), and created xyz file from resultant points.		2–D mesh generation file (.mdf) and scatter data text file (.xyz)
		Bathymetry assignment to mesh: In MDF file, use the following scatter data - scatter from: xyz file created from the previous step; DHI version of the mesh (for the gaps only); Gurra Gurra model scatter data for consistency with standalone Gurra Gurra model; Outflow boundary area at end of model, setting the area to a constant 2.59 m AHD. Use prioritisation with the latest xyz data for the global floodplain area, DHI scatter data for filling in gaps (generally permanent water bodies that don't need high density of points given they don't vary much), Gurra		2–D mesh generation file (.mdf) and scatter data text file (.xyz)

Model Version	Model Details	Update Summary	Additional Details	Updated File
		Gurra scatter for only the Gurra Gurra area, and the outflow boundary for only the end point of the model.		
		Adjust links or create new ones as applicable in couple file: for standard links, create as normal and manually locate the start and end coordinates of the links as does not always fall where expected; for lateral links, export the arc coordinates selected from the left and right banks of each excluded area, create link as normal, then replace those coordinates with the ones just extracted (plus ensure left or right bank is selected as applicable - default is left bank). Break lateral links that span the blocking alignment into two sections to avoid bypassing the bank when managed inundation occurring (i.e. link ends with a 1-2 element spacing to bank, and starts on other side with another 1-2 element spacing from the bank)		1–D/2–D coupling file (.couple)
		Create water level boundaries for the standard links in the bnd11 file for newly generated links (or adjust existing boundary chainages as applicable).		1D boundary file (.bnd11)
		Adjust elevations at standard links to avoid differences between 1D and 2D - run couple file, then refer to log file to determine where differences lie. Inspect the differences and either: edit scatter points around link location to better match cross-section, then regenerate mesh using new bathy elevations; or adjust the elevation in the cross-section itself. Repeat iteratively until all elevations match. Also edit scatter points where flow path elevations on the floodplain may not adequately be represented (i.e. too high in elevation).		Scatter data text file (.xyz)
		Create new scatter file and adjust elevations that have been biased high (following initial base flow run which showed overestimated river and Kat Ck levels). River Murray and Kat Ck areas with split flow paths around in-stream islands; general floodplain flow paths, including Splash area and Berri evap basin inlet channels.		Scatter data text file (.xyz)

Model Version	Model Details	Update Summary	Additional Details	Updated File
		Adjusted dike structure at Lock 4 road north section to allow flow into terminal area in Gurra Gurra on western side of road to north of main inlet - broken dike structure into Loxton road north and mid-section. Also adjusted point elevations at connection between northern and southern lakes to remove artificial blockage in mesh.		2–D FM run file (.m21fm)
		Added arcs and adjusted point elevations at minor floodrunners, to ensure connection above appropriate flows.	Edits including at Banks D and H, and floodplain area between Sawmill and Ngak Indau wetlands, horseshoe lagoons on Media Island.	2–D mesh generation file (.mdf) and scatter data text file (.xyz)
		Reduce maximum element size at selected sections (e.g. narrow sections and locations of in-stream islands) of River Murray and Katarapko Creek to improve resolution for appropriate representation of bathymetry.	Used maximum element size in Kat Creek = 200; River Murray = 250.	2–D mesh generation file (.mdf)
		Adjustment of Car Park inlet and outlet excluded areas to avoid overly small element generation.		2–D mesh generation file (.mdf)
		Reduce point elevations at wetland areas where DEM shows water surface elevation at these locations rather than bed elevations. Ensure hot start file (dry bed) has wetted lower boundary - manually edit dry bed at Lock 3 area to constant elevation of 5 m.	Areas include Lake Bonney and Yatco lagoon, including connecting streams, which have elevations at normal Lock 3 pool in the DEM - incorrect elevations. Adjust down by estimated depths e.g. Assume maximum Lake Bonney depth of up to 4m at centre. Also adjust elevations at Berri evap basin (gap in DEM) - reduce elevations in northern section to ~12.8 m AHD to allow wetting of area at normal pool.	1–D/2–D coupling file (.couple)
		Adjust edge elevations of main channels (River Murray and Kat Creek) to avoid large changes in elevations parallel to flow, which create local instabilities e.g. point elevations extracted from flow sometimes captured top of bank and sometimes bottom of channel depending on location of arcs defining banks - make adjacent elevations consistent.		Scatter data text file (.xyz)
		Adjusted lateral links at start/end of branches (where applicable) to move back 1-2 elements from standard link to reduce local instabilities.	Adjustments of lateral links includes Splash_2 branch top and bottom (N.B. delete left bank lateral link section on creek side of blocking bank), Car Park inlet and outlet,	1–D/2–D coupling file (.couple)

Model Version	Model Details	Update Summary	Additional Details	Updated File
			Piggy Ck Nth inlet from creek, Gurra Gurra inlet connecting to northern lake, and adjustment of inlets at Banks J, K and N.	
		Creation of dike structures (2D) along the main channels at River Murray (U/S and D/S Lock 4) and Kat Creek at targeted locations where large elevations changes occur perpendicular to flow, including: deep sections of river, usually on outside of bends, and/or where high cliffs are present adjacent to the river. N.B. instabilities may result where large elevation changes occur over small distance. Also, added further 2D dikes to represent couple of minor existing structures/banks.	Dikes created in 2D along bank arcs at the selected locations on outside of bends, at edges of in-stream islands and/or adjacent to cliffs. N.B. adding dikes along full length of channels was not favourable as it caused considerable increase in run times. Dikes also created to represent Bank B outlet (associated with Berri evap basin) to avoid excessive flow through this connection into Eckert northern arm; Banks D and H; also dike to represent ridge between Ngak Indau outlet and flow path directly to west of it (avoid instability); also bank dividing Yatco Lagoon nth and south sections.	2–D FM run file (.m21fm)
		Adjustment of Manning's n value for sensitivity in order to better match observed levels at flows of 10 and 40 GL/d as main effort.	Tried multiple n values (0.026 from Lock 3 to Kat Ck outlet, 0.025 up to ~ Loxton P.S., 0.024 up to Lock 4); single values for reach at 0.025, 0.024 and 0.022 (v. low); adjust down Kat Ck from 0.04 originally to 0.025. Best values appear to be 0.024 for Lock 3 weir pool and 0.025 for Kat Ck.	Roughness map (.dfs2)
		Tested impact of evaporation rate, trying 0 evaporation value in comparison to standard maximum 9.5 mm/d.	General insensitivity to evaporation rate of river profile, only very minor difference observed.	2–D FM run file (.m21fm)

8 References

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