APPENDIX A

MODEL REVIEW

A1 Darlington Point Flood Study Model Review

1.1 Overview

Flood behaviour within Darlington Point and its surrounds was defined through a combination of hydrologic and hydraulic models developed for the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (WBM BMT, 2018). Specifically, the models developed for the flood study included:

- An XP-RAFTS model to simulate the rate of local storm runoff behind the levee. The output from the hydrologic model was used to define local inflows behind the levee within the TUFLOW model of Darlington Point township.
- A broad-scale TUFLOW HPC model to provide a two-dimensional (2D) representation of the Murrumbidgee River channel and floodplain that extends approximately 600 metres upstream and almost 5 km downstream of the study area, covering a total area of around 200 km^2. This model is referred to hereafter as the "Murrumbidgee River TUFLOW Model".
- A more detailed TUFLOW HPC model of the Darlington Point township to simulate local catchment runoff behind the levee. This model is a linked 1D/2D model and covers an area of around 2.1 km^2. This model is referred to hereafter as the "Darlington Point Local TUFLOW Model".

Detailed reviews of the XP-RAFTS and TUFLOW models were completed and are presented in the following sections.

1.2 XP-RAFTS Model Review

The Murrumbidgee River catchment area upstream of Darlington Point is over 32,000 km^2. Due to the long history of stream gauge records along the Murrumbidgee River upstream of Darlington Point, mainstream inflows into the broad-scale TUFLOW model were not defined based on hydrologic modelling, but rather using historic streamflow data recorded at the Darlington Point gauge for calibration event, and based on flow rates determined through Flood Frequency analysis for design events.

However, local catchment rainfall-runoff within the levee extent has also been considered for the determination of design flood conditions at Darlington Point. Therefore, the XP-RAFTS hydrological model was developed to provide local inflows into the detailed TUFLOW model of the township behind the levee. Storm Injector software was used in conjunction with XP-RAFTS to run the model simulations.

Given the lack of historic flood level data behind the levee, local runoff was not simulated for historic events. Local model inflows were generated for simulation of design flood events only.

1.2.1 Subcatchment Delineation and Parameterisation

The XP-RAFTS model comprises 23 local sub-catchments at Darlington Point and 10 sub-catchments at North Darlington Point, as shown in **Plate A1.** No discussion is included in the flood study regarding how subcatchment boundaries were delineated. However, the subcatchment boundaries were compared to ground surface elevations within the 1m x 1m gridded DEM derived from NSW LPI LiDAR survey. On this basis, the alignment of the subcatchment boundaries appear to be reasonably defined.

Only the 19 hydrological sub-catchments located within the existing levee extent were applied to the TUFLOW model. However, the additional sub-catchments were incorporated into the hydrological model to enable future assessments of the potential levee extension at Darlington Point and a levee construction at North Darlington Point.

The XP-RAFTS model also includes four (4) detention basins in sub-catchments C2, C15, C16 and C17 (refer locations in **Plate A2**). These basins represent "informal" storages behind the levee embankment that would serve to reduce flows during large events.

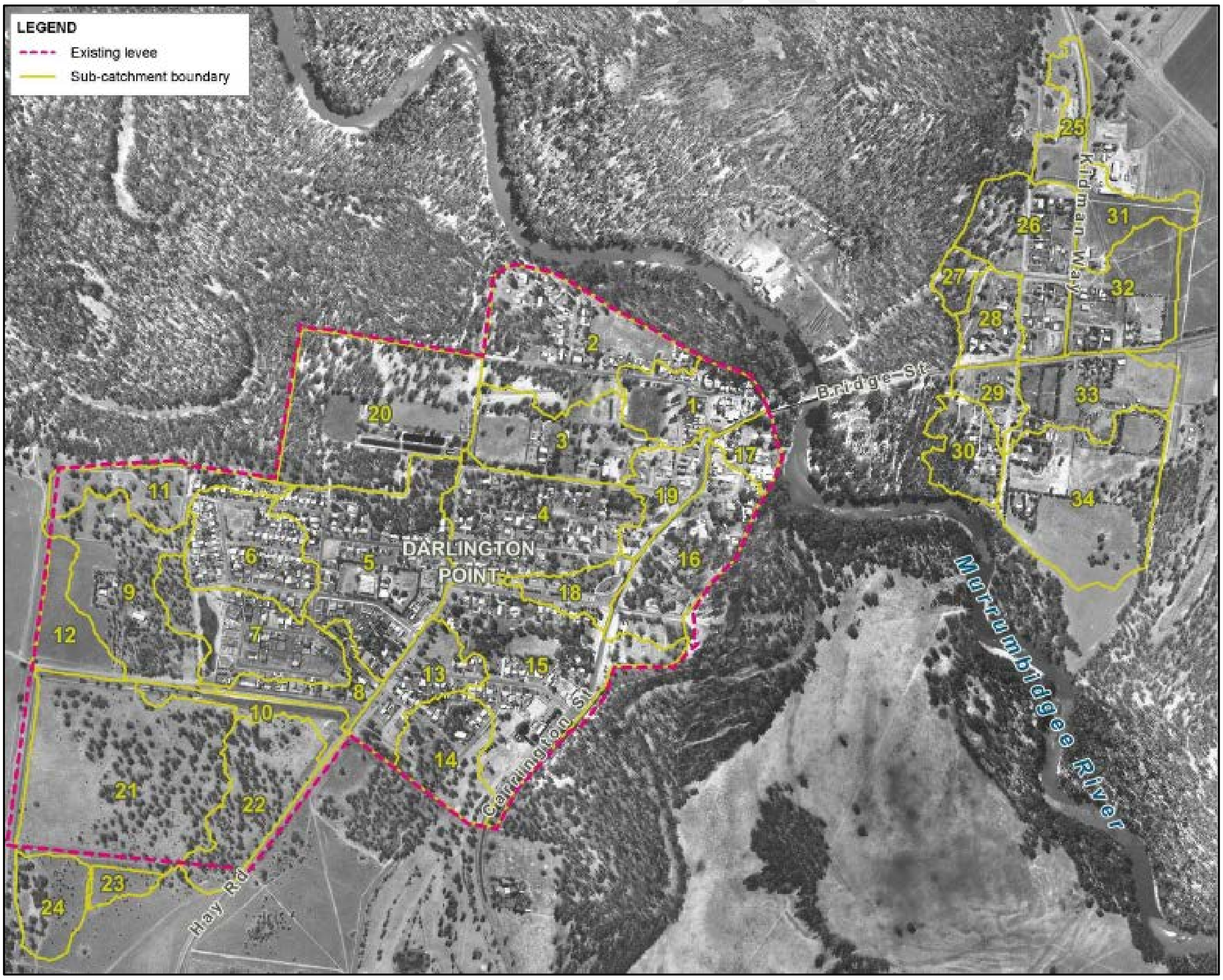


Plate A1 **XP-RAFTS Model sub-catchment delineation for the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018)**

The report also documents that it was assumed that around 25% of each sub-catchment was comprised of impervious surfaces (roads, roofs etc.) based on analysis of a sample of aerial photography of the town. Therefore, an impervious sub-area equal to 25% of the total subcatchment area was applied to subcatchments 1 to 19 that are located within the levee and comprise a reasonable degree of urbanisation. It is recommended that these values be reviewed and specific values for the pervious/impervious subareas within each sub-catchment be applied in order to provide the best description of hydrologic processes across the sub-catchments within the levee.

It was also noted that a pervious "n" (PERN) value of 0.06 was adopted for pervious sections of each subcatchment, while a PERN value of 0.025 was adopted for impervious sections of each subcatchment. As impervious surfaces (e.g., roads, concrete) will have a lower roughness relative to pervious sections of the catchment (e.g., grass, shrubs, trees), the use of different PERN values is appropriate. However, it is suggested that the PERN values could be modified to better reflect the different resistance to flow afforded by the pervious/impervious areas. The XP-RAFTS User Manual suggests a PERN value of 0.015 for impervious sub-areas. For pervious areas, it is recommended that a weighted average PERN value be calculated for each sub-catchment based on the constituent land uses/material types within each area. Therefore, it is recommended that the PERN values used in the model be reviewed and revised, as appropriate.

1.2.2 Link Parameterisation

The routing of flow along each of the main watercourses was represented in the XP-RAFTS model using time delay links. No information is provided in the report regarding how the lag values were calculated for each link.

1.2.3 Design Rainfall Information

Design rainfall depths were based on the generation of intensity-frequency-duration (IFD) design rainfall curves utilising the procedures outlined in the 2016 version of 'Australian Rainfall and Runoff' (Engineers Australia, 2016) (referred to hereafter as "ARR 2016"). Input data for the design rainfall analysis was obtained online through the ARR 2016 Data Hub and used to determine the average design rainfall depths applicable to the centre of the Darlington Point township based on the ARR 2016 IFDs.

The PMP was estimated using the Generalised Short Duration Method (GSDM) derived by the Bureau of Meteorology (1998). The GSDM method for the estimation of the PMP provided an average rainfall intensity of 97 mm/h for the 6-hour storm duration.

Areal Reduction Factors (ARFs) were applied to the design point rainfall depths. These factors were calculated for each of the modelled design events and durations based on a 2.8 hectare catchment and ranged from 0.9888 to 0.9962 for all events and durations. The calculation and application of these factors is in accordance with ARR 2016 requirements.

1.2.4 Rainfall Losses

Initial and continuing loss values for impervious and pervious catchment areas (including pre-burst rainfall depths) were determined in accordance with methods outlined in ARR 2016 for a catchment located in the Murrumbidgee River basin. The loss values are as follows:

- Impervious areas:
  - Initial loss = 1mm
  - Continuing loss rate = 0mm/hr
- Pervious areas:
  - Storm Initial loss = 27mm
  - Storm Continuing loss rate = 0mm/hr

ARR 2016 employs a variable initial rainfall loss that varies accordingly to the storm severity and duration. The initial loss (burst loss) for the study catchment was determined by subtracting median pre-burst rainfall losses from the overall storm loss for the area. The ARR Data Hub hosts a selection of pre-burst depth tables (i.e. Median, 10%, 25%, 75% and 90%) relevant to the catchment location. The median pre-burst depths were used in the estimation of design rainfall for this study and are shown in **Table 1**. The resultant design burst losses are shown in **Table 2**.

Table 1 Median Pre-burst Depth from the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018)

Storm Duration (hours)	Preburst Ratio				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
6	0.8	1.1	1.5	1.6	1.6
12	0.5	0.8	1.1	1.6	1.9
24	0.0	0.0	0.0	0.2	0.4

Table 2 Design Burst Losses from the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018)

Storm Duration (hours)	Design Burst Loss (mm)				
	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
9	26.2	25.9	25.5	25.4	25.4
12	26.5	26.2	25.9	25.4	25.1
24	27.0	27.0	27.0	26.8	26.6

However, it should be noted that a new version of ARR is now available (ARR 2019). In transitioning from ARR 2016 to ARR 2019, the *'Review of ARR Design Inputs for NSW'* (2019) was completed to review and advise on addressing under-estimation bias being experienced when using standard ARR 2016 design event methods with default data from the ARR data hub. The outcomes of this study indicated that there is significant bias in the standard ARR 2016 design event method with default ARR data hub losses and pre-burst information.

Accordingly, ARR 2019 provides improved information on initial and continuing losses and pre-burst information to use and replaces the default initial and continuing loss or pre-burst information or approaches developed as part of ARR 2016 and applied as part of the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018). Therefore, the design rainfall losses should be reviewed in line with ARR 2019 as part of this study.

1.2.5 Temporal Patterns and Design Simulations

Eight (8) design rainfall events were modelled as part of the study – 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the Probable Maximum Flood (PMF). The design storms were applied based upon procedures documented in the 2016 version of Australian Rainfall & Runoff (ARR) (Engineers Australia).

Under ARR 2016, ten temporal patterns are defined for each storm duration and design event magnitude. The procedures for ARR 2016 provide for the selection of the temporal pattern that gives the peak flow closest to the mean of the peak flows from all ten temporal patterns. This method was followed by the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018) to find the critical temporal pattern for each event duration based on assessment at three (3) of the ten (10) catchment outlet locations. Due to the discrete nature of the sub-catchments behind the levee, not all catchment outlet points had the same critical temporal pattern. The temporal pattern deemed to give the best match across the whole local catchment area was selected and applied to all sub-catchments for each design event for simplicity, as the overall impact on the estimation of design peak flood levels as reported to be insignificant.

On this basis, the temporal pattern and critical duration combinations listed in **Table 1** were selected for each of the design events.

Table 3 Adopted Temporal Pattern and Critical Duration from the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018)

Event	Temporal Pattern ID	Critical Duration
20% AEP	4154	24 hours
10% AEP	4087	12 hours
5% AEP	4087	12 hours
2% AEP	4058	9 hours
1% AEP	4058	9 hours

These critical durations will need to be revised as a result of the recommended updates to the subcatchment parameters and as a result of the application of the new ARR 2019 rainfall loss approach.

1.3 Murrumbidgee River TUFLOW Model Review

A TUFLOW HPC model was developed to provide a fully two-dimensional (2D) representation of the channel and floodplain of the Murrumbidgee River floodplain at Darlington Point. The hydraulic model uses a 10 metre grid size, covers an area of 204 km2 and extends approximately 46 km along the Murrumbidgee River

The floodplain topography is defined using a 5m x 5m gridded digital elevation model (DEM) derived from aerial survey data. Available channel cross section survey was used to inform and reinforce channel capacity and channel bed elevations along the Murrumbidgee River.

The calibration data available for the study area comprises the record from the Darlington Point streamflow gauge that has been in operation since 1939, with continuous time series records available from 1970. The 1956, 1974, 2010, 2012 and 2016 events were utilised for model calibration. Due to the long period of record and high flow spot gaugings available at the gauge site, the TUFLOW HPC model parameters were adjusted so the modelled rating curve matched the spot gaugings at the gauge site. The calibration process firstly involved calibrating the modelled channel bed elevation and roughness to low, in-channel flows, before calibrating the floodplain roughness to higher, out-of-bank flows.

The TUFLOW derived rating curve was used to adjust historical peak flows estimated from the gauge site rating curve. These updated historical flows were used to complete a Flood Frequency Analysis at the Darlington Point Bridge gauge location, and mainstream inflows into the model domain were determined from the result of this Flood Frequency Analysis. The model was used to simulate a range of design events including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and extreme flood event.

1.3.1 TUFLOW Version

- *Used:* TUFLOW.2017-09-AC-w64_iSP
- *Latest Version:* 2018-03-AE-iSP-w64
- *Suggested Update:* Not required.
  The single precision version of TUFLOW was used which is correct when using the HPC engine. Although the model could be re-run with the latest version of TUFLOW as part of the current study, this would require re-running all "base" design floods. As the differences are likely to be negligible and would require significant additional time and expense, this is not considered necessary

1.3.2 Control and Input Files

- *Control and Input File Structure:* Adheres to TUFLOW standard structure and naming conventions. The .tcf is not specifying the requirement to output 2D check files (it is commended out with a "!" at the start). Therefore, the model inputs cannot be fully checked.
- *Suggested Update:* Switch the 2D check files on.

1.3.3 Model Timestep

- *Used:* TUFLOW HPC engine used based on an adaptive timestep to achieve a target courant number. Initial 2D timestep of 5 seconds is specified for first calculation timestep.
- *Suggested Update:* Not required.
  Initial timestep of 5 seconds is consistent with the recommended range of 1/2 to 1/5 the 2D cell size of 10m.

1.3.4 Model Configuration

- *Used:* Fully 2D with 2D bridge representation, 2D breaklines to reinforce river channel, roadways and levee embankments.
- *Suggested Update:* Not required.
  2D grid size of 10 metres is considered appropriate based on the 204 km^2 extent of the model.

1.3.5 Grid Size

- *Used:* 10 metre grid
- *Suggested Update:* Not required.
  Given the large model extent of 204 km^2 and the resolution of the 5m x 5m gridded DEM used to define the ground surface elevations within the model, the adopted grid size is considered to be appropriate.

1.3.6 Model Extent

- *Used:* The TUFLOW model was developed to extend 17.3 km upstream and 28.5 km downstream of Darlington Point, covering almost 46 km of the Murrumbidgee River. The hydraulic model extends between 6 to 10 km laterally across the floodplain, which was reported in the flood study to be limited by the extent of the available high resolution topographic survey (LiDAR data).
- *Suggested update:* A review of the documented flood extents for all modelled events in the 2018 flood study was completed. "Glass walling" is evident in the north-western extent of the model in events greater than or equal to the 2% AEP flood (refer **Plate 1**) and also along the southern extent for events greater than or equal to the 1% AEP flood. The extent of the PMF versus the model boundary is shown in **Plate 2**. Therefore, it is recommended that the lateral extent of this model be extended based on available 5 metre resolution "ADS DEM".

1.3.7 Initial Water Level

- *Used:* Initial water level set to 110 mAHD.
- *Suggested update:* None required.

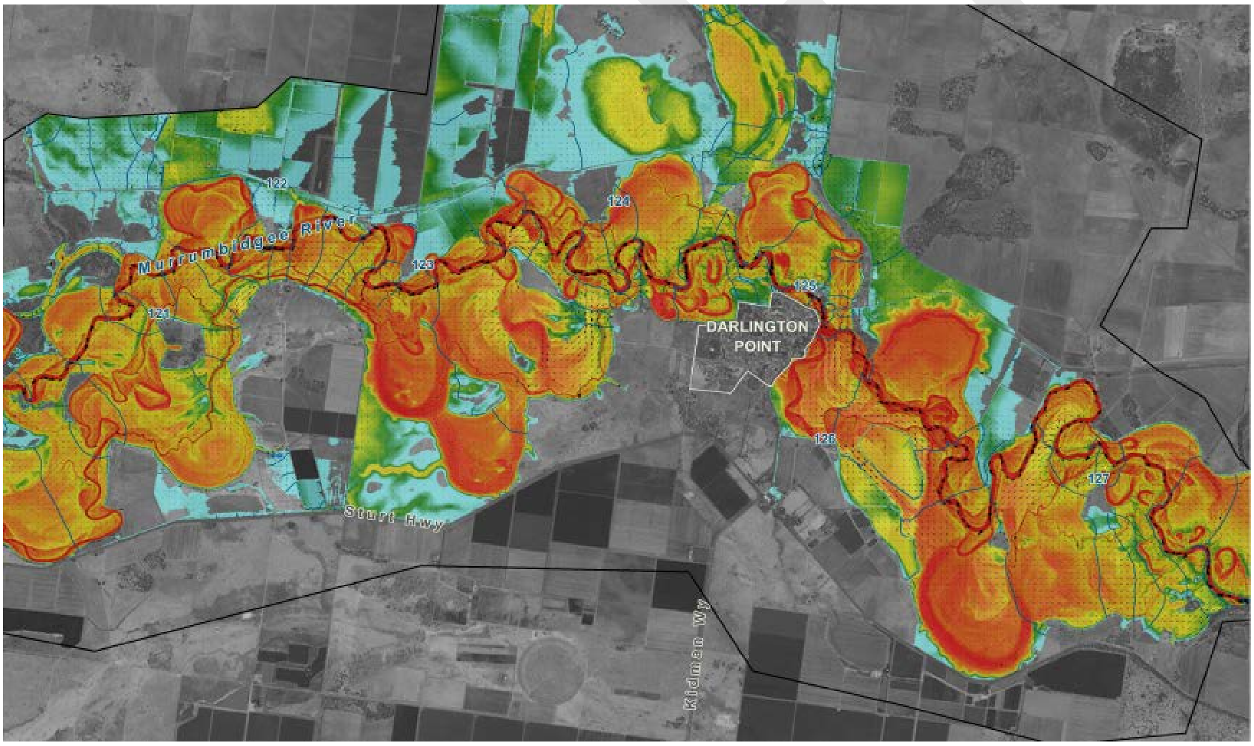


Plate 2 2% AEP Flood Extent and Model Boundary from 2018 Flood Study

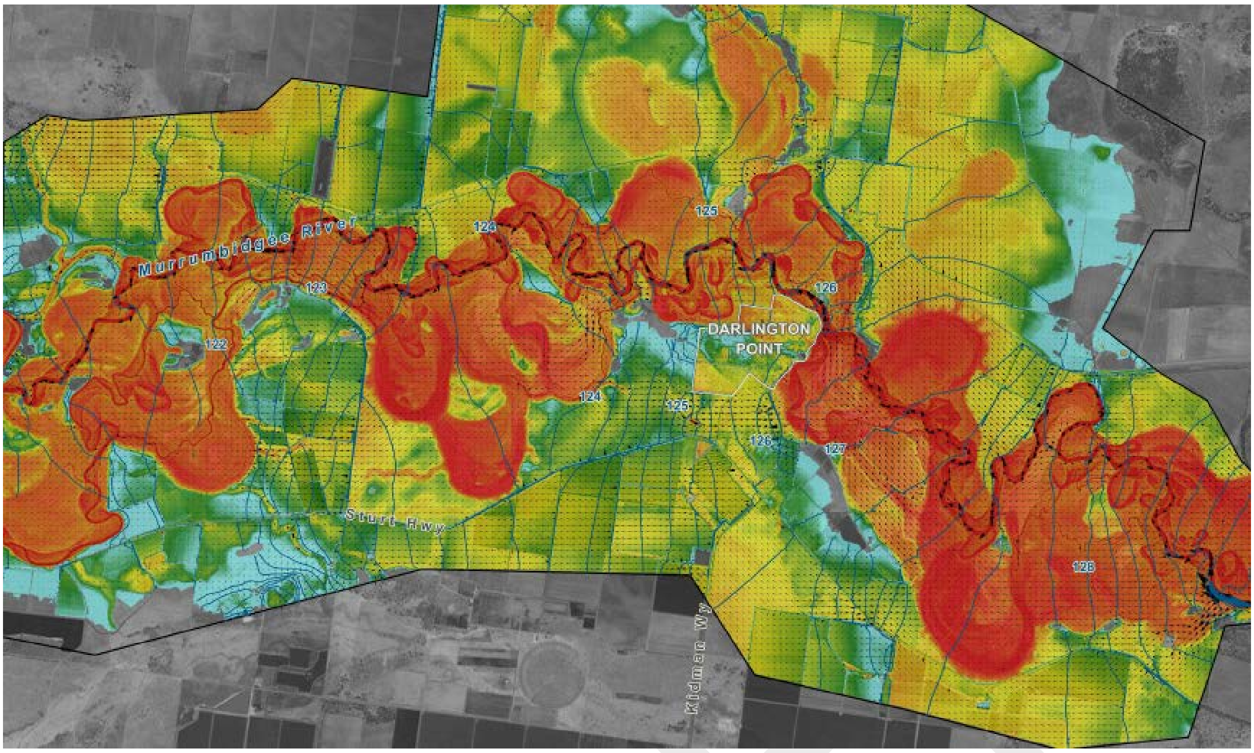


Plate 3 **PMF Extent and Model Boundary from 2018 Flood Study**

1.3.8 Model Topography

- *Used:* The flood study model utilised a 5m x 5m gridded DEM derived from NSW LPI LiDAR survey and Murrumbidgee River cross section survey data that was also available. Ground surface elevations across the model were assigned based on the DEM.
  Local topographical and hydraulic controls are reinforced within the model using "2d_zsh" (or z shape) layers to define the crest elevations using the "MAX" command – this includes all major roadways and levees within the model extent. The flood study report indicates that the elevations for the river and the roadways, levee embankments, etc are based on crest elevations along the embankment alignments that were extracted from the DEM. "2d_zsh" layers are also used to 'carve' the Murrumbidgee River channel through the 2D domain using the "MIN" command to lower elevations along a 50 metre wide river centreline based on survey datasets.
- Suggested Update: Not required.

1.3.9 Structures

- *Used:* Only two bridges (Bridge Street waterway crossings of the main river channel and eastern channel) were included in the TUFLOW model as layered flow constrictions to represent the bridge superstructure and associated losses based on assigned obvert levels, road crests and handrail obstruction. The model applies the following blockage to both of these structures for all modelled design events – 5% applied to bridge opening, 100% for deck and 20% to handrail. The model applied the following loss coefficients – 0.15/0.1 applied to underbridge, 1.56 for deck and 0.4 to handrail.
- *Suggested Update:* A number of additional structures in and around Darlington Point have been identified in Council's GIS database of structures and should be added to the model to enable flow through embankments where structures exist. The blockage of the structures should be reviewed based on guidelines contained in the Australian Rainfall &

Runoff document titled 'Blockage of Hydraulic Structures' (Engineers Australia, 2015) and requires an assessment of potential debris type, debris availability, debris mobility and debris transportability at each structure location. The blockage may also vary depending on the magnitude of the flood modelled.

1.3.10 Model Upstream Boundary Conditions

- *Used:* "QT" type boundary to define input flow hydrographs for the Murrumbidgee River.
- *Suggested Update:* Not required.

1.3.11 Model Downstream Boundary Conditions

- *Used:* "HQ" type boundary with a specified slope of 0.001 adopted at the downstream boundary of the river, as well as other outlets of the model where floodwaters spill into floodplains beyond the model extent. This type of boundary is used to generate a height-flow relationship based on a water level gradient.
- *Suggested Update:* A review of the water level gradient for the 1% AEP flood along the downstream extent of the model indicated gradients ranging between approximately 0.00063 and 0.0011. Therefore, the adopted slope of 0.001 is considered to be appropriate at the western boundary of the model and considering that the downstream limit of the model is located sufficiently far downstream from the area of interest for this study that it should not influence flood behaviour within the Darlington Point township. It is recommended that the applied slopes be reviewed as part of the model extension along the north-western and southern boundaries of the model.

1.3.12 Hydraulic Model Parameters (Manning's 'n')

- *Used:* Roughness (Manning's 'n') values assigned in "Materials_003.tmf" file.
  A total of five (5) different material types / Manning's "n" values were used (refer **Table 4**).

Table 4 Manning's 'n' Roughness Values from 2018 Flood Study

TUFLOW Identifier	Material Description	Manning's 'n'
1	Cleared floodplain	0.04
2	Murrumbidgee River channel	0.015
3	River red gum floodplain	0.12
4	Urban Areas	0.06
5	Sealed road	0.03

- *Suggested Update:* Not required.
  The majority of the Manning's "n" values are considered appropriate and in agreement with values quoted in literature. Whilst more detailed and varied spatial definition of the material types may have been applied and some Manning's "n" values, such as the river channel value of 0.015, is below values typically recommended in literature, the model has undergone calibration and the Manning's n values have been modified and selected on the basis of the calibration process. However, it may be useful to run a sensitivity simulation with an updated value for the river channel and assess its impact on the results for the 1% AEP simulation.

1.3.13 Hydraulic Model Health and Stability

- *Criteria*: Due to the explicit 2D shallow equation HPC calculation engine, loss of mass error no longer occurs and it is rare for models to go unstable and crash. However, there can still be unhealthy elements and model input and outputs should be checked and reviewed. For this HPC model checks including final cumulative mass error, bouncing of dt (timestep) values and extremely small timesteps were completed.
- *Suggested Update:* Not required. A review of overall mass balance errors for the 1% design flood simulation of 0.1% indicates that the TUFLOW model does not suffer from higher than desirable mass balance errors throughout the simulation.

1.4 Local Darlington Point TUFLOW Model Review

A local TUFLOW HPC model was developed to represent the Darlington Point township behind the levee. This dynamically linked 1D/2D model uses a 4 metre grid size and covers an area of approximately 2.4 km^2.

The floodplain topography is defined using a 1m x 1m gridded digital elevation model (DEM) derived from aerial survey data. Available channel cross section survey was used to inform and reinforce channel capacity and channel bed elevations along the Murrumbidgee River.

There are a number of smaller culverts allowing for cross-drainage through the levee, roads and field embankments. To allow for both overland flow within the town centre and for filling of storages behind embankments, these minor flow connections have been incorporated into the 1D network which is dynamically linked into the 2D domain.

No calibration or validation of the local township TUFLOW model was completed. The model was used to simulate a range of design events including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and extreme flood event. For simulation of local flood conditions behind the levee, a coincident 10% AEP Murrumbidgee River flood event was assumed.

1.4.1 TUFLOW Version

- *Used:* TUFLOW.2017-09-AC-w64_iSP
- *Latest Version:* 2018-03-AE-iSP-w64
- *Suggested Update:* Not required.
  The single precision version of TUFLOW was used which is correct when using the HPC engine. Although the model could be re-run with the latest version of TUFLOW as part of the current study, this would require re-running all “base” design floods. As the differences are likely to be negligible and would require significant additional time and expense, this is not considered necessary

1.4.2 Control and Input Files

- *Control and Input File Structure:* Adheres to TUFLOW standard structure and naming conventions. The .tcf is not specifying the requirement to output 1D or 2D check files (it is commended out with a “!” at the start). Therefore, the model inputs cannot be fully checked. The 1D control commands are included in the .tcf file rather than an .ecf file. This is acceptable for the small number of commands included in the current model, however more 1D elements may need to be included in the model for this study and it would be preferable to have a separate 1D control .ecf file.

- Suggested Update: Switch the 1D and 2D check files on. Separate the 1D control commands into an .ecf file.

1.4.3 Model Timestep

- *Used:* TUFLOW HPC engine used based on an adaptive timestep to achieve a target courant number. Initial 2D timestep of 1 second is specified for first calculation timestep.
- *Suggested Update:* Not required.
  Initial timestep of 1 second is consistent with the recommended range of 1/2 to 1/5 the 2D cell size of 4 metres.

1.4.4 Model Configuration

- *Used:* Linked 1D/2D model with 2D breaklines within the 2D domain to reinforce river channel, roadways and levee embankments and 1D structures.
- Suggested Update: Not required.

1.4.5 Grid Size

- *Used:* 4 metre grid.
- *Suggested Update:* Not required.
  A grid size of 2 metres may be more appropriate for the modelling of local overland flooding within the township. Considering the model size and use of the HPC version of TUFLOW, the durations of the simulations should still be reasonable.

1.4.6 Model Extent

- *Used:* The TUFLOW model was developed to cover the extent of the township within the levee (i.e. the levee forms the boundary of the local hydraulic model).
- Suggested update: Not required.

1.4.7 Initial Water Level

- *Used:* Initial water level set to 110 mAHD.
- *Suggested update:* There are also storages within the Sewage Treatment Plant in the town. Although these water bodies do have the potential to temporarily store water during rainfall events, none of the storages are explicitly designed to serve as flood detention basins. As a result, these storages should be assumed to be "full" at the start of each simulation and provide no attenuation of flows, which is the most conservative approach.

1.4.8 Model Topography

- *Used:* The flood study model uses a 1m x 1m gridded DEM derived from NSW LPI LiDAR survey. Ground surface elevations across the model were assigned based on the DEM. Local topographical and hydraulic controls are reinforced within the model using "2d_zsh" (or z shape) layers to define the crest elevations using the "MAX" command – this includes the levees and Kidman Way. The flood study report indicates that the elevations for the river and the roadways, levee embankments, etc are based on crest elevations along the embankment alignments that were extracted from a 2 metre horizontal grid resolution LiDAR DEM.
- Suggested Update: Not required.

1.4.9 Structures

- *Used:* 26 culvert structures are included in the model as 1D elements dynamically linked to the 2D domain. These include smaller culverts allowing from cross-drainage through the levee that have floodgates at the outlet and are modelled as one-way structures to only allow flow in the positive direction. Contraction and entry/exit losses have been applied to these circular and rectangular culverts in accordance with recommended values from the TUFLOW manual. 0% blockage is applied to all structures for all modelled design events.
  A combination of 2D SX cells and "CN" line connections are used upstream and downstream of these structures to link the culverts to the 2D domain. If a 2D SX is snapped to a 1D node (i.e. the end of a 1D structure), no CN object is required. Moreover, the location of the SX point may be located on the floodplain rather than within a drainage channel immediately upstream/downstream of the structure. As a "Z" flag is applied to the SX points, the cell at the location of the SX point is lowered to be below the 1D node elevation (i.e. below the upstream/downstream culvert invert elevation) and as these points are located on the floodplain rather than at low points or within channels at the culvert face, a review of the warnings layer for the simulation indicates that cells within the floodplain are lowered by up to 1.07m (refer Plate X). Therefore, this approach should be adjusted to only use an SX point and ensure that the point is applied directly at the locations of the structure inlets/outlets.
  A review of the messages layer also included warnings related to 2 pipes that are connected in sequence; specifically "pipe02_exg" drains directly into "pipe03_NEW". Both pipes have the same invert and outlet levels, resulting in the inlet of "pipe03_NEW" being 0.8m above the outlet of "pipe02_exg". This should be reviewed and modified, as necessary.

  Stormwater pits and pipes within the town have also been incorporate into the 1D structures layer. The stormwater pits are represented as SX points. This approach allows for infinite pit inflow capacity, which does not reflect the variation in pit capacity based on pit attributes such as grate size and lintel length. It is more appropriate to represent inlet pits using "Q" type 1D nodes which allow unique inflow relationships and blockage factors to be defined for different pit types and permit the application of different blockage factors, if necessary.

  Suggested Update: The blockage of the structures should be reviewed based on guidelines contained in the Australian Rainfall & Runoff document titled *'Blockage of Hydraulic Structures'* (Engineers Australia, 2015). Stormwater pits should also be modified to be represented as "Q" type 1D nodes.
  Modify 1D/2D connections at 1D culverts to remove "CN" connections and apply SX point directly at the ends of structures.
  Review invert levels for structures "pipe02_exg" and "pipe03_NEW".

Plate 4 Example of 1D/2D connections at a levee cross-drainage structure (SX point shown as a yellow dot, CN as a red dashed line, culvert as a dark blue arrow, gully line in aqua and model warnings in yellow text)

1.4.10 Model Upstream Boundary Conditions/Inflows

- *Used:* Inflow "SA" boundaries define input flow hydrographs (flow versus time) over an area for local sub-catchments within the levee. These areas correspond to the sub-catchment areas from the XP-RAFTS model. This will apply water to the lowest cell in the area if no other cells are wet, and then equally amongst all wet cells as the catchment is flooded. The model uses inflows that correspond to the XP-RAFTS outputs for a single temporal pattern/critical duration combination for each design event. This may not always provide the peak flood level at all locations within the model extent and may be reviewed as part of a model sensitivity assessment.
- Suggested Update: Not required.

1.4.11 Model Downstream Boundary Conditions

- *Used:* The downstream boundary of the model extends around the outside of the floodplain around the Darlington Point levee. A 2D "HT" type boundary is applied to the boundary of the model and specifies a constant stage elevation based on water level outputs for the floodplain from the Murrumbidgee River TUFLOW model. A 1D "HT" type boundary is also applied at the outlet of each levee cross-drainage structure and specifies a constant stage elevation based on water level outputs from the Murrumbidgee River TUFLOW model at each of these locations. A 10% AEP Murrumbidgee River flood event was adopted to occur coincidently with all local catchment runoff events. For outlets not inundated at the 10% AEP event, the boundary condition has been represented as a low 1D water level, allowing free discharge of floodwater onto the floodplain.

- *Suggested Update:* None required.

1.4.12 Hydraulic Model Parameters (Manning's 'n')

- *Used:* The same roughness (Manning's 'n') values assigned in "Materials_003.tmf" file for the Murrumbidgee River TUFLOW model were applied to this local Darlington Point TUFLOW model (refer **Table 4**).
- *Suggested Update:* Not required.
  The majority of the Manning's "n" values are considered appropriate and in agreement with values quoted in literature. Whilst more detailed and varied spatial definition of the material types may have been applied, the model has undergone calibration and the Manning's n values have been modified and selected on the basis of the calibration process.

1.4.13 Hydraulic Model Health and Stability

- *Criteria*: Due to the explicit 2D shallow equation HPC calculation engine, loss of mass error no longer occurs in the 2D domain and it is rare for models to go unstable and crash. However, mass errors can still occur when coupling HPC with 1D elements in either the 1D/2D linking, or in the 1D domain itself. Therefore, model input and outputs should be checked and reviewed. For this HPC model checks including final cumulative mass error, bouncing of dt (timestep) values and extremely small timesteps were completed. A cumulative mass error at the end of the simulation of -2.95% is reported in the model log file. A review of the messages layer for the simulation indicated a number of warnings related to SX connections and 2 pipes within the model. These issues and suggested updates are discussed in Section 1.4.9.
- *Suggested Update:* Not required.
  This mass error value at the end of the simulation is outside the desirable mass balance error of ±1%. This is likely due to the 1D domain and/or 1D/2D connections within the model. Some modifications to 1D structures and 1D/2D connections are recommended for the model. It is suggested that the mass error and model health be review following these modifications and the subsequent simulations.

1.5 Summary

The review of the XP-RAFTS and TUFLOW models developed for the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (WBM BMT, 2018) indicates that these models were developed in accordance with modern best practice and are suitable for application as part of the floodplain risk management study. However, a small number of updates are recommended for each model, as summarised in **Table 5.**

Table 5 Recommended Model Updates

Model	Recommended Updates
Darlington Point XP-RAFTS Model	• Review and update specific values for the pervious/impervious subareas within each sub-catchment. • Revise and update pervious 'n' (PERN) values, as necessary. • Review and modify rainfall inputs (depths, losses, etc) in the model based on the latest ARR 2019 guidelines. • Re-assess the suitability of the critical duration/temporal pattern combinations based on the modified model.
Broad-scale Murrumbidgee River TUFLOW Model	• Extend the model domain laterally to remove "glass walling" in larger magnitude floods. • Add additional structures in and around Darlington Point to enable flow through embankments where structures are identified in Council's GIS database. • Review and update structure blockage based on ARR 2016 guidelines. • Assess the sensitivity of the model to the modification of the Manning's "n" values for the river channel value of 0.015, which is below recommended values from literature.
Detailed Darlington Point TUFLOW Model	• Reduce the model grid size from 4m to 2m. • Review and update structure blockage based on ARR 2016 guidelines. • Modify the representation of stormwater pits to "Q" type 1D nodes. • Modify 1D/2D connections at 1D culverts to remove "CN" connections and apply SX point directly at the ends of structures. • Adjust initial water level within the treatment ponds in the Sewerage Treatment Plant to assume ponds are full at the start of the flood simulation and do not provide any flood storage.

APPENDIX B

COMMUNITY CONSULTATION

B1 Community Consultation

1.1 Overview

The following pages contain copies of the survey that was sent out to the community and major stakeholders as part of Stage 1 Community Consultation.

DARLINGTON POINT FLOODPLAIN RISK MANAGEMENT STUDY AND PLAN COMMUNITY QUESTIONNAIRE

In 2018, Murrumbidgee Council completed a detailed flood study for the Murrumbidgee River at Darlington Point. This flood study defined the existing flood behaviour in the floodplain and produced information on flood flows, velocities, levels and extents for a range of flood events under existing catchment and floodplain conditions.

Council is now seeking your assistance in the creation of a Floodplain Risk Management Study and Plan for the Murrumbidgee River at Darlington Point. The aim of the risk management study is to assess a range of potential measures that may help manage this flood risk. This may include structural options such as levees, non-structural options such as planning controls, and response measures such as evacuation and emergency management planning. The subsequent floodplain risk management plan will include the recommended measures aimed at best managing the flood risk with the resources available at that time.

Council has appointed consulting firm Catchment Simulation Solutions to prepare the Floodplain Risk Management Study and Plan. This project is partly funded through the Natural Disaster Resilience Program, which is a joint initiative of the Commonwealth and NSW Governments.

Please complete the enclosed survey and return it by Thursday 12 December 2019, by

- dropping it into the Darlington Point Council office
- posting it using the enclosed reply-paid envelope
- emailing it to tim.morrison@csse.com.au

A community drop-in session will also be held on Thursday 28 November from 8.00 to 9.30 am and 4.00 to 6.00 pm at Figtree Park, Stock Street, Darlington Point.

Please answer as many questions as you can and give as much detail as possible (attach additional pages if necessary).

If you have any questions or require further information, please contact:

- Catchment Simulation Solutions Project Manager – Tim Morrison on 8355 5500
- Murrumbidgee Council - 1300 676 243 or email mail@murrumbidgee.nsw.gov.au

Your Contact details

Please provide your address details within the study area. If you do not want to put your address, it would be great if you could put a locality, such as Darlington Point, North Darlington Point, Rural

Address (Lot/Section/DP) or street address ____

____

Providing full contact details is optional, but useful so we can contact you for more information if required. If you choose to provide full contact details, this information will remain confidential at all times and will not be published.

Name: ____

Phone number: ___________________________ Email: ____________________________________

About you

Q1 – About you

☐ I am a resident
☐ I am a business owner
☐ I own the property
☐ I rent the property
☐ Other – please specify_______________

Q2 - Property type

☐ House
☐ Hotel / Motel / Caravan Park
☐ Shop / retail
☐ Commercial or industrial business
☐ Community facility /School / Church
☐ Rural
☐ Other – please specify_________________________________

About your property

Q3 - How long have you been at this address?

☐ Less than 1 year
☐ 1 - 5 years
☐ 5 – 10 years
☐ 10 – 20 years
☐ More than 20 years

Q4 - Do you know if your property has a risk of being flooded?

☐ My property is beyond the extent of all potential floods
☐ My property could be flooded from the river
☐ My property could be flooded if the levee breaches
☐ My property could be flooded behind the levee
☐ No, I am not sure if my property could be flooded

Experiences of flooding

Q5 – Have you experienced a flood before?

☐ Yes
☐ No – please go to Question 15

Q6 – Which floods have you experienced?

☐ 1956 ☐ 1974
☐ 2010 ☐ 2012
☐ 2016 ☐ Other – please specify

Q7 – How did this flooding affect you?

☐ Flooding in my yard
☐ Flooding over my building floor levels
☐ Flooding in my garage / sheds
☐ Lost access due to flooding of roads
☐ Lost access to water / sewer/ electricity / telephone (please circle all that apply)
☐ Had to move machinery / livestock
☐ Lost business due to loss of road access to town
☐ Other – please specify - _______________
____

Q8 – Was your property damaged by floodwaters?

☐ No
☐ Yes – please provide details _______________________
____
____
____

Q9 – Do you have details on the flooding you have experienced? Please add extra pages including photos if needed

☐ Floodwater depth or height
☐ Location
☐ Date and time
☐ Other – please specify ________________________________
____

Q10 – How did you respond during the flood?

☐ I evacuated to an official evacuation centre
☐ I evacuated to a family or friend's house
☐ I stayed at home and did not evacuate
☐ Other – please specify

Q11 – If you did evacuate, when did you return home?

☐ After 1 day
☐ After 2-3 days
☐ After 5+ days
☐ Other – please specify _____________________________
☐ N/A – I did not evacuate

Q12 – How did you obtain information during the flood?

☐ Radio
☐ Television
☐ Internet / online
☐ Emergency Services e.g. SES / Police / RFS
☐ Friends or Family
☐ We have a phone tree set up with other residents
☐ Other – please specify ___________________________

Q13 – Did you think the levee was going to breach during the flood? i.e. floodwaters would come across the top of the levee

☐ Yes
☐ No

Q14 – Did you have confidence in the flooding predictions? i.e. that the flood levels that were being predicted were actually going to be reached?

☐ Yes
☐ No

Future flooding

Q15 – How did you think you will respond during future flooding?

☐ Evacuate early to an evacuation centre
☐ Evacuate elsewhere
☐ Remain at my house
☐ Other ____________________________
☐ Not sure / don't know

Q16 - If you are likely to evacuate, what factors are most important?

☐ Discomfort/inconvenience/cost of being isolated by floodwater
☐ Need for access to medical facilities
☐ Safety of our family
☐ Other – please describe:_________________________________
☐ ____

Q17 – How will you obtain information during future flooding events?

☐ Radio
☐ Television
☐ Internet / online
☐ Emergency Services e.g. SES / Police / RFS
☐ Council
☐ Friends or family
☐ Other – please specify _____________
____

Q18 – If you are likely to remain at your house, what factors are most important?

☐ Discomfort/inconvenience/cost of evacuating
☐ Inability to evacuate (disability / illness or lack of transport)
☐ Need to care for animals (domestic pets)
☐ Need to care for livestock
☐ Distance to evacuation centres
☐ Concern for security for my property if I evacuate
☐ Faster clean up after the flood
☐ Other – please specify___________________________________
____

Development controls

Q19 - Please rank the following development types according to which you think are the most important to protect from floods

☐ Residential
☐ Commercial
☐ Essential community facilities (school, community halls, Church)
☐ Roads
☐ Critical utilities (water, electricity)
☐ New developments
☐ Other – please specify _______________
____

Q20 - What notifications do you think Council should give about the potential flood affectation of individual properties?

☐ Advise every resident and property owner on a regular basis of the known potential flood threat
☐ Advise only those who enquire to Council about the known potential flood threat
☐ Advise prospective purchasers of property of the known potential flood threat.
☐ Provide no notifications
☐ Other – please specify____________________________________
____

Q22 - What level of control do you think Council should place on new development to minimise flood-related risks? (Please tick only one)

☐ Prohibit all new development on land with any potential to flood
☐ Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters, or evacuation difficulties
☐ Place restrictions on developments which reduce the potential for flood damage (e.g. minimum floor level controls or using flood compatible building materials)
☐ Advise of the flood risks, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks
☐ Provide no advice regarding the potential flood risks or measures that could minimise those risks
☐ Don't know

Q23 Below is a list of possible options that may be looked at to try to minimise the effects of flooding in the Study Area. This list is not in any order of importance and there may be other options that you think should be considered. For each of the options listed, please indicate "yes", or "no" to indicate if you favour the option or "don't know" if undecided.

Option	**Yes**	**No**	**Don't Know**
Management of vegetation along creek corridors			
Removal of floodplain obstructions			
Upgrading the roads to be less susceptible to flooding			
Upgrade stormwater drainage system behind the levee			
Upgrade stormwater drainage system in North Darlington Point			
Levee upgrades – Darlington Point			
Levee construction to protect north Darlington Point			
Voluntary purchase of the most severely affected flood-liable properties			
Provide funding or subsidies to raise houses above major flood level			
Flood proofing of individual properties that are currently affected by flooding			
Improve flood warning and evacuation procedures			
Community education, participation and flood awareness programs.			
Ensuring all residents and business owners have Flood Action Plans			
Specify controls on future development in flood-liable areas (e.g. extent of filling, minimum floor levels, etc.)			
Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.			
Installation of signs/boom gates at roadway overtopping locations			
Ensuring all information about the flood risks is available to all residents and business owners			

Please indicate if you would like to be contacted for more information or to provide you with study updates:

☐ Yes – telephone/ email/ mail (circle your preferred method of contact) ☐ No

Other Information

Is there anything else you would like to add related to flooding and floodplain risk management options for the Darlington Point area (please attach additional pages if needed)

____
____
____
____
____
____

Thank You

Thank you for taking the time to complete this questionnaire. This means Council is now better informed about your local area and our decisions about managing flooding in the Darlington Point and surrounding areas will be better informed. You can keep up to date with the study as it progresses at https://darlingtonpoint.fprms.com.au/.

Murrumbidgee COUNCIL NSW GOVERNMENT SES NSW STATE EMERGENCY SERVICE Catchment Simulation Solutions

Respondent	About your property			
#	What is the residential status of your property	How long have you been at this address?	What type of property is it	Do you know if your property has a risk of being flooded?
1	I own the property	10 - 20 years	House	My property could be flooded from the river
2	I own the property	5 - 10 years	House	My property could be flooded if the levee breaches No, I am not sure if my property could be flooded
3	I own the property	More than 20 years	House	My property could be flooded from the river
4	I own the property	More than 20 years	House	My property could be flooded from the river My property could be flooded if the levee breaches My property could be flooded behind the levee
5	I own the property	More than 20 years	Rural	My property is beyond the extent of all potential floods
6	I am a resident	10 - 20 years	House	My property is beyond the extent of all potential floods
7	I am a resident	Less than 1 year	House	No, I am not sure if my property could be flooded
8	I own the property	5 - 10 years	House	My property could be flooded if the levee breaches
9	I am a resident	1 - 5 years	House	No, I am not sure if my property could be flooded
10	I am a business owner	10 - 20 years	House Shop/retail	My property could be flooded if the levee breaches

11	I own the property	More than 20 years	House	My property could be flooded if the levee breaches
12	I own the property	10 - 20 years	House	My property could be flooded if the levee breaches
13	I am a resident	5 - 10 years	House	My property could be flooded behind the levee
14	I own the property	10 - 20 years	House	My property could be flooded from the river
15	I rent the property	1 - 5 years	House	No, I am not sure if my property could be flooded
16	I own the property	More than 20 years	House	My property could be flooded if the levee breaches
17	I own the property	More than 20 years	House	My property could be flooded from the river My property could be flooded if the levee breaches
18	I am a resident	More than 20 years	House	My property is beyond the extent f all potential floods
19	I own the property	More than 20 years	House	My property could be flooded if the levee breaches
20	I own the property	More than 20 years	House	My property could be flooded if the levee breaches
21	I own the property	Less than 1 year	-	-
22	I own the property	10 - 20 years	House	My property could be flooded if the levee breaches
23	I own the property	10 - 20 years	House	My property could be flooded from the river My property could be flooded if the levee breaches My property could be flooded behind the levee

24	I own the property	5 - 10 years	House	My property could be flooded if the levee breaches
25	I own the property	More than 20 years	House	My property could be flooded if the levee breaches
26	I rent the property	10 - 20 years	-	My property could be flooded if the levee breaches My property could be flooded behind the levee
27	I rent the property	More than 20 years	House	My property is beyond the extent of all potential floods. My property could be flooded from the river. My property could be flooded if the levee breaches My property could be flooded behind the levee
28	I am a business owner	1 - 5 years	House Shop/retail	My property could be flooded if the levee breaches
29	I am a resident	10 - 20 years	House	My property could be flooded from the river
30	I own the property	10 - 20 years	House	My property could be flooded from the river. My property could be flooded if the levee breaches My property could be flooded behind the levee
31	I own the property	More than 20 years	Rural	My property could be flooded from the river
32	I rent the property	More than 20 years	House	My property is beyond the extent of all potential floods

Flood experiences 1/2								
#	Have you experienced a flood before?	What floods did you experience?	How did this flooding affect you?	Was your property damaged by floodwaters?	Do you have details on the flooding you experienced?	How did you respond during the flood?	If you did evacuate, when did you return home?	How did you obtain information during the flood?
1	Yes	2010 2012 2016	-	No -the road stopped the water from entering our property	-	I stayed at home and did not evacuate	n/a	Radio Television Internet/online
2	Yes	2010 2012 2016	Lost access due to flooding of roads Lost access to water / sewer/electricity/telephone	No -the road stopped the water from entering our property	-	I stayed at home and did not evacuate	n/a	Radio Television Emergency services
3	Yes	1956 1974 2010 2012 2016	Flooding in my yard Lost access due to flooding of roads Had to move machinery / livestock Erosion	Loss of pasture crop structures	Up to 3 metres	I stayed at home and did not evacuate	n/a	Radio Television Emergency services Friends or family Observation
4	Yes	2010 2012 2016	Flooding in my yard Flooding over my building floor level Flooding in my garage / sheds Lost access due to flooding of roads Had to move machinery / livestock	House and sheds and yard	-	I evacuated to a family or friends house	4 weeks	Emergency services
5	Yes	1974 2010 2012 2016	Lost access due to flooding of roads Lost access to water / sewer / electricity	No	-	I evacuated to a family or friends house, My husband stayed at the house	After 5+ days	Radio Television Internet/online Emergency services Friends or family
6	Yes	1974 2010 2012 2016	-	-	-	I stayed at home and did not evacuate	n/a	Friends or family
7	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a
8	No	n/a	n/a	n/a	n/a	n/a	n/a	n/a
9	Yes	2012 in Yenda	-	-	-	Evacuated to a friends or family house	about 7 weeks	Emergency services Friends or family
10	Yes	2010 2012 2016	Flooding n my yard	No	-	I stayed at home and did not evacuate	n/a	Emergency services

11	Yes	1956 1974 2010 2012 2016	Flooding in my yard	No	1956 = 1.5 metres 1974 7.7 metres 1989 = 7.6 metres 1991 = 6.8 metres 2010 = 7.11 metres	Evacuated to a friends or family house I stayed at home and did not evacuate	After 5+ days	Radio
12	Yes	2012 2016	Lost access due to flooding of roads	N	floodwater depth/height location Date and time	Wife evacuated to friends or family house I stayed at home and did not evacuate	After 5+ days	Radio Internet Emergency services
13	Yes	2016	Flooding in my yard Lost access due to flooding of roads	No	Yes - location	I evacuated to an official evacuation centre	After 5+ days	Emergency Services Friends or family
14	Yes	1974 2012	Flooding in my yard Lost access to water / sewer / electricity / telephone	no	n/a	I stayed at home and did not evacuate	n/a	Radio
15	Yes	2012	evacuation	No	No	I evacuated to an official evacuation centre	After 5+ days	We have a phone tree set up with other residents
16	Yes	2012	Lost access to water / sewer / electricity / telephone	No	-	Evacuated to a friends or family house	After 2-3 days	Radio
17	Yes	1956 1974 2010 2012 2016	Flooding in my yard Flooding in my garage / sheds Lost access to water / sewer / electricity / telephone Had to move machinery	Yes - mould and rot due to failure of power Damage to yard in general	Yes - floodwater depth or height but cannot find photos	Evacuated to a friends or family house	After 5 + days	Radio Television Emergency services. Friends or family Phone tree set up with other residents
18	Yes	1956 1974 2010 2012 2016	Flooding in my yard Lost access to water and sewer Property was used as emergency access by neighbours on lower ground(Boona St / Flood St) resulting in some damage	Fences flattened or destabilised by debris	Photos attached with marked up plan of high water levels	I stayed at home and did not evacuate	n/a	Observation
19	Yes	1952 1956 1974 2010 2012 2016	Flooding in my yard Flooding in my garage / sheds Lost access due to flooding of roads	No	Floodwater depth or height Location Date and time	I stayed at home and did not evacuate	n/a	Emergency Services
20	Yes	2010 2012 2016	-	No	-	I stayed at home and did not evacuate	n/a	Emergency Services
21	No	-	-	-	-	-	-	-
22	Yes	2012 2016	Flooding in my yard Flooding in my garage / sheds Lost access due to flooding of roads Lost access to water / sewer / electricity / telephone Had to move machinery / livestock	Yes - mould and rot due to failure of power Damage to yard in general	Yes - floodwater depth or height but cannot find photos	Evacuated to a friends or family house	After 5 + days	Radio Television Emergency services. Friends or family Phone tree set up with other residents
23	Yes	2010 2012 2016	Flooding in my yard Flooding in my garage / sheds Lost access due to flooding of roads Had to move machinery / livestock	No	Floodwater depth or height Location Date and time	Evacuated to a friends or family house	After 5 + days	Radio Friends or family

24	Yes	2012	Flooding in my yard	No	-	Evacuated to a friends or family house	After 5 + days	Radio Television Friends or family
25	Yes	2012	Nil	No	-	Evacuated to a friends or family house	3 weeks	Emergency services
26	Yes	1974 2010 2012 2016	Flooding in my yard	No	-	I stayed at home and did not evacuate	n/a	Television Emergency services
27	Yes	2010 2012 2016	-	N	n/a	Evacuated to a friends or family house	After 5 + days	Radio Friends or family
28	Yes	2016	Not affected	No	n/a	I stayed at home and did not evacuate	n/a	Internet/online
29	Yes	2012 2016	Lost access due to flooding of roads	No	n/a	Evacuated to a friends or family house	After 5 + days	Television Internet/online Emergency Services Friends or family
30	Yes	2010 2012	Flooding in my garage	No	5 inches rain, not sure what date	I stayed at home and did not evacuate	n/a	Emergency Services
31	Yes	1974 2012	Lost access due to flooding of roads Had to move machinery / livestock Extensive flooding over crops	Yes - damage to crops	Location Date and time	I stayed at home and did not evacuate	n/a	Emergency services Friends or family Council workers Facebook
32	Yes	1974 2010 2012 2016		No	No yard or house flooding	I stayed at home and did not evacuate	N/A – I did not evacuate	

Flood experiences 2/2			Future flooding			
#	Did you think the levee was going to breach during the flood? i.e. floodwaters would come across the top of the levee?	Did you have confidence in the flooding predictions? i.e. that the flood levels that were being predicted were actually going to be reached?	How did you think you will respond during future flooding?	If you are likely to evacuate, what factors are most important?	If you are likely to remain at your house, what factors are most important?	How will you obtain information during future flooding events?
1	Yes	Yes	Remain at my house	-	Need to care for animals (domestic pets) To stop water that may come up in our block	Radio Television Internet / online
2	No	No	Not sure / don't know	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Discomfort / inconvenience / cost of evacuating Need to care for animals (domestic pets) Distance to evacuation centres Concern for security of my property if I evacuate	Television Emergency Services Council
3	No	Yes	Remain at my house Circumstantial	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our families	Need to care for animals (domestic pets) Need to care for livestock Concern for security of my property if I evacuate	Radio Television Internet / online Emergency Services Council Friends or family Observation
4	No	No	Remain at my home	Safety of our family	Discomfort / inconvenience / cost of evacuating Faster clean up after the flood	Emergency services Council
5	Yes	No	Remain at my house	Safety of our family	Discomfort / inconvenience / cost of evacuating Need to care for animals (domestic pets) Distance to evacuation centres Concern for security of my property if I evacuate Faster clean up after the flood	Radio Television Internet / online Emergency Services Council Friends or family
6	No	-	Remain at my house	-	Concern for security of my property if I evacuate	Radio Friends or family
7	n/a	n/a	Not sure / don't know	Discomfort / inconvenience / cost of being isolated by floodwater Safety of our family	Concern for security of my property if I evacuate	Radio Internet / online Emergency Services Friends or family
8	n/a	n/a	Remain at my house	I would like to stay at home as long as possible	I would like to be at home if the water rises so I can out things away etc..	Radio Council Friends or family Neighbours
9	-	-	Remain at my house	Discomfort / inconvenience / cost of being isolated by floodwater Safety of our family	Discomfort / inconvenience / cost of evacuating Distance to evacuation centres	Emergency services
10	No	Yes	Remain at my house	-	Need to care for animals (domestic pets) Need to cater for livestock Concern for security of my property if I evacuate	Emergency services

11	No	Yes	Remain at my house	Need for access to medical facilities	Inability to evacuate (disability / illness/lack of transport) Concern for security of my property if I evacuate	Radio Television Council
12	Yes	Yes	Not sure / don't know Monito river heights	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Discomfort / inconvenience / cost of being isolated by floodwater. Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Council Friends or family Observation
13	Yes	Yes	Remain at my house	Safety of our family	Need to care for animals (domestic pets)	Emergency services Council
14	No	Yes	Remain at my house	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Discomfort / inconvenience / cost of evacuating Inability to evacuate (disability / illness or lack of transport). Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Council Friends or family Observation
15	Yes	Yes	Evacuate to an evacuation centre	Discomfort / inconvenience / cost of being isolated by floodwater	Discomfort / inconvenience / cost of evacuating	Emergency Services
16	No	Yes	Remain at my house	Safety of our family	Concern for security of my property if I evacuate	Radio Council
17	* -there is no levee on north side	no	Not sure / don't know	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Discomfort / inconvenience / cost of evacuating Inability to evacuate (disability / illness or lack of transport). Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Friends or family Observation
18	No	-	Remain at my house	Need for access to medical facilities Safety of our family	Concern for security of my property if I evacuate	-
19	No	Yes	Remain at my house	Discomfort / inconvenience / cost of being isolated by floodwater	Concern for security of my property if I evacuate	Radio Emergency services
20	no	yes	Don't know	Safety of our family	Need to care for animals (domestic pets) Concern for security of my property if I evacuate Faster clean up after the flood	Radio Emergency services
21	-	-	-	Safety of our family	Faster clean up after the flood	Council
22	* -there is no levee on north side	No	Not sure / don't know	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Discomfort / inconvenience / cost of evacuating Inability to evacuate (disability / illness or lack of transport). Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Friends or family Observation
23	No	Yes	Evacuate elsewhere	Safety of our family	Discomfort / inconvenience / cost of evacuating Distance to evacuation centres Concern for security of my property if I evacuate.	Radio Friends or family

24	No	No	Remain at my house	-	Concern for security of my property if I evacuate	Radio Television Internet/online Council Friends or family
25	No	Yes	Remain at my house	nil	Discomfort / inconvenience / cost of evacuating Inability to evacuate (disability / illness or lack of transport). Need to care for animals (domestic pets). Need to care for livestock. Distance to evacuation centres. Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Council Friends or family
26	no	yes	Evacuate early to an evacuation centre Evacuate elsewhere Remain at my house Buy a boat	Discomfort / inconvenience / cost of being isolated by floodwater Need for access to medical facilities Safety of our family	Concern for security of my property if I evacuate. Faster clean up after the flood	Radio Television Internet / online Emergency Services Council
27	Yes	No	Remain at my house	-	Concern for security of my property if I evacuate. Faster clean up after the flood	Council
28	no	Yes	Remain at my house	Discomfort / inconvenience / cost of being isolated by floodwater	Concern for security of my property if I evacuate.	Internet / online
29	Yes	No	Not sure - maybe evacuate again to my daughters house in Griffith	Discomfort / inconvenience / cost of being isolated by floodwater Safety of our family	Discomfort / inconvenience / cost of evacuating Need to care for animals (domestic pets).	Television Internet / online Emergency Services Council Friends or family
30	No	Yes	Not sure	Discomfort / inconvenience / cost of being isolated by floodwater	Discomfort / inconvenience / cost of evacuating. Need to care for animals (domestic pets). Concern for security of my property if I evacuate.	Emergency Services Council Friends or family
31	No	No	Remain at my house	n/a	Maintaining electricity supply	Radio didn't work last time Emergency Services Council Friends or family
32	No	Yes	Remain at my house	Safety of our family;	Need to care for animals (domestic pets) Concern for security for my property if I evacuate;	Radio Television Internet / online Friends or family

Development Controls 1/3			
#	**Please rank the following development types according to which you think are the most important to protect from floods (highest priority at top of list and lowest priority at bottom of list)**	**What notifications do you think Council should give about the potential flood affectation of individual properties?**	**What level of control do you think Council should place on new development to minimise flood-related risks? Tick only one box**
1	Residential Roads Critical Utilities	Advise prospective purchasers of property of the known potential flood threat	Place restrictions on developments which reduce the potential for flood damage. Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
2	Residential Critical Utilities	-	Prohibit all new development on land with any potential to flood. Place restrictions on developments which reduce the potential for flood damage. Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks. Provide no advice regarding the potential flood risks or measures that could minimise those risks
3	All equally important - Residential Commercial Critical Utilities Essential community facilities Roads New developments	-	Place restrictions on developments which reduce the potential for flood damage
4	Residential Critical utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters or evacuation difficulties.
5	Residential Commercial Critical Utilities Essential community facilities Roads New developments	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters or evacuation difficulties. Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
6	-	Advise prospective purchasers of property of the known potential flood threat - but honestly and true	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
7	Residential Critical Utilities Commercial Essential community facilities Roads New developments	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development on land with any potential to flood.
8	Residential Land based mitigation e.g. planting of suitable trees	Advise every resident and property owner on a regular basis of the known potential flood threat -only if it is imminent no need to cause alarm	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters or evacuation difficulties.
9	Residential Critical utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters or evacuation difficulties Place restrictions on developments which reduce the potential for flood damage
10	No order - Residential Critical Utilities Commercial Essential community facilities Roads	Advise prospective purchasers of property of the known potential flood threat	Prohibit all new development on land with any potential to flood

11	Residential Critical utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Place restrictions on developments which reduce the potential for flood damage
12	Roads Critical Utilities Residential Commercial Essential community facilities New developments	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
13	Residential	Advise every resident and property owner on a regular basis of the known potential flood threat	Place restrictions on developments which reduce the potential for flood damage
14	Residential Essential community facilities Roads Critical	Advise every resident and property owner on a regular basis of the known potential flood threat. Advise prospective purchases of property of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
15	No order - Residential Commercial Essential community facilities Roads Critical Utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
16	Critical Utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development only in those locations that would be extremely hazardous to persons or property
17	No order - Residential Commercial Essential community facilities Roads Critical Utilities New development	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
18	Residential Critical Utilities Commercial Roads Essential community facilities New developments	Advise every resident and property owner on a regular basis of the known potential flood threat. Advise prospective purchases of property of the known potential flood threat	Prohibit all new development on land with any potential to flood
19	Residential	Advise only those who enquire to Council about the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
20	No order - Residential Commercial Essential community facilities Roads Critical Utilities	Advise every resident and property owner on a regular basis of the known potential flood threat. Advise prospective purchases of property of the known potential flood threat	Prohibit all new development on land with any potential to flood
21	-	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development only in those locations that would be extremely hazardous to persons or property due to the depth and/or velocity of floodwaters or evacuation difficulties.
22	No order - Residential Commercial Essential community facilities Roads Critical Utilities New development	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
23	No order - Residential Commercial Critical Utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Don’t know

24	Critical Utilities Residential Commercial Essential community facilities Roads	Advise every resident and property owner on a regular basis of the known potential flood threat	Place restrictions on developments which reduce the potential for flood damage. Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
25	nil	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development on land with any potential to flood
26	No order - Residential Essential community facilities Roads Critical Utilities New development	Advise every resident and property owner on a regular basis of the known potential flood threat	Don't know
27	No order - Residential Essential community facilities Roads Critical Utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development on land with any potential to flood
28	Critical utilities	Advise every resident and property owner on a regular basis of the known potential flood threat	Prohibit all new development on land with any potential to flood
29	Residential	Advise every resident and property owner on a regular basis of the known potential flood threat	Place restrictions on developments which reduce the potential for flood damage.
30	Residential Commercial Essential community facilities Roads Critical Utilities New development Rural	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risk, but allow the individual a choice as to whether they develop or not, provided steps are taken to minimise potential flood risks.
31	Residential Commercial	-	Provide no advice regarding the potential flood risks or measures that could minimise those risks
32	Critical utilities (water, electricity) Essential community facilities Residential Commercial Roads New developments	Advise every resident and property owner on a regular basis of the known potential flood threat	Advise of the flood risks, but allow the individual a choice about developing or not, provided steps are taken to minimise potential flood risks

Development Controls 2/3									
	Management of vegetation along creek corridors	Removal of floodplain obstructions	Upgrading the roads to be less susceptible to flooding	Upgrade stormwater drainage system behind the levee	Upgrade stormwater drainage system in North Darlington Point	Levee upgrades – Darlington Point	Levee construction to protect north Darlington Point	Voluntary purchase of the most severely affected flood-liable properties	Provide funding or subsidies to raise houses above major flood level
1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes	Yes	Yes	No	No	No	No	Yes
3	Yes	Yes	No	Don't know	Don't know	No	Yes	Yes	Yes
4	Yes	No	Yes	Yes	Yes	Yes	Yes	-	No
5	Yes	Yes	Yes	Yes	No	Yes	No	No	n
6	-	-	Yes	Yes	Yes	Done	-	-	-
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Don't know	-	-	-	-	-	-	-	No
9	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
10	-	No	Yes	Yes	Yes	Yes	Yes	No	n

11	Don't know	Don't know	Yes	Yes	Yes	Yes	Yes	Don't know	Don't know
12	-	-	Yes	Yes	Don't know	Yes	Don't know	Don't know	No
13	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	n
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	n
16	n	Yes	No	Yes	Yes	Yes	Yes	No	Yes
17	Don't know	Yes	Yes	Yes	Yes	Yes	Yes - this is the most important	Don't know	No
18	Don't know	Yes	Yes	Yes	Yes	Yes	No	Yes	No
19									
20	Yes	Don't know	Yes	Yes	Yes	Yes	Yes	Don't know	Don't know
21	Yes	Yes	Yes	dd	Don't know	Don't know	Don't know	Yes	Yes
22	Don't know	Yes	Yes	Yes	Yes	Yes	Yes - this is the most important	Don't know	No
23	Yes	Yes	No	Yes	Yes	No	Yes	No	Yes

24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
25	Yes	Yes	Yes	Yes	Yes	Yes	-	No	No
26	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
27	-	-	-	-	-	-	-	-	-
28	Don't know	Don't know	Don't know	Yes	Yes	Yes	Yes	No	Yes
29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
30	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes
31	-	second bridge in Darlington Point	No - this impacts land holders	-	-	-	-	-	-
32	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No

Development Controls 3/3								
	Flood proofing of individual properties that are currently affected by flooding	Improve flood warning and evacuation procedures	Community education, participation and flood awareness programs	Ensuring all residents and business owners have Flood Action Plans	Specify controls on future development in flood-liable areas (e.g. extent of filling, minimum floor levels, etc.)	Provide a Planning Certificate to purchasers in flood prone areas, stating that the property is flood affected.	Installation of signs/boom gates at roadway overtopping locations	Ensuring all information about the flood risks is available to all residents and business owners
1	Yes	No	No	Yes	Yes	Yes	No	No
2	No	Yes	Yes	Yes	Yes	No	No	Yes
3	Yes	No	Yes	N	Yes	Don't know	No	Yes
4	Yes	No	No	-	Yes	Yes	Don't know	Yes
5	No	Yes	Yes	Yes	Yes	No	No	Yes
6	-	-	No	-	Yes	-	No	-
7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
8	Yes	Yes	Yes	Yes	Yes	Don't know	Temporary road closed signs	Council website
9	-	No	No	Yes	n	Don't know	No	Yes
10	Yes	Yes	Don't know	Don't know	Yes	Yes	No	Yes

11	Don’t know	Yes	Don’t know	Don’t know	Yes	Don’t know	Don't know	Yes
12	Don’t know	Yes	Yes	Yes	Yes	Yes	No	Yes
13	No	Yes	No	Yes	Yes	Yes	No	Yes
14	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
15	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
16	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
17	Yes - this did not work previously	Yes	No	Yes	Yes	Yes	Yes	Yes
18	No	Yes	Yes	Don’t know	No - don’t allow	Yes	Yes	Yes
19								
20	yes	don’t know	Yes	Yes	don’t know	Yes	Yes	Yes
21	yes	Yes	Don’t know	Yes	Yes	Don’t know	Yes	Yes
22	Yes - this did not work previously	Yes	No	Yes	Yes	Yes	Yes	Yes
23	Yes	Yes	Yes	Yes	Yes	Yes	Don't know	Yes

24	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
25	Yes	_	_	Yes	yes - No development in floodprone areas	yes - No development in floodprone areas	Yes	Yes
26	yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
27	-	-	-	-	Yes	-	-	-
28	Yes	Yes	Yes	No	Yes	yes	No	Yes
29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
30	Yes	Yes	Yes	Yes	yes	yes	yes	yes
31	-	Yes	-	-	-	-	-	-
32	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes

Other comments	
	Is there anything else you would like to add related to flooding and floodplain risk management options for the Darlington Point area?
1	
2	Does not matter as the shire office is a business and does not worry about house holders
3	-
4	more water clearances under bridges, larger culverts under roads
5	-
6	Make sure its done and controlled by locals not people who have never been to Darlington Point before and know nothing about the place. Talk to some of the older residents and get real issues not computer generated guessing.
7	Being new to the area it is vital to me to have as much information as possible for my confidence and peace of mind living in a new place.
8	Please can we have the trees lost due to the levee works replaces elsewhere e.g. twin corner entries in to town
9	
10	

11	
12	I would use the 2012 flood levels as a guide i.e. I would not consider evacuation before that river peak is reached, especially now that the levee banks.
13	Yes clean out old trees and branches that can be carried by floods so no one gets hurt and use all the wood in Darlington Point for firewood e.g. put it to the town and see what they say.
14	
15	
16	Prevent SES from taking control of evacuations, the local police and council are better suited and have the local knowledge necessary.
17	Levee bank is desperately needed for North Darlington Point. A proposal for this was given to Council in 1974 but it was totally overlooked by Council.
18	
19	
20	
21	Just only prepare when the flood coming, ready to prepare
22	Levee bank is desperately needed for North Darlington Point. A proposal for this was given to Council in 1974 but it was totally overlooked by Council.
23	Reconsider impact of proposed new boat ramp regarding effects on river flooding, erosion and possibility of undermining of current levee banks and structures.

24	
25	
26	
27	Constant land forming around the town such as on farms has shifted natural water courses, putting pressure on flood levels in the river through tow. In the last flood (2016) less water volume, resulting in higher flood levels. Land production greed will end up in a flooded township. No flood plan just greed for production.
28	
29	
30	
31	Flooding affects rural properties as well. Some properties have been greatly affected due to structures being built which affect the natural flow of the water causing hundreds of thousands of dollars of damage. The Darlington Point bridge choke, the Sturt Highway and the Kerarbury Channel all impact the natural flow of water.
32	

APPENDIX C

MODEL UPDATE

C1 Darlington Point Flood Study Model Update

1.1 Overview

Flood behaviour within Darlington Point and its surrounds was defined through a combination of hydrologic and hydraulic models developed for the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (WBM BMT, 2018). Specifically, the models developed for the flood study included:

- An XP-RAFTS model to simulate the rate of local storm runoff behind the levee. The output from the hydrologic model was used to define local inflows behind the levee within the TUFLOW model of Darlington Point township.
- A broad-scale TUFLOW HPC model to provide a two-dimensional (2D) representation of the Murrumbidgee River channel and floodplain that extends approximately 600 metres upstream and almost 5 km downstream of the study area, covering a total area of around 200 km^2. This model is referred to hereafter as the "Murrumbidgee River TUFLOW Model".
- A more detailed TUFLOW HPC model of the Darlington Point township to simulate local catchment runoff behind the levee. This model is a linked 1D/2D model and covers an area of around 2.1 km^2. This model is referred to hereafter as the "Darlington Point Local TUFLOW Model".

Updates were undertaken on both the XP-RAFTS local Darlington Point model, and the broad-scale TUFLOW HPC and the more detailed local Darlington Point TUFLOW HPC models to better represent the existing conditions in the study area. Details of these updates are provided below.

1.2 Local Darlington Point XP-RAFTS Model Update

1.2.1 Subcatchment Delineation and Parameterisation

The XP-RAFTS model was updated to with the local sub catchment delineation across the Darlington Point area behind the levee, as shown in **Plate C. 1** below.

Subcatchment boundaries and characteristics were defined using the CatchmentSIM program. CatchmentSIM is a proprietary software developed by Catchment Simulation Solutions, and facilities the expedition of the XP-RAFTS model development by performing the following tasks:

- Developing a Digital Elevation Model (DEM);
- Automatically delineating catchment boundaries and flow path alignments;
- Automatically subdividing the overall catchment into smaller subcatchments;
- Calculating a range of hydrologic attributes for each subcatchment including area, average vectored slope, pervious 'n' and percentage impervious;
- Calculating weighted average impervious percentages for each subcatchment; and
- Automatically developing an XP-RAFTS input file incorporating all required hydrologic inputs.

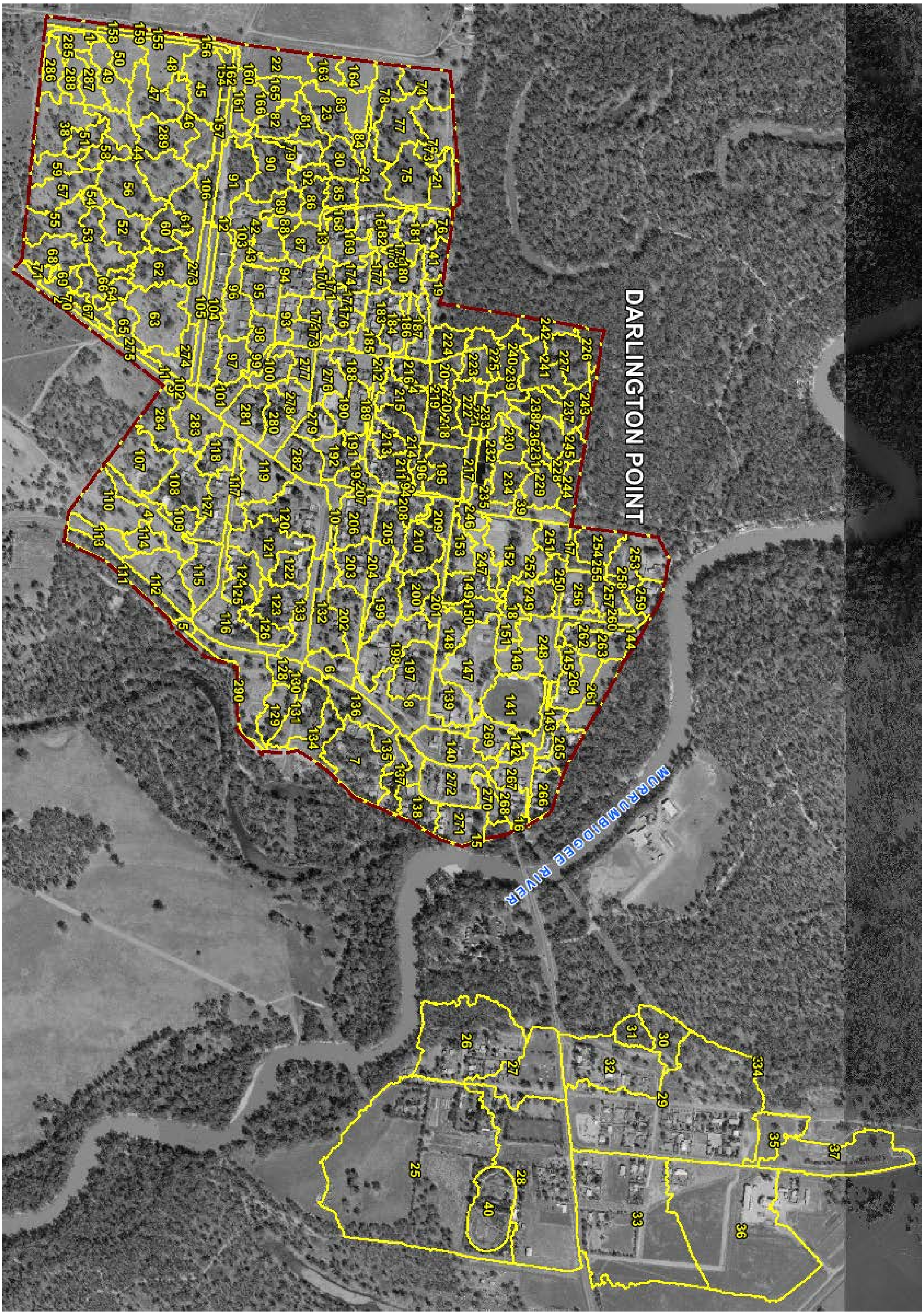


Plate C. 1 - Updated XP-RAFTS Model sub-catchment delineation for the Darlington Point Local TUFLOW Model

Table C. 1 - RAFTS inputs for updated hydrological RAFTS model

Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value	Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value
1	0.21	0.12	0.00	0.040	**146**	0.75	0.87	3.37	0.117
2	0.52	0.16	69.31	0.036	**147**	2.06	0.41	51.23	0.066
3	0.11	1.78	100.00	0.030	**148**	0.83	0.56	40.16	0.082
4	1.12	0.00	64.51	0.061	**149**	0.89	0.47	23.29	0.096
5	0.13	0.00	100.00	0.030	**150**	0.58	0.43	27.00	0.092
6	0.72	0.00	100.00	0.024	**151**	0.40	0.70	8.46	0.111
7	2.24	0.00	14.09	0.106	**152**	1.71	0.20	0.00	0.120
8	1.60	0.78	79.37	0.041	**153**	0.75	0.00	12.94	0.108
9	0.11	0.29	48.90	0.076	**154**	0.32	1.15	0.00	0.052
10	0.49	1.39	94.99	0.034	**155**	0.17	0.00	0.00	0.040
11	0.04	4.75	19.54	0.038	**156**	0.13	0.00	0.00	0.040
12	0.14	0.00	24.89	0.091	**157**	0.29	0.65	0.00	0.068
13	0.27	1.41	49.74	0.075	**158**	0.11	0.00	0.00	0.040
14	0.10	0.00	49.18	0.071	**159**	0.70	0.67	0.23	0.040
15	0.38	0.71	42.11	0.081	**160**	0.09	0.00	0.00	0.040
16	0.11	0.44	100.00	0.021	**161**	0.49	0.34	13.40	0.045
17	0.34	0.73	13.18	0.108	**162**	0.43	0.06	24.77	0.072
18	0.18	0.83	0.00	0.120	**163**	0.43	0.01	0.00	0.040
19	1.48	0.81	19.11	0.097	**164**	0.62	0.12	0.00	0.040
20	0.43	1.57	0.00	0.120	**165**	0.53	0.07	0.00	0.040
21	0.72	1.07	0.00	0.042	**166**	0.66	0.38	0.00	0.040
22	1.32	1.14	2.14	0.040	**167**	0.66	0.32	100.00	0.025
23	1.01	0.27	1.88	0.080	**168**	0.32	0.41	100.00	0.026
24	1.06	0.26	4.87	0.054	**169**	0.88	0.00	100.00	0.023
25	14.84	0.47	19.47	0.102	**170**	0.32	0.28	80.74	0.043
26	4.65	0.61	30.12	0.092	**171**	0.13	0.41	100.00	0.027
27	2.45	1.13	51.69	0.073	**172**	0.63	0.40	87.85	0.033
28	7.47	0.03	47.63	0.074	**173**	0.78	0.00	98.79	0.020
29	10.65	0.51	59.24	0.064	**174**	0.60	0.38	100.00	0.021
30	1.09	0.96	1.81	0.118	**175**	0.36	0.00	100.00	0.018
31	0.58	0.99	0.00	0.120	**176**	0.53	0.31	100.00	0.017
32	3.07	0.46	13.46	0.106	**177**	0.31	0.25	100.00	0.026
33	8.34	0.11	83.79	0.042	**178**	0.21	0.00	100.00	0.029
34	0.01	3.04	0.00	0.120	**179**	0.29	0.00	100.00	0.030
35	1.06	1.22	2.14	0.118	**180**	0.79	0.41	98.10	0.028
36	8.97	0.13	100.00	0.025	**181**	0.64	0.40	88.16	0.023
37	2.80	0.18	11.04	0.110	**182**	0.39	0.00	100.00	0.023
38	1.61	0.12	0.00	0.047	**183**	0.81	0.00	100.00	0.021
39	0.60	0.84	0.00	0.120	**184**	0.55	0.12	100.00	0.018
40	1.97	0.07	73.01	0.054	**185**	0.46	0.00	100.00	0.022
41	0.48	1.75	61.18	0.025	**186**	0.41	0.56	100.00	0.027
42	1.41	0.38	20.33	0.099	**187**	0.59	1.79	99.66	0.017

Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value	Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value
43	0.09	1.47	30.26	0.091	**188**	0.74	0.00	89.34	0.037
44	1.93	0.00	0.00	0.048	**189**	0.12	0.00	100.00	0.024
45	1.45	0.09	0.00	0.045	**190**	1.01	0.90	57.18	0.062
46	1.15	0.00	0.00	0.045	**191**	0.23	0.00	69.79	0.050
47	1.18	0.07	0.00	0.045	**192**	0.81	0.27	13.47	0.106
48	1.19	0.10	0.00	0.041	**193**	0.55	0.81	81.55	0.040
49	0.94	0.00	0.00	0.040	**194**	0.14	1.01	41.32	0.079
50	0.83	0.00	0.00	0.040	**195**	1.10	0.27	2.14	0.118
51	0.56	0.17	0.00	0.050	**196**	0.41	0.00	0.00	0.120
52	1.07	0.14	0.00	0.050	**197**	1.29	0.43	52.99	0.066
53	1.13	0.00	0.00	0.050	**198**	1.83	0.38	82.37	0.038
54	0.23	0.00	0.00	0.050	**199**	1.02	0.00	99.46	0.019
55	1.22	0.02	0.00	0.050	**200**	0.84	1.03	26.61	0.094
56	1.63	0.00	0.00	0.050	**201**	0.55	0.46	36.07	0.085
57	1.18	0.05	0.00	0.050	**202**	1.03	0.59	100.00	0.019
58	0.57	0.08	0.00	0.050	**203**	0.89	0.70	100.00	0.019
59	0.72	0.04	0.00	0.050	**204**	0.78	0.33	80.91	0.043
60	0.86	0.16	0.00	0.050	**205**	0.86	0.41	47.32	0.074
61	1.13	0.09	0.00	0.046	**206**	1.11	0.84	100.00	0.025
62	1.26	0.00	0.00	0.048	**207**	0.15	1.86	100.00	0.029
63	2.10	0.09	0.00	0.047	**208**	0.60	0.72	73.82	0.053
64	0.40	0.00	0.00	0.050	**209**	0.62	1.15	56.68	0.068
65	0.60	0.12	0.00	0.047	**210**	1.10	1.14	80.02	0.044
66	0.67	0.11	0.00	0.050	**211**	0.89	0.71	38.05	0.083
67	0.35	0.19	0.00	0.050	**212**	0.51	1.12	88.92	0.037
68	1.13	0.07	0.00	0.050	**213**	0.43	0.74	30.83	0.089
69	0.26	0.00	0.00	0.050	**214**	0.79	0.41	13.19	0.107
70	0.40	0.21	18.80	0.046	**215**	0.95	0.74	41.35	0.079
71	0.18	0.35	0.00	0.050	**216**	0.56	1.46	58.42	0.066
72	1.12	1.05	0.00	0.060	**217**	0.46	0.00	97.41	0.018
73	0.28	0.13	0.00	0.040	**218**	0.72	1.21	0.28	0.120
74	1.01	0.00	0.00	0.040	**219**	0.23	2.14	0.00	0.120
75	1.37	0.23	0.00	0.040	**220**	0.42	1.01	0.00	0.120
76	0.50	1.77	24.19	0.039	**221**	0.30	0.00	100.00	0.015
77	1.49	0.19	0.00	0.040	**222**	0.65	0.00	9.23	0.105
78	0.85	0.14	0.00	0.040	**223**	0.56	0.00	0.00	0.094
79	0.52	0.00	10.75	0.073	**224**	0.69	0.41	1.51	0.118
80	0.75	0.15	0.00	0.120	**225**	0.53	0.10	0.00	0.100
81	0.65	0.10	0.71	0.096	**226**	0.42	0.37	0.00	0.120
82	0.76	0.27	0.00	0.076	**227**	1.09	3.38	0.00	0.120
83	0.84	0.13	0.00	0.040	**228**	0.16	0.00	0.00	0.120
84	0.32	0.14	0.00	0.098	**229**	0.81	0.22	0.00	0.120
85	0.54	0.19	0.00	0.120	**230**	0.55	0.00	0.00	0.055

Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value	Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value
86	0.63	1.26	0.00	0.120	**231**	0.34	1.10	0.00	0.118
87	0.79	0.74	10.84	0.109	**232**	0.77	0.36	46.78	0.062
88	0.29	0.80	0.00	0.120	**233**	0.48	0.39	13.42	0.097
89	0.39	1.17	0.00	0.120	**234**	0.78	0.41	0.00	0.070
90	1.44	0.36	2.31	0.108	**235**	0.54	0.00	17.94	0.101
91	1.39	0.71	13.73	0.104	**236**	0.96	1.00	0.00	0.087
92	0.41	0.22	0.00	0.115	**237**	0.74	0.10	0.00	0.100
93	0.56	0.25	95.36	0.026	**238**	0.65	0.00	0.00	0.094
94	0.95	0.23	64.68	0.054	**239**	0.64	0.15	1.24	0.058
95	1.04	0.29	100.00	0.026	**240**	0.52	0.20	0.00	0.092
96	1.25	0.30	91.80	0.029	**241**	1.05	0.13	0.00	0.105
97	0.76	0.21	100.00	0.021	**242**	0.54	0.13	0.00	0.120
98	0.63	0.00	100.00	0.019	**243**	0.28	0.25	0.00	0.119
99	0.26	0.31	100.00	0.027	**244**	0.52	0.52	0.00	0.120
100	0.54	0.04	100.00	0.022	**245**	0.37	0.73	0.00	0.120
101	0.73	0.28	100.00	0.023	**246**	0.37	0.27	14.87	0.104
102	0.18	0.64	28.53	0.037	**247**	0.65	0.20	3.53	0.116
103	0.15	0.00	39.41	0.079	**248**	1.23	0.19	21.40	0.100
104	1.64	0.15	88.96	0.034	**249**	0.92	0.37	0.00	0.120
105	0.70	0.09	17.39	0.038	**250**	0.49	0.00	15.05	0.107
106	0.58	0.69	0.00	0.083	**251**	0.63	0.00	5.08	0.115
107	1.71	0.00	8.76	0.103	**252**	0.39	0.20	0.00	0.120
108	1.57	0.00	64.64	0.056	**253**	1.36	0.27	14.95	0.105
109	0.43	0.00	59.02	0.059	**254**	0.85	0.03	0.00	0.120
110	1.65	0.17	0.50	0.107	**255**	0.10	1.73	12.53	0.109
111	1.16	0.24	62.10	0.064	**256**	0.91	0.47	73.55	0.051
112	1.44	0.35	59.32	0.062	**257**	0.64	0.56	10.75	0.109
113	0.67	0.00	9.42	0.102	**258**	0.29	0.95	58.28	0.064
114	0.55	0.67	14.20	0.107	**259**	0.66	0.14	72.86	0.048
115	1.22	0.06	99.74	0.023	**260**	0.40	0.35	63.19	0.058
116	1.92	0.39	76.15	0.047	**261**	0.98	0.23	54.67	0.064
117	0.60	0.00	100.00	0.027	**262**	0.46	0.25	74.66	0.045
118	0.86	0.00	100.00	0.022	**263**	0.60	0.40	82.96	0.037
119	1.47	0.21	100.00	0.030	**264**	0.92	0.22	56.17	0.062
120	2.22	0.20	95.59	0.031	**265**	0.82	1.06	67.31	0.051
121	1.54	0.34	38.90	0.082	**266**	0.79	0.60	76.82	0.041
122	0.79	0.30	62.26	0.055	**267**	0.81	0.00	100.00	0.026
123	1.09	0.12	25.83	0.093	**268**	0.60	0.85	99.88	0.021
124	0.67	0.10	63.51	0.057	**269**	0.85	0.00	70.33	0.051
125	0.43	1.02	81.76	0.038	**270**	0.54	0.69	91.69	0.035
126	0.62	0.45	9.61	0.110	**271**	1.09	0.46	99.62	0.026
127	1.07	0.03	99.02	0.019	**272**	1.43	0.29	100.00	0.025
128	0.38	0.00	100.00	0.030	**273**	0.77	0.60	0.00	0.040

Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value	Subcatchment ID	Area (ha)	Subcatchment Slope (%)	Impervious Proportion (%)	Mannings "n" Value
129	0.88	1.07	100.00	0.030	**274**	0.81	0.00	0.00	0.040
130	0.40	0.88	77.83	0.050	**275**	0.33	0.38	19.48	0.040
131	1.23	0.38	44.61	0.079	**276**	0.91	0.38	74.47	0.047
132	1.40	0.49	100.00	0.027	**277**	0.67	0.05	100.00	0.023
133	1.07	0.61	90.46	0.032	**278**	0.61	0.00	99.74	0.018
134	0.85	0.96	27.44	0.093	**279**	0.62	0.00	32.74	0.087
135	0.62	0.53	72.14	0.054	**280**	0.94	0.69	59.48	0.060
136	1.09	0.64	58.55	0.067	**281**	1.16	0.36	73.53	0.049
137	0.90	0.27	26.99	0.096	**282**	0.98	0.54	61.87	0.059
138	0.85	0.49	45.35	0.075	**283**	1.14	0.28	87.37	0.039
139	1.03	0.31	86.55	0.034	**284**	1.13	0.14	21.87	0.098
140	1.37	0.58	99.76	0.027	**285**	0.45	0.08	0.00	0.040
141	1.83	0.26	17.82	0.101	**286**	0.70	0.27	0.00	0.042
142	0.65	0.16	67.74	0.057	**287**	0.61	0.16	0.00	0.040
143	0.53	0.36	92.98	0.032	**288**	0.52	0.22	0.00	0.040
144	0.65	0.00	98.23	0.030	**289**	1.12	0.18	0.00	0.047
145	0.33	0.00	18.59	0.101	**290**	1.96	0.35	100.00	0.030

Table C. 2 - RAFTS link details for updated hydrological RAFTS model

US Node	DS Node	Link Lag (minutes)	US Node	DS Node	Link Lag (minutes)
DP-1	node3	0.0	DP-157	DP-154	10.2
DP-2	node3	0.0	DP-158	DP-159	10.9
DP-3	node4	0.0	DP-159	node3	0.0
DP-4	DP-114	11.3	DP-160	DP-22	6.1
DP-5	node1	0.0	DP-161	DP-22	6.1
DP-6	DP-136	19.7	DP-162	DP-161	6.6
DP-7	node1	0.0	DP-163	DP-22	22.1
DP-8	DP-135	6.7	DP-164	DP-163	8.0
DP-9	DP-208	7.7	DP-165	DP-160	4.5
DP-10	DP-207	5.8	DP-166	DP-160	4.5
DP-11	DP-3	0.0	DP-167	DP-168	7.7
DP-12	DP-273	23.0	DP-168	DP-13	3.8
DP-13	DP-87	7.0	DP-169	DP-13	3.8
DP-14	DP-219	3.2	DP-170	DP-13	10.5
DP-15	node1	0.0	DP-171	DP-170	8.4
DP-16	node1	0.0	DP-172	DP-170	8.4
DP-17	node2	0.0	DP-173	DP-172	6.7
DP-18	DP-248	5.7	DP-174	DP-171	6.9
DP-19	node2	0.0	DP-175	DP-171	6.9
DP-20	DP-224	6.0	DP-176	DP-175	6.8
DP-21	node2	0.0	DP-177	DP-169	16.3
DP-22	node3	0.0	DP-178	DP-169	16.3

US Node	DS Node	Link Lag (minutes)	US Node	DS Node	Link Lag (minutes)
DP-23	DP-165	8.0	DP-179	DP-178	8.4
DP-24	DP-168	18.0	DP-180	DP-178	8.4
DP-38	node3	0.0	DP-181	DP-179	6.1
DP-39	node2	0.0	DP-182	DP-181	3.4
DP-41	node2	0.0	DP-183	DP-185	11.5
DP-42	DP-103	4.1	DP-184	DP-186	2.9
DP-43	DP-103	4.1	DP-185	DP-186	2.9
DP-44	DP-49	23.5	DP-186	DP-187	4.4
DP-45	DP-48	13.4	DP-187	DP-224	13.4
DP-46	DP-48	13.4	DP-188	DP-189	9.4
DP-47	DP-50	13.7	DP-189	DP-191	5.7
DP-48	DP-50	13.7	DP-190	DP-191	5.7
DP-49	DP-1	14.0	DP-191	DP-193	10.1
DP-50	DP-1	14.0	DP-192	DP-193	10.1
DP-51	DP-38	0.5	DP-193	DP-194	4.3
DP-52	DP-54	7.0	DP-194	DP-9	1.2
DP-53	DP-54	7.0	DP-195	DP-196	10.3
DP-54	DP-57	8.7	DP-196	DP-9	2.0
DP-55	DP-57	8.7	DP-197	DP-198	4.1
DP-56	DP-58	5.8	DP-198	DP-201	14.2
DP-57	DP-58	5.8	DP-199	DP-200	14.1
DP-58	DP-51	7.2	DP-200	DP-210	5.0
DP-59	DP-51	7.2	DP-201	DP-210	5.0
DP-60	DP-52	13.4	DP-202	DP-203	12.2
DP-61	DP-60	10.6	DP-203	DP-206	8.5
DP-62	DP-64	7.8	DP-204	DP-205	10.4
DP-63	DP-64	7.8	DP-205	DP-208	13.5
DP-64	DP-66	9.6	DP-206	DP-208	13.5
DP-65	DP-67	14.4	DP-207	DP-208	12.6
DP-66	DP-69	7.6	DP-208	DP-210	6.8
DP-67	DP-70	8.2	DP-209	DP-210	6.8
DP-68	DP-71	6.4	DP-210	DP-217	0.0
DP-69	DP-71	6.4	DP-211	DP-213	4.3
DP-70	DP-2	5.9	DP-212	DP-213	0.3
DP-71	DP-2	5.9	DP-213	DP-214	5.3
DP-72	DP-21	15.4	DP-214	DP-215	7.1
DP-73	DP-21	15.4	DP-215	DP-14	0.8
DP-74	DP-72	9.5	DP-216	DP-14	0.8
DP-75	DP-73	9.6	DP-217	DP-218	15.5
DP-76	DP-21	0.7	DP-218	DP-219	4.4
DP-77	DP-24	14.9	DP-219	DP-20	4.8
DP-78	DP-24	14.9	DP-220	DP-20	1.8
DP-79	DP-81	12.0	DP-221	DP-222	11.8
DP-80	DP-23	7.1	DP-222	DP-223	8.5

US Node	DS Node	Link Lag (minutes)	US Node	DS Node	Link Lag (minutes)
DP-81	DP-23	7.1	DP-223	DP-225	6.9
DP-82	DP-81	10.7	DP-224	DP-19	7.9
DP-83	DP-23	11.4	DP-225	DP-19	7.9
DP-84	DP-23	11.4	DP-226	DP-242	15.3
DP-85	DP-86	10.2	DP-227	DP-242	11.6
DP-86	DP-88	6.6	DP-228	DP-231	7.2
DP-87	DP-88	6.6	DP-229	DP-231	7.2
DP-88	DP-42	7.1	DP-230	DP-236	6.7
DP-89	DP-42	7.1	DP-231	DP-236	6.7
DP-90	DP-42	20.8	DP-232	DP-230	9.5
DP-91	DP-42	20.8	DP-233	DP-239	13.8
DP-92	DP-90	17.4	DP-234	DP-230	9.5
DP-93	DP-94	13.8	DP-235	DP-234	12.7
DP-94	DP-43	5.0	DP-236	DP-238	7.8
DP-95	DP-43	4.8	DP-237	DP-241	15.1
DP-96	DP-43	4.8	DP-238	DP-241	15.1
DP-97	DP-96	20.7	DP-239	DP-240	5.6
DP-98	DP-95	14.0	DP-240	DP-242	11.3
DP-99	DP-101	16.7	DP-241	DP-242	11.3
DP-100	DP-101	17.2	DP-242	DP-19	14.0
DP-101	DP-104	34.5	DP-243	DP-226	13.5
DP-102	DP-105	33.7	DP-244	DP-228	4.5
DP-103	DP-12	5.9	DP-245	DP-228	4.5
DP-104	DP-12	6.1	DP-246	DP-153	12.3
DP-105	DP-12	0.9	DP-247	DP-153	12.3
DP-106	DP-273	22.1	DP-248	DP-250	12.6
DP-107	DP-284	12.5	DP-249	DP-248	2.6
DP-108	DP-4	9.5	DP-250	DP-17	7.9
DP-109	DP-4	7.1	DP-251	DP-250	4.3
DP-110	DP-4	6.7	DP-252	DP-250	4.3
DP-111	DP-5	1.5	DP-253	DP-254	10.6
DP-112	DP-5	2.1	DP-254	DP-17	14.8
DP-113	DP-112	19.8	DP-255	DP-17	14.8
DP-114	DP-112	19.8	DP-256	DP-255	4.3
DP-115	DP-112	2.0	DP-257	DP-255	4.3
DP-116	DP-112	2.0	DP-258	DP-255	4.3
DP-117	DP-119	14.9	DP-259	DP-258	7.7
DP-118	DP-127	16.1	DP-260	DP-256	14.2
DP-119	DP-120	18.9	DP-261	DP-263	6.3
DP-120	DP-121	16.3	DP-262	DP-145	4.6
DP-121	DP-123	7.5	DP-263	DP-145	4.6
DP-122	DP-123	7.5	DP-264	DP-145	8.5
DP-123	DP-125	3.3	DP-265	DP-266	15.0
DP-124	DP-125	3.3	DP-266	DP-16	2.3

US Node	DS Node	Link Lag (minutes)	US Node	DS Node	Link Lag (minutes)
DP-125	DP-116	17.2	DP-267	DP-16	2.3
DP-126	DP-116	17.2	DP-268	DP-16	2.7
DP-127	DP-115	17.3	DP-269	DP-142	19.4
DP-128	DP-130	6.9	DP-270	DP-15	3.5
DP-129	DP-130	7.0	DP-271	DP-15	3.5
DP-130	DP-136	19.0	DP-272	DP-138	1.0
DP-131	DP-136	19.1	DP-273	DP-274	15.0
DP-132	DP-6	6.7	DP-274	DP-11	1.5
DP-133	DP-6	6.7	DP-275	DP-11	1.5
DP-134	DP-7	1.4	DP-276	DP-278	9.7
DP-135	DP-7	10.5	DP-277	DP-278	9.7
DP-136	DP-135	5.1	DP-278	DP-280	7.1
DP-137	DP-135	6.0	DP-279	DP-280	7.1
DP-138	DP-137	12.1	DP-280	DP-282	10.9
DP-139	DP-8	8.9	DP-281	DP-280	4.3
DP-140	DP-8	3.3	DP-282	DP-10	7.1
DP-141	DP-248	13.7	DP-283	DP-3	4.7
DP-142	DP-248	13.7	DP-284	DP-3	1.8
DP-143	DP-248	14.3	DP-285	node3	0.0
DP-144	DP-248	11.7	DP-286	node3	0.0
DP-145	DP-248	11.7	DP-287	DP-285	8.7
DP-146	DP-151	7.3	DP-288	DP-285	8.7
DP-147	DP-151	7.3	DP-289	DP-47	19.7
DP-148	DP-150	12.4	DP-290	DP-128	8.9
DP-149	DP-150	12.4	node1	node5	0.0
DP-150	DP-18	6.4	node2	node6	0.0
DP-151	DP-18	6.4	node3	node6	0.0
DP-152	DP-246	6.9	node4	node5	0.0
DP-153	DP-149	6.3	node5	node7	0.0
DP-154	DP-156	9.2	node6	node7	#N/A
DP-155	DP-158	7.8	node7	OUTLET	#N/A
DP-156	DP-155	11.7			

1.2.2 RAFTS Subcatchment Parameters

In addition to the parameters listed in **Table C. 1** and **Table C. 2,** above, the following parameters were determined for the update of the RAFTS model:

- Pervious Continual Loss = 0mm/hr
- Impervious Initial Loss = 1mm
- Impervious Continual Loss = 0mm/hr
- Routing Factor (Bx) = 1

1.2.3 Design Rainfall Information

The *'Review of ARR Design Inputs for NSW'* (2019) was completed to review and advise on addressing under-estimation bias being experienced when using standard Australian Rainfall and Runoff (ARR) 2016 design event methods with default data from the ARR data hub. The significant bias presented in this study using the standard ARR 2016 design event method with default ARR data hub losses and pre-burst information necessitated an update of these parameters.

Australian Rainfall and Runoff 2019 provides improved information on initial and continuing losses and pre-burst information to use and replaces the default initial and continuing loss or pre-burst information or approaches developed as part of ARR 2016 and applied as part of the *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (2018). Therefore, design losses (pervious initial losses) were updated as per **Table C. 3**

Table C. 3 - Updated design burst losses

Design Storm	Design Burst Loss (mm)					
	2018 Flood Study Storm Duration			2020 Flood Study Storm Duration		
	9 hour	12 hour	24 hour	9 hour	12 hour	24 hour
20% AEP	26.2	26.5	27	16.2	17.7	20.6
10% AEP	25.9	26.2	27	15.2	16.6	19.2
5% AEP	25.5	25.9	27	15.2	16.3	18.8
2% AEP	25.4	25.4	26.8	13.3	14.2	16.7
1% AEP	25.4	25.1	26.6	9	9.5	12.2
0.5% AEP				9	9.5	12.2
0.2% AEP				9	9.5	12.2

1.2.4 Temporal Patterns and Design Simulations for local model

As part of the update to the local Darlington Point subcatchment information, the critical temporal patterns were reviewed and the selection from the 2018 Flood Study maintained. **Table C. 4** details the critical temporal patterns adopted in the 2018 and 2020 flood studies.

Table C. 4 - Adopted Temporal Pattern and Critical Durations for the 2018 and 2020 flood study

Event	2018 and 2020 Flood Study	
	Temporal Pattern ID	Critical Duration
20% AEP	4154	24 hours
10% AEP	4087	12 hours
5% AEP	4087	12 hours
2% AEP	4058	9 hours
1% AEP	4058	9 hours
0.5% AEP	4058	9 hours
0.2% AEP	4058	9 hours

For simulation of local flood conditions behind the levee, a coincident 10% AEP Murrumbidgee River flood event was assumed.

1.3 Local Darlington Point TUFLOW Model Review

The updated local TUFLOW model was used to simulate a range of design events including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP and 0.2% AEP design flood events.

Calibration or validation of the local township TUFLOW model was not completed during the flood study due to a lack of calibration data. No calibration or validation of the local township TUFLOW model was undertaken during the model update process.

1.3.1 Grid Size

The model grid size was updated to 2m from 4m.

1.3.2 Details of hydraulic structures in local TUFLOW model

Stormwater pits were updated to "Q" type nodes in the TUFLOW model.

1D/2D connections at 1D culverts were updated so that the SX point was directly applied at the end of structures.

Invert levels of all hydraulic structures were reviewed to ensure there was a descending grade line from the top of the catchment to the outlets.

1.4 Murrumbidgee River TUFLOW Model Review

1.4.1 Ground level information

The 2018 TUFLOW HPC model developed a two-dimensional (2D) representation of the channel and floodplain of the Murrumbidgee River floodplain at Darlington Point, covering an area of 204 km^2 using a 10 metre grid size. The floodplain topography was defined using a 5m x 5m gridded digital elevation model (DEM) derived from aerial survey data.

As part of the model update process, the ground level information was supplemented with photogrammetry derived DEM from "Elvis", commonly referred to as the 5 metre resolution ADS DEM at the outer extents of the flood model.

The model was updated to extend approximately 10 kilometres laterally, so as to include a more detailed representation of the flooding hazards beyond the Sturt Highway to the south and further north along the Kidman Way in the north. The approximate area covered by this updated model is 342 km^2.

1.4.2 Levee upgrade works

The Work-As-Executed information of all levee upgrade works were also included in this model update. This included updating the crest levels as a result of the works undertaken as part of Stages 3, 5 and 6 of the levee upgrade works.

The implementation of the levee crest for the events larger than the design protection level require an assessment without factoring in freeboard. It was found with the model adopted from the 2018 flood study that the method implemented for the freeboard removal from the levee crest was inadvertently lowering terrain within the levee. Subsequently, the levee crest without freeboard was implemented directly as part of the model update.

1.4.3 Hydraulic structures

A number of additional structures were included in the update of the TUFLOW model. These have been included in **Table C. 5** and their locations noted on **Plate C. 2** below.

Table C. 5 - Additional or updated hydraulic structures

Structure ID	Upstream Invert Level	Downstream Invert Level	Diameter	Number of Culverts
KidSthSturt	124.98	124.84	0.9	1
KidNthSturt	124.8	124.7	0.9	1
BrittsRdE	124.95	124.78	0.6	1
BrittsRdC	124.6	124.56	0.9	1
BrittsRdW	123.34	122.77	0.6	1
Whitton	124.75	124.45	1.2	1
KidmanN1	125.18	125.16	1.2	2
KidmanN2	124.87	124.86	1.2	2
KidmanN3	125.08	124.98	1.2	2
Darlington	125.26	124.52	0.9	1
Tubbo	125.6	125.39	0.75	1
Uri	125.24	125	1.2	1

Plate C. 2 - Culvert updates included in the TUFLOW model as part of the updates in the 2020 Flood Study

1.4.4 Hydrologic Inputs

The hydrological inputs of the Murrumbidgee River 2018 TUFLOW model were not modified as part of this model update as the flood frequency analysis had been undertaken relatively recently and the design flows would not vary significantly from what had been previously applied.

APPENDIX D

FREEBOARD ANALYSIS

D1 Freeboard Analysis - Darlington Point Levee

1.1 Overview

The *'Murrumbidgee River at Darlington Point and Environs Flood Study'* (WBM BMT, 2018) undertook a preliminary assessment of the existing freeboard as part of the preliminary levee spillway design. This detailed freeboard analysis has been undertaken in accordance with the methodology undertaken by NSW Governments Public Works Advisory as part of the assessment of the Wagga Wagga Levee Upgrade in 2010 (NSW Public Works 2010).

1.2 Darlington Point levee information

Darlington Point levee has been progressively upgrade over the past 5 years. A brief synopsis of the levee upgrade is provided to give an understanding to the existing crest level design, which is used as the basis for this freeboard assessment.

The geotechnical investigations undertaken in 2009 (Worley Parsons, 2009) included modelling to determine a range of design flood levels for the Murrumbidgee River at Darlington Point. This assessment included the crest levels along the existing levee alignment and assumed the levee would remain intact during flooding. The report included two options for levee rehabilitation – one with a levee crest level equivalent to the 1% AEP design flood level plus one (1) metre freeboard and one with a levee crest level equivalent to the 1% AEP design flood level plus a varying freeboard between 0.75 and 1.0 metres.

The preliminary designs for the levee (SMEC, 2010) proposed levee upgrade works in accordance with the recommendations made in the 2009 geotechnical report (Worley Parsons, 2009). The levee design report (SMEC, 2010) states that the formation of the proposed upgrade to the levee crest was taken as 1 metre above the design flood level listed in the geotechnical report (Worley Parsons, 2009). A layer of DGB20 was proposed above this formation level to cater for inspection vehicles.

Modelling for design flood events in the Murrumbidgee River was undertaken in 2018 flood study (BMT, 2018) with the design levee crest in place for all proposed upgrade works. This study used a combination of Work-As-Executed plans for completed works and design drawings for upgrade works that were yet to be complete.

Late 2019 the final construction works for the Darlington Point levee upgrade were complete. A Work as Executed Survey was undertaken that detailed the final crest levels and alignment of these levee upgrade works (Murray Constructions Pty. Ltd., 2019).

This floodplain risk management study includes a review and update of the 2018 flood study (BMT, 2018) design flood levels. This includes an update of the hydrological inputs that were used to determine the design flood levels, in addition to inclusion of all Work as Executed Survey data on all levee upgrade works that have been completed.

1.3 Previous freeboard assessment

The 2018 flood study (BMT, 2018) states that the flood modelling results in that study indicate that the Darlington Point levee may have a freeboard level approximately 0.85 metres above the 1% AEP design flood level along the eastern side (sic). For events greater than the 1% AEP design flood, the levee provides approximately 0.75 metres freeboard during a 0.5% AEP design flood level and 0.65 metres above the 0.2% AEP design flood level.

The report does not detail how this information was derived. It is assumed that design flood levels were compared to the levee crest level at various locations around the levee to determine the existing freeboard.

1.4 Freeboard assessment components

A flood freeboard is calculated from several specific components. Each of these components can be assessed with a certain level of accuracy, or past performance of the levee. Each of these components is detailed below.

1.4.1 Wave action

Waves can be generated under windy conditions across any water surface. If a levee or structure is exposed to large expanse of water, waves that are generated have the potential to overtop a levee. Wind and associated wave impacts are estimated based on the *Australian / New Zealand Standard Wind Loading – AS/NZ1170.2 (2002)*.

1.4.1.1 Fetch

Fetch refers to the length of water over which a given wind has travelled to its point of impact. The fetch influences the extent of exposure of wind to a wave will have, so the longer the fetch, the greater the wave height. As the Murrumbidgee River has an irregularly shaped shoreline, an effective fetch is calculated by determining an average horizontal distance across the water surface on which wind may travel to generate waves.

To determine the average horizontal distance across the Murrumbidgee River, nine (9) radial lines are drawn from the levee to the northern side of the river embankment. These distances are calculated for a 90 degree arc from the nominated point on the levee.

$$\boldsymbol{F = \frac{\sum x_i cos\ \alpha_i}{\sum cos\ \alpha_i}}$$

Where:

F = Effective Fetch (km)

$\boldsymbol{x_i}$ = length of projection of radial (1) on the central radian

$\boldsymbol{\alpha_i}$ = angle between the central radial from the levee wall and radial (i)

Table D. 1 outlines these parameters for the Murrumbidgee River at Darlington Point.

Table D. 1 - Fetch Calculation parameters

Radian	Angle (α)	Length xi (m)	Cos (α)	Length x Cos (α)
Left	45	58	0.707	41.01
Left	33.75	70	0.831	58.20
Left	22.5	84	0.923	77.60
Left	11.25	82	0.981	80.42
Centre	0	335	1	335
Right	11.25	247	0.981	242.25
Right	22.5	180	0.9239	166.29
Right	33.75	125	0.831	103.93
Right	45	97	0.7071	68.58
SUM			7.886	1173.32
Fetch (m)				**148.776**

1.4.1.2 Design Wind

Wind speed is determined based on the design standard of the levee crest and the strength of wind (low moderate, high). The design level of the Darlington Point levee is the 1% AEP design flood event, so the conservative wind speed of the 1% AEP has been applied based on information contained within AS/NZ1170.2 (2002).

Table D. 2 outlines these parameters for the Murrumbidgee River at Darlington Point.

Table D. 2 - Design Wind Speeds

Wind Event (ARI)	Design Wind Speeds (m/s)
1 (1EY)	17
10 (10% AEP)	22
100 (1% AEP)	**26**

1.4.1.3 Wave Height

Wave heights for a design wind speed are influenced by the wind duration and the fetch distance, as well as river velocity and the current in the waterway. Wave heights progressively increase under constant wind action as they move along the fetch, until a maximum limiting value is reached (Reference 0).

A significant wave is defined as the average wave height of the highest one-third of waves, measured from the trough to the crest of the wave. The height and period of this significant wave are referred to as Hs and Ts respectively.

The significant wave height and significant wave period are calculated as per the following:

$$gH_s/U^2 = 0.0026\ (gF/U^2)^{0.47}$$
$$gT^2/U = 0.46\ (gF/U^2)^{0.28}$$

Where:
H_s = significant wave height (feet)
T = significant wave period T_s (seconds)
F = Wave fetch (miles)
g = acceleration due to gravity (79.03 miles/h^2)
U = average integrate wind velocity over water (miles per hour)

NOTE that the units are in US imperial units`

$$L = 1.56T^2$$

Where:
L = wave length (metres)
T = wave period (seconds)

Table D. 3 outlines these parameters for the Murrumbidgee River at Darlington Point to determine the significant wave height and wave length.

Table D. 3 - Significant wave height and wave length parameters

Wind speed U (miles/hour)	Gravity g (miles/hour^2)	Fetch F		Significant wave height Hs		Wave Period T (seconds)	Wave Length L (metres)
		miles	kms	feet	metres		
58.16	79036	0.0924	0.148	0.84	**0.26**	**1.6**	**3.99**

0.5 x wave length = 1.99 metres.

Deep water is assumed once the water depth exceeds 0.5 of the wave length. An average water depth through the main channel of the Murrumbidgee River flowpath has been assumed as approximately 6 metres. Therefore wave length has been determined based on the assumption that the flooding includes water of a depth that would facilitate the development of deep water waves.

Therefore, with the wave type is assumed as **DEEP.**

1.4.1.4 Wind set-up

Wind set up is defined as the changes in water level as a result of the horizontal shear stress from the wind blowing across the surface of the water. Water level increase (pile up) on the leeward end of the wind, and decrease on the windward side. Wind set up is calculated by:

$$S = U^2F/1400D$$

Where:
S = wind set-up or height above still water level (feet)
U = average integrated wind velocity of water (miles/hr)
F = wind fetch (miles)
D = average water depth (5 metres).

Table D. 4 outlines the various wave length parameters for the Murrumbidgee River at Darlington Point.

Table D. 4 - Wave length parameters

Wind speed U (miles/hour)	Effective fetch F (metres)	Average water depth D (metres)	Wind set-up S	
			feet	metres
58.16	0.0924	6	0.011	0.003

It should be noted that the depth for wave run up has been assumed as the depth in the centre of the main waterway. This assumption is considered conservative as the levee does not bound the deeper water, rather the shallower water along the southern overbank areas.

1.4.1.5 Wave Run-up

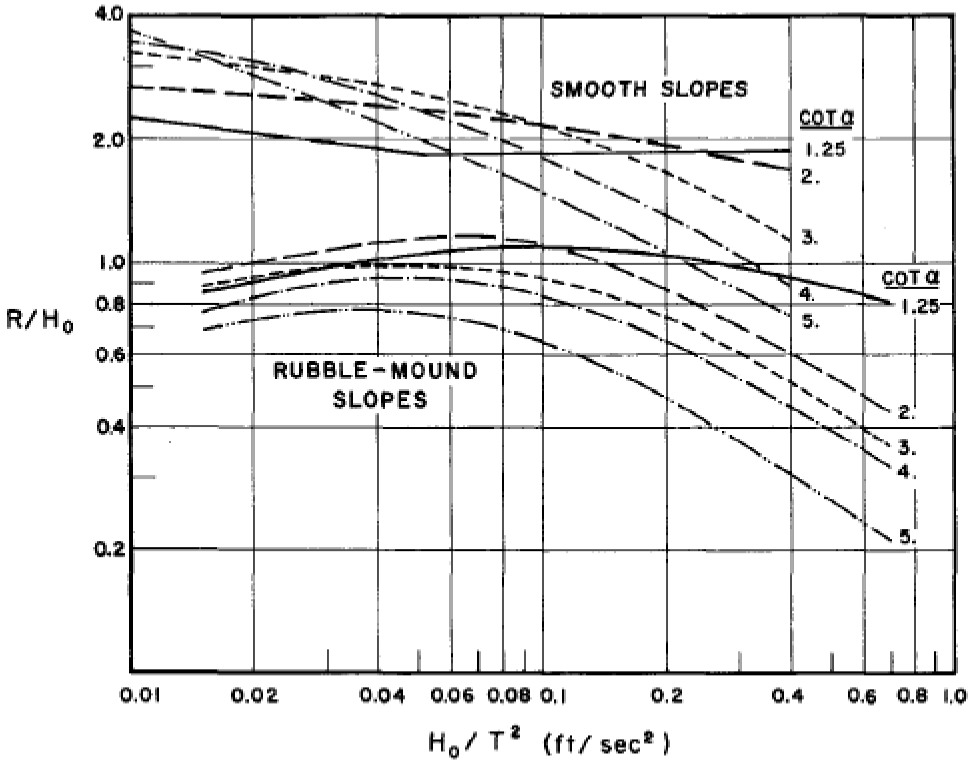
Wave run up is defined as the maximum height reached by a wave on a structure above the still water level. Wave run-up is influenced by the geometric and structural characteristics of the structure, such as slope, surface roughness, permeability and porosity of the slope. Hydraulic parameters also affect the run-up value, including wave steepness, wave height and the angle of the wave attack (Reference 0).

Wave run-up has been calculated by the following equation, as defined in Saville (1956).

$$\mathbf{R_u = H_0 \times (R/ H_0)}$$

Where :
$\mathbf{R_u}$ = wave run-up an embankment (vertical height)
$\mathbf{H_0}$ = wave height
$\mathbf{R/H_0}$ = run-up ratio

Run-up ratio can be determined from the Figure below, taken from Raichlen (1974**).**



The levee around Darlington Point primarily consists of moderately vegetated slopes with a small section of vertical, smooth wall. The allowance for a moderately vegetated slope in this equation is considered more conservative and has therefore been included in lieu of a vertical brick wall. A vertical brick wall would have a run-up ratio that was only 75% of that moderately vegetated sloped embankment.

Table D. 5 outlines the various wave run-up parameters for the Murrumbidgee River at Darlington Point.

Table D. 5 - Wave run-up parameters

Wave Height H (metres)	R/H_0	Wave Run-up R_u
0.26	0.75	**0.193**

1.4.2 Local Water Surge

When water velocities and flow directions change locally, such as at a levee alignment which is oblique to the direction of flow or as a result of local blockages in the channel, local flood water levels can be higher than the general flood level. These changes can be difficult to predict under flood conditions, however flood modelling results can be used to assess likely surge heights (NSW Public Works, 2010).

Local water surge can be calculated by the following equation:

$$\mathbf{h_s = v^2/2g}$$

Where:
h_s = surge height (metres)
v = local velocity (m/s)
g = gravity (m^2/s).

Table D. 6 outlines these parameters for the Murrumbidgee River at Darlington Point to determine the surge height.

Table D. 6 - Local water surge parameters

Local Velocity v (metres/second)	Gravity g m^2/s	Surge Height h_s (metres)
1.4	9.81	**0.1**

1.4.3 Uncertainties in flood levels

Reference 0 states that uncertainties in the determination of flood levels generally consists of being unsure about the value of some of the parameters used during the calculations. These uncertainties can have a localised and/or cumulative impact on the accuracy of the hydrologic and hydraulic modelling, and may include:

- Curve of best fit of the theoretical recurrence interval and discharge fits against recorded flood levels;
- Availability and accuracy of detailed survey and other topographic data;
- Reliability of the historical flood data;
- Accuracy in flood slope along the levee, given the difficulties in determining precise direction of flow in a wide floodplain;
- Estimated parameter used in modelling process that contain a certain level of uncertainty – rainfall pattern and rainfall losses, evaporation loss or surface roughness.

The 2018 flood study included the use of detailed topographic data, such as 2009 LiDAR provided by the NSW Land Registry Services that includes a vertical accuracy of +/-0.30 metres and a horizontal accuracy of +/-0.80 metres *(Finance Services and Innovation, 2015).* In addition, cross sections from the river measured in 2004 and information obtained during the survey of cross sections of the Murrumbidgee River in 2011. A road crest-elevation was undertaken specifically for the flood study which enabled verification of the 2009 LiDAR data, which indicated the LiDAR was fit-for purpose.

Darlington Point has been impacted by a number of significant flood events in the Murrumbidgee River, the most recent in 2010, 2012 and 2016. These events had a number of flood levels recorded throughout the catchment as well as the more localised study area. The calibration process for the 2018 flood study included calibrating the modelled channel bed elevation and roughness to low, in-channel flows before calibrating the floodplain roughness to higher, out-of-bank flows. The flood study found that there was a reasonable match between modelled and observed levels, therefore the level of accuracy of the topographic data used in the flood study is considered high.

The direction of flow along the levee adjacent to the Murrumbidgee River at Darlington Point is considered reasonably accurate, due to the confines and shape of the floodplain at this location. The channel and floodplain areas are fairly narrow, compared to other areas of the floodplain, which leads to a more straightforward assessment of flood slope.

The parameters used in the hydraulic modelling were derived using a flood frequency analysis that used a number of fairly recent flood events and were shown to be a good fit. Therefore the level of uncertainty with these parameters is considered insignificant due to the level of accuracy assumed in the flood frequency analysis.

Overall, the uncertainties related to the estimation of the design flood levels in the Murrumbidgee River at Darlington Point are considered minimal. A value of **0.3 metres** Is considered reasonable to use for this freeboard estimation.

1.4.4 Levee settlement

A post construction settlement allowance needs to be determined based on the characteristics and condition of the levee at Darlington Point. The settlement allowance is based on the:

- embankment design
- age of the embankment
- embankment material types
- construction methods
- post construction maintenance methods

The recent works around Darlington Point were referred to as Areas 5 and 6. The existing levee through these areas included a clay core earth fill embankment that was upgraded. According to the WAE documents and the project manager (pers. Comm.) these works were completed to a high standard with high degrees of compaction. Works were also completed in the past to upgrade other parts of the levee around Darlington Point (Areas 1, 2, 3), which were also completed to a high standard with high degrees of compaction. These levee upgrade works will be followed up by Council with regular asset management procedures for maintenance to ensure the levee remains as per the concept design principles.

The Wagga Wagga Levee Upgrade Report (*NSW Public Works, 2010*) that well-constructed embankments with a high degree of compaction and good construction quality control would be expected to experience post-construction settlement of up to 0.5% of their constructed height. The report further states that levees are usually constructed with a reasonable degree of compaction and a normal post construction settlement of 1% could be expected. The Wagga Wagga Levee Upgrade Report (*NSW Public Works, 2010*) also states that vertical, well-constructed retaining walls are not expected to experience any significant settlement.

Therefore, the settlement expected around the Darlington Point levee is estimated to be minor. A value of **0.02 metres** is considered reasonable to use for this freeboard estimation.

1.4.5 Defects in levee

Defects in a levee could be an outcome of a number of factors, primarily those listed in **Section 1.4.4**, such as the age of the embankment, type of materials used, construction and maintenance, erosion. Embankments can erode, holes and cracks can appear, however regular maintenance can identify these defects and reduce the risk of levee failure.

Due to the recent completion of the upgrade works to the Darlington Point levee, and the standard to which these works were constructed, the defect allowance is anticipated to be minor. A value of **0.10 metres** is considered reasonable to use for this freeboard estimation.

1.4.6 Climate change

The NSW Governments Floodplain Development Manual states that climate change impacts on flood behaviour should be considered as part of a floodplain risk management study and plan. Climate change impacts that may influence the freeboard allowance in this study are related to the potential changes in rainfall patterns as a result of changes to rainfall volume, rainfall intensity during storm events, and evaporation.

The CSIRO report on climate change in the Murrumbidgee catchment (*CSIRO, 2006*) states that current predictions (at the time of writing of that document) include suggestions there will be more hot days, bushfires, droughts and intense storms in the Murrumbidgee catchment as a result of climate change. Projected climate change impacts in the Murrumbidgee Catchment include changes in average annual rainfall of between -13 - + 7% by 2030 with an increase in extreme rainfall of +7%, with evaporation estimated to change from +1 - +15%. By 2070, rainfall annual average rainfall is expected to change to +40 - +20% from current conditions, with extreme rainfall increasing +5% and evaporation +2 - +40%.

The flood characteristics in the Murrumbidgee River at Darlington Point is one of a wide floodplain with minimal grade along the channel and associated floodplains on the east and wet banks. A significant change in rainfall would be required to have a significant impact on the result flood levels at Darlington Point.

According, a value of **0.15m** is considered reasonable for climate change impacts in the freeboard analysis of this study.

1.4.7 Freeboard components Summary

It is unlikely that all of these components would be acting simultaneously, therefore a joint probability analysis needs to be undertaken in order to combine the various freeboard components. Probabilities for each component have been assigned as per the NSW Governments Public Works Advisory methodology (as shown in **Table D.7**).

The freeboard components are then multiplied by the probability to produce the joint probability component. The joint probability components are then summed to produce the overall freeboard allowance.

Table D. 7 - Freeboard components for Darlington Point levee

Freeboard	Maximum height	Probability	Probability Comment	Joint Probability component
Wave run-up	0.19	0.5	Winds can come from many directions and may not be along the main fetch length	0.095
Wave set-up	0.01	0.5	As above	0.005
Local Water surge	0.10	1	Natural features and flood impacts imply that this is almost certain at some point along the levee	0.100
Uncertainty in flood level	0.30	1	This is the assessed model accuracy and therefore is certain	0.300
Levee Settlement	0.02	0.5	It is assumed that this is mitigated through regular maintenance	0.01
Defects in levee	0.1	0.5	It is assumed that this is mitigated through regular maintenance	0.050
Climate change	0.15	1	This will increase from current conditions over time, for future flood planning we assume it has occurred.	0.150
TOTAL				0.71
FREEBOARD ALLOWANCE				**0.75**

1.5 Summary

This freeboard assessment has followed the process undertaken by NSW Governments Public Works Advisory as part of the assessment of the Wagga Wagga Levee Upgrade in 2010 (NSW Public Works 2010). Where assumptions had to be made, conservative estimates were made in accordance with current best practice and current literature. The detailed freeboard assessment has determined a freeboard of 0.71m, so this has been rounded up and a value of 0.75 metres will be used in this study.

2 References

BMT (2018). Murrumbidgee River at Darlington Point and Environs Flood Study. Prepared for Murrumbidgee Council.

CSIRO (2006), Climate Change in the Murrumbidgee Catchment, prepared for the NSW Government.

Diwedar, A. I, (2016) *Investigating the effect of wave parameters on wave runup*, Alexandria Engineering Journal, Volume 55, Issue 1, March 2016, pp 627-633.

Finance Services and Innovation, 2015, *Elevation data products specification and description – Source:Airborne Light Detecting and Ranging (LiDAR) No 2*, Department of Finance, Services and Innovation.

Murray Construction Pty. Ltd.,(2019) Plan of W.A.E. Survey of Darlington Point Levee (Areas 5 and 6). For Murrumbidgee Council.

Murrumbidgee Shire Council (2015). Darlington Point Levee Realignment – Review of Environmental Factors, Prepared for Murrumbidgee Shire Council by NSW Public Works, Departments of Finance and Service.

NSW Public Works (2010), Wagga Wagga Levee Upgrade: Flood Freeboard, prepared for Wagga Wagga City Council.

Raichlen, F. (1974). "*The Effect of Waves on Rubble-Mound Structures*", W.M.Keck Laboratory of Hydraulics and Water Resources, California Institute of Technology, California.

Saville Jr., T. (1956) *Wave run-up on shore structures*. Journal of the Waterways Division, Volume 82 Issue 2, pp 1-14.

SMEC (2010). Darlington Point Levee – Preliminary Design: Final Report, Prepared for Murrumbidgee Shire Council by SMEC, 23 December 2010.

Standards Australia. (2002) *Australian / New Zealand Standard Wind Loading – AS/NZ1170.2.*

Worley Parsons (2009), Darlington Point Levee Rehabilitation Project: Phase A – Geotechnical Investigations and Options Assessment, Prepared for Murrumbidgee Council.

APPENDIX E

FLOOD RISK ASSESSMENT OF FUTURE DEVELOPMENT SITES

APPENDIX F

FLOOD DAMAGE ASSESSMENT

F1 - Flood Damage Calculations

1.1 Introduction

In an effort to quantify the financial impact that flooding has on residents and business owners within the study area in and around Darlington Point, the number of properties subject to over floor flooding and the flood damage cost that would likely be incurred during the full range of design floods was calculated. The approach that was adopted to estimate the flood damage costs is presented below.

1.2 Property Database

A property database was developed as part of the study to enable damage calculations to be prepared across residential, commercial and industrial properties. The database was developed in GIS and included the details of all habitable buildings located within the extent of the extreme flood extent within the study area.

Floor level data was obtained from a number of different sources:

- The 2018 Flood Study (BMT 2018),
- This study

1.2.1 The 2018 Flood Study

- The 2018 Flood Study (BMT 2018), which used the floor level information from several different sources.
- Floor level information contained within 2009 Worley Parsons Report (Reference 3) for 426 properties in Darlington Point. Floor levels were assumed as either “slab on ground” or “transportable”, with the floor levels assumed as 0.2m or 0.4 metres above ground level, respectively. BMT, the author of the 2018 Flood Study, extracted ground levels from the LiDAR information used during that study, with the same assumptions that floor levels would be either 0.2m or 0.4m above ground level as per Reference 3. A number of additional properties were added to this database during the 2018 study using the same assumptions.
- The floor levels of nine (9) properties south of Darlington Point between the Sturt Highway were surveyed as part of the 2018 Flood Study.

1.2.2 This Floodplain Risk Management Study

- The floor levels of sixty-two (62) properties were surveyed as part of this study. These properties were located in North Darlington Point.
- Floor levels for additional properties located within the extreme flood extent and within the study boundary and not included in any of the previous floor level estimations were included in this analysis. The floor levels were estimated using the ground level information available from LiDAR and an allowance above the ground as per the estimations in 2018 flood study. Attributes of each property were determined based on information using a “drive by” survey. This was completed using Google Street View.

1.2.3 Building and building floor levels Information in property database

Each of the sources of floor level information included a range of different data and characteristics relating to each of the property's' listed. Overall, the following information was included as fields within all of the databases which will be used as part of the flood damage assessment:

- Property type (i.e., residential, commercial or industrial);
- Number of storeys;
- Lowest ground level;
- Lowest floor level;
- Residential building type (i.e., two story, single level high set or single level low set);
- Building material type (brick, weatherboard, cladded);
- Number of buildings on the lot;
- Commercial and industrial property contents value (low, medium or high value);

1.3 Types of Damage Costs

The damage costs associated with floodwater inundation can be broken down into a number of categories, as shown in **Plate F. 1** below. However, broadly speaking, damage costs fall under two major categories;

- tangible damages; and
- intangible damages.

Tangible damages are those which can be quantified in monetary terms (e.g., cost to replace household items damaged by waters). Intangible damages cannot be as readily quantified in monetary terms and include items such as inconvenience and emotional stress.

Tangible damages can be further broken down into direct and indirect damage costs. Direct costs are associated with water coming into direct contact with buildings and contents. Indirect flood damage costs are costs incurred outside of the specific inundation event. This can include clean-up costs, loss of trade (for commercial/industrial properties) and/or alternate accommodation costs while clean-up/repairs are undertaken.

1.4 Flood Damage Calculations

Flood damages are most commonly estimated using depth-damage curves for residential, commercial and industrial properties. The curves quantify the damage that could be expected relative to the depth of above floor flooding. Further information on the flood damage curves that were used as part of the study is provided below.

1.4.1 Residential Properties

The NSW Department of Planning, Industry and Environment (DPIE) has prepared a spreadsheet that provides a standardised approach for deriving depth-damage curves for residential properties (version 3.00, October 2007). The spreadsheet requires a range of parameters to be defined to enable a meaningful damage estimate to be derived. The parameters that were adopted for the current study are provided on the following page.

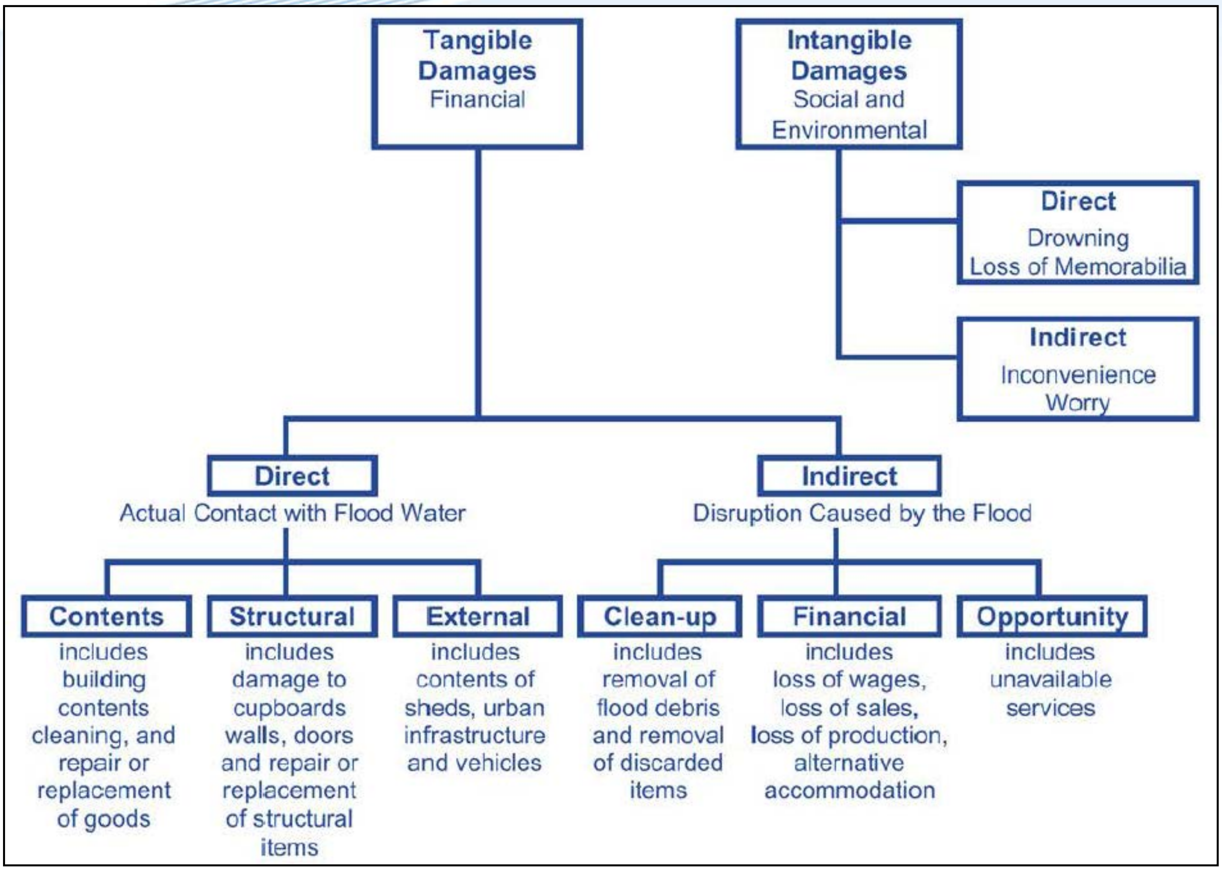


Plate F. 1 - Flood Damage Categories (NSW Government, 2005)

Building floor area serves as one of the residential damage curve inputs that must be adapted to the local catchment. An average building floor area for the study area was determined to be 200 metre squared.

The resulting residential depth-damage curves (shown on the following pages) incorporate a damage allowance for 'negative' above floor flooding depths. This is intended to reflect that property damage can be incurred when the water level is below floor level (e.g., damage to fences, sheds, belongings stored below the building floor). Therefore, flood damages were assumed to commence when water levels reached 0.2 metres below the flood level of each property.

The resulting residential depth-damage curves are included on the following page. The residential depth-damage curves include allowances for both direct and indirect cost components.

On top of the direct flood damage costs, additional factors are incorporated in the residential damage curves to help quantify the indirect damages that may be incurred as a result of flood damage at a residential property. This includes the time and cost associated with alternate accommodation and costs associated with cleaning up after the flood. These factors are included in the residential damage curves presented on the following pages.

1.4.2 Commercial/Industrial Properties

Unlike residential flood damage calculations, there are no standard curves available for estimating commercial and industrial flood damages in NSW. Commercial property types include offices and shops, and industrial properties include facilities such as warehouses and automotive repairs.

Catchment Simulation Solutions has prepared flood damage curves as part of floodplain risk management studies for other local government areas. These damage curves were originally developed based on flood damage information that was compiled following the Nyngan and Inverell floods during the 1990s, as well as data gained from interviews of 41 businesses in Gloucester. The curves were subsequently adjusted based upon flood damage information that was collected by Tweed Shire Council following the 2017 floods at Murwillumbah (the “old” curves were found to underestimate the reported damages). It was considered appropriate to use these curves for the current study in the absence of a standard set of damage curves. However, the base damage curves were updated to 2019 dollars using Consumer Price Index (CPI) values published by the Australian Bureau of Statistics (ABS) before application to the catchment calculations.

In order to apply the damage curves, it was necessary to categorise each commercial and industrial property according to the use of the land and the associated size of the building and the value of the contents (i.e. low, medium and high value contents). This is intended to reflect the fact that the damage incurred across commercial and industrial properties is likely to be directly related to the value of its contents. **Table F. 1** provides a summary of common commercial and industrial property types and the associated damage curves that each would fall under.

Land uses that are non -residential, however not necessarily commercial or industrial, were considered as part of the commercial and industrial damage land uses. These include parks and recreation areas, and buildings such a church or community hall. Each of these facilities were considered as a low value commercial development for the flood damage calculation process. The swimming pool and associated buildings in Darlington Point were considered as a medium value commercial development, with the cost of damage below the ground level and the cost to clean and refurbish the pools with fresh water after a flood event taken into account. The Darlington Point Sports Club and the Punt Hotel have been considered as high value commercial development for these flood damage calculations.

No specific allowance is included in the commercial and industrial damage curves for indirect losses, such as clean-up costs and loss of income while clean-up occurs. The recovery from flood damage for industrial developments is considered significant, as flood damage are expected to occur to large scale machinery or assets that would require significant time and or investment to return to full working condition. The recovery for commercial and small-scale industrial developments is typically less of a financial impact as the contents of these developments are anticipated to be simpler to replace.

Therefore, indirect damage costs were estimated as 20% of the direct flood damages for commercial and small industrial developments and 50% for medium and large industrial developments. These inflation factors were added to the direct damage costs to determine the total flood damage cost curves that were applied in this study.

SITE SPECIFIC INFORMATION FOR RESIDENTIAL DAMAGE CURVE DEVELOPMENT						
Version 3.00 October 2007						
PROJECT	**DETAILS**			**DATE**	**JOB No.**	
Darlington PointFRMS&P	Residential Buildings Flood Damages Assessment			1/08/2020	DP	
BUILDINGS						
Regional Cost Variation Factor	1.20	From Rawlinsons				
Post late 2001 adjustments	1.87	Changes in AWE see AWE Stats Worksheet				
Post Flood Inflation Factor	1.00	1.0	to	1.5		
Multiply overall structural costs by this factor		*Judgement to be used. Some suggestions below*				
	Regional City			*Regional Town*		
	Houses Affected		*Factor*	*Houses Affected*		*Factor*
Small scale impact	<	50	1.00	<	10	1.00
Medium scale impacts in Regional City		100	1.20		30	1.30
Large scale impacts in Regional City	>	150	1.40	>	50	1.50
Typical Duration of Immersion	48	hours				
Building Damage Repair Limitation Factor	1.00	*due to no insurance*		*short duration*		*long duration*
		Suggested range		*0.85*	*to*	*1.00*
Typical House Size	200	m^2		*240 m^2 is Base*		
Building Size Adjustment	0.8					
Total Building Adjustment Factor	**1.87**					
CONTENTS						
Average Contents Relevant to Site	$ 50,000		*Base for 240 m^2 house*		*$ 60,000*	
Post late 2001 adjustments	1.87	*From above*				
Contents Damage Repair Limitation Factor	0.75	*due to no insurance*		*short duration*		*long duration*
Sub-Total Adjustment Factor	1.41	*Suggested range*		*0.75*	*to*	*0.90*
Level of Flood Awareness	high	*low or high only. Low default unless otherwise justifiable.*				
Effective Warning Time	24	hour				
Interpolated DRF adjustment (Awareness/Time)	0.44	IDRF = Interpolated Damage Reduction Factor				
Typical Table/Bench Height (TTBH)	0.90	*0.9m is typical height. If typical is 2 storey house use 2.6m.*				
Total Contents Adjustment Factor AFD <= TTBH	**0.62**	AFD = Above Floor Depth				
Total Contents Adjustment Factor AFD > TTBH	**1.41**					
Most recent advice from Victorian Rapid Assessment Method						
Low level of awareness is expected norm (long term average) any deviation needs to be justified.						
Basic contents damages are based upon a DRF of	*0.9*					
Effective Warning time (hours)	*0*	*3*	*6*	*12*	*24*	
RAM Average IDRF Inexperienced (Low awareness)	*0.90*	*0.80*	*0.80*	*0.80*	*0.70*	
DRF (ARF/0.9)	*1.00*	*0.89*	*0.89*	*0.89*	*0.78*	
RAM AIDF Experienced (High awareness)	*0.80*	*0.80*	*0.60*	*0.40*	*0.40*	
DRF (ARF/0.9)	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*	
Site Specific DRF (DRF/0.9) for Awareness level for iteration	*0.89*	*0.89*	*0.67*	*0.44*	*0.44*	
Effective Warning time (hours)	*24*	*24*	*24*			
Site Specific iterations	*0.44*	*0.44*	*0.44*			
ADDITIONAL FACTORS						
Post late 2001 adjustments	1.87	*From above*				
External Damage	$ 6,700	*$6,700 recommended without justification*				
Clean Up Costs	$ 4,000	*$4,000 recommended without justification*				
Likely Time in Alternate Accommodation	4	weeks				
Additional accommodation costs /Loss of Rent	$ 220	*$220 per week recommended without justification*				
TWO STOREY HOUSE BUILDING & CONTENTS FACTORS				-0.5		
Up to Second Floor Level, less than	2.6	m		70%	Single Storey Slab on Ground	
From Second Storey up, greater than	2.6	m		110%	Single Storey Slab on Ground	
Base Curves		AFD = Above Floor Depth				
Single Storey Slab/Low Set	13164	+	4871	x	AFD in metres	
Structure with GST	AFD	greater than	-0.2	m		
Validity Limits	AFD	less than or equal to		6	m	
Single Storey High Set	16586	+	7454	x	AFD	
Structure with GST	AFD	greater than	-0.5 m			
Validity Limits	AFD	less than or equal to		6	m	
Contents	20000	+	20000	x	AFD	
Contents with GST	AFD	greater than		0		
Validity Limits	AFD	less than or equal to		2		

Plate F. 2 - Residential Flood damage curve inputs

Table F. 1 - Content Value Categories for Commercial and Industrial Property Types

Commercial Low Value	Commercial Medium Value	Commercial High Value and Industrial low value	Industrial Medium Value
Recreation Uses – skate park, public parks	Mixed commercial such as chemists, food shops, newsagencies.	Primary school	Silo storage
Environmental Uses	Swimming pool	Cemetery	Food processing plant
Church	Office	Darlington Point Sports Club	Sewer Treatment Plant
Community Hall		Pub	
		Council Administration Centre	
		Grain storage sheds	

1.4.3 Infrastructure Damage

Infrastructure damage refers to damage to public infrastructure and utilities such as roads, water supply, sewerage, gas, electricity and telephone. Where major assets are known to exist (e.g. water treatment plant), they were included as part of the commercial/industrial damages (refer **Table F. 1**). For the remainder of the infrastructure located in the catchment, such as roads and telecommunication assets, the damage was incorporated into the residential, commercial and industrial damage curves. More specifically, the base damage curves were inflated by a further 15% to account for infrastructure damage throughout the study area.

1.4.4 Potential versus Actual Damages

The residential, commercial and industrial damage calculations outlined above assume that no actions are taken by residents and business owners to reduce the potential damage. However, if some warning is provided of the impending inundation event, there may be sufficient time for residents and business owners to undertake actions to reduce the potential damage costs incurred during a flood. For example, residents/business owners could potentially 'sandbag' properties to prevent the ingress of floodwaters, relocate vehicles to high ground and/or elevate electrical devices onto tables or shelves. As a result, actual flood damages will typically be lower than the potential calculated flood damages.

Only very limited data has been collected in Australia to assist in quantifying how flood warnings can reduce potential flood damages. Information presented by Water Studies (1992) infers that direct residential property damages can be reduced by up to 50% with some effective warning time (although no specific information is provided on the minimum warning time required to achieve this).

More extensive research in flood damage reductions associated with effective flood warning has been completed across Europe. This research notes that the flood damage reduction potential is not only dependent on the amount of warning time provided, but also how effectively this warning information is disseminated, the reliability of the warning information, the proportion of households that are proactive with the warning information and how well these households respond to the warning information (Parker, 1991). The Flood Hazard Research Centre (FHRC) also published the following table which relates the potential flood damages avoided (PFA) with respect to variations in depth of flooding and flood warning time for short duration floods (Penning-Rowsell et al, 2013).

Table 8.3: Calculation of Potential Flood Damages Avoided (PFA) for a short duration flood (<12 hour) for residential property

Depth of Flooding (m)	Total Potential Damage £	Total Potential Household Inventory Damage £	Flood warning lead times							
			Up to 2hours		2-4 hours		6 hours		8 hours	
			PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage	PFA £	PFA % of Total Damage
1.2	33,040	20,423	8,359	25.3	11,795	35.7	12,786	38.7	13,447	40.7
0.9	31,265	20,237	8,254	26.4	11,756	37.6	12,694	40.6	13,319	42.6
0.6	29,268	19,051	7,463	25.5	10,888	37.2	11,766	40.2	12,351	42.2
0.3	26,105	18,046	7,832	30.0	10,990	42.1	11,774	45.1	12,296	47.1
0.1	13,507	9,977	3,309	24.5	4,430	32.8	4,835	35.8	5,105	37.8

It indicates that reductions in direct flood damages of around 25% are typical with up to 2 hours warning time increasing to reductions of over 40% with 8 hours warning time. The FHRC also noted that reductions in potential flood damages above 50% are unlikely as only 40-50% of potentially damageable items can be relocated/moved.

Flooding in Darlington Point behind the levee as a result of local flooding is very "flashy" with floodwaters typically peaking within 30 minutes to 60 minutes of the onset of rainfall. This is considered to be insufficient warning time for residents or business owners to undertake any preparations to reduce flood damages, such as lifting objects from the ground or moving vehicles. Flooding as a result of elevated water levels in the Murrumbidgee River would include a significantly long warning time, up to 3 months has been experienced in the past. Therefore, there is opportunity for residents to prepare for the flooding and protect their property and contents where feasible. As such, a flood damage reduction factor was included in the determination of the flood damages within this study area.

1.4.5 Breaching of levee for flood damage assessment

The levee was assumed to breach at levels greater than the 1% AEP design flood event. As such, flood damages for areas behind the levee would be realised from mainstream Murrumbidgee River flooding in events greater than the 1% AEP design flood event.

1.5 Summary of Number of Properties Impacted by Inundation

Above floor flooding depths were estimated for each design flood for each potentially flood affected property within the catchment. This was completed using peak design flood levels generated by the TUFLOW model in conjunction with the building floor level information discussed in **Section 1.2.** This enabled the number of residential, commercial and industrial properties subject to above floor flooding during each design flood to be estimated, which is summarised in **Table F. 2**. The number of residential properties subject to property damage (even if above floor flooding is not predicted) are also provided in **Table F. 2** . This includes damage to external items such as fences, sheds and garages.

1.5.1 Local Catchment Flooding behind the levee

Table F. 2 outlines the number of properties behind the levee that would be impacted by local overland flooding. Residential properties have been furthers divided into those that would be impacted by flooding below floor level. That is floodwaters are expected to impact the external parts of the residential property however would not inundate above floor level. These flood impacts to external parts of the property would be anticipated to cause external flood damage, which was included in the flood damage curves.

Table F. 2 - Number of Properties Incurring Flood Damages as a result of local flooding behind the levee only

Flood Event	Number of Properties Impacted by flooding			
	Residential		Commercial/ Industrial	Total
	External Damage only	Above floor Flooding		
20% AEP	16	0	1*	**17**
10% AEP	18	0	1*	**19**
5% AEP	21	0	1*	**22**
2% AEP	25	0	1*	**26**
1% AEP	30	2	2	**34**
0.5% AEP	32	3	2	**37**
0.2% AEP	39	4	2	**45**
Extreme Flood	97	158	24	**279**

*This property is one of the community open space areas in Darlington Point behind the levee that only consists of open space with no buildings.

1.5.2 Murrumbidgee River Flooding

Table F. 3 outlines the number of properties behind the levee that would be impacted by mainstream flooding from the Murrumbidgee River. As with the local flooding, the impacts to residential properties have been divided into those estimated to be impacted by external flood impacts only, and those properties estimated to be impacted by over floor flooding.

Table F. 3 - Number of Properties Incurring Flood Damages as a result of Murrumbidgee River flooding only

Flood Event	Number of Properties Impacted by flooding			
	Residential		Commercial/ Industrial	Total
	External Damage only	Above floor Flooding		
20% AEP	0	0	0	**0**
10% AEP	0	0	1**	**1**
5% AEP	2	1	1**	**4**
2% AEP	11	8	5	**24**
1% AEP	17	15	5	**37**
0.5% AEP	86	146	29	**261**
0.2% AEP	98	179	33	**310**
Extreme Flood	106	306	40	**452**

**Darlington Point Caravan Park

These numbers are the best estimate of the extent of damage as a result of flooding within the study area only. These estimates do not consider the impact of flooding below floor level on infrastructure or buildings associated with agricultural or more rural activities that are undertaken on the larger properties surrounding Darlington Point. Those impacts will be assessed as part of the review of the rural floodplain management plan for the Murrumbidgee River.

1.6 Summary of Inundation Costs

The number of properties impacted by over floor flooding was combined with the appropriate depth-damage curves to estimate the damage cost incurred at each property during each design flood event.

1.6.1 Local Catchment Flooding behind the levee

Table F. 2 indicates the number of properties that are estimated to be impacted by flooding behind the levee. **Table F. 4.** indicates the costs that are estimated to be incurred as a result of these properties being impacted by local catchment flooding.

Table F. 4 - Total Flood Damage Cost Estimates as a result of local flooding behind the levee only

Flood Event	Flood Damages ($)		
	Residential	Commercial / Industrial	Total Damages
20% AEP	$197,660	$23,154	**$220,814**
10% AEP	$289,206	$23,132	**$312,338**
5% AEP	$359,926	$24,562	**$384,488**
2% AEP	$419,978	$25,629	**$445,670**
1% AEP	$530,389	$44,342	**$ 574,740**
0.5% AEP	$637,739	$45,504	**$683,343**
0.2% AEP	$776,362	$47,213	**$823,575**
PMF	$12,718,881	$792,729	**$13,511,610**

1.6.2 Murrumbidgee River Flooding

Table F. 2 indicates the number of properties that are estimated to incur flood damage as a result of mainstream flooding in the Murrumbidgee River. **Table F. 5** indicates the costs that are estimated to be incurred as a result of these properties being impacted by mainstream river flooding.

Table F. 5 - Total Flood Damage Cost Estimates as a result of Murrumbidgee River flooding only

Flood Event	Flood Damages ($)		
	Residential	Commercial/ Industrial	Total Damages
20% AEP	0	0	**$ -**
10% AEP	0	$33,096	**$33,096**
5% AEP	$105,791	$69,219	**$175,010**
2% AEP	$638,948	$296,802	**$935,750**

1% AEP	$1,347,270	$389,238	**$1,736,508**
0.5% AEP	$12,252,069	$1,209,652	**$13,461,721**
0.2% AEP	$14,531,866	$1,621,824	**$16,153,690**
Extreme Flood	$27,162,342	$3,258,438	**$30,420,780**

These numbers are the best estimate of the extent of damage as a result of flooding within the study area only. These estimates do not consider the impact of flooding below floor level on agriculture or more rural activities that are undertaken on the larger properties surrounding Darlington Point. Those impacts will be assessed as part of the review of the rural floodplain management plan for the Murrumbidgee River.

1.6.3 Average Annual Damages

The total flood damages for each flood event was subsequently used to estimate the Average Annual Damage (AAD) cost for the study area. The AAD provides an estimate of the average annual cost of inundation across the study area over an extended timeframe. The AAD for the study area for existing conditions were calculated as follows:

- AAD for mainstream flooding = **$165,188**
- AAD for local flooding behind the levee = **$81,176**

1.7 Limitations of Damage Costs

The damage costs presented in this document are based on the best information that was available at the time this report was prepared and are the best estimate of the extent of damage as a result of flooding within the study area only. They are not an estimate of the extent of flood damage throughout the whole Murrumbidgee catchment.

The flood damage estimates have been based on the best available information at the time of writing. However, the estimates are exactly that – estimates. Actual damage costs during future floods may vary. Land uses may also change in future, which would impact on potential flood damages.

References

1. BMT (2019). *Murrumbidgee River at Darlington Point and Environs Flood Study*. Prepared for Murrumbidgee Council.
2. Department of Environment and Climate Change (2007) *Floodplain Risk Management Guideline: Residential Flood Damages*. Version 1.0.
3. Worley Parsons (2009), *Darlington Point Levee Rehabilitation Project: Phase A – Geotechnical Investigations and Options Assessment,* Prepared for Murrumbidgee Council.

APPENDIX G

COST ESTIMATES OF OPTIONS

<u>Preliminary Cost Estimate</u>

Flood Management Option 1

- Levee to provide protection up to the 1% AEP flood event to North Darlington Point
- Refer to concept design for alignment used in the modelling

Reference:

Rawlinson's 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Foundation preparation**				
1.1	Remove cover vegetation and topsoil	58,829	$1.80	sqm	$105,892.20
1.2	Compact foundation	58,829	$3.55	sqm	$208,842.95
	SUB TOTAL				**$314,735.15**
2	**Cut-off foundation construction**				
2.1	Excavate foundation channel	12,232	$32.40	cum	$396,316.80
2.2	Compact foundation	9,900	$3.55	sqm	$35,145.00
2.3	Clay fill, including compaction and lime treatment	12,232	$13.55	cum	$165,743.60
	SUB TOTAL				**$597,205.40**
3	**Levee Core Construction**				
3.1	Clay fill, including compaction and lime treatment	19,517	$13.55	cum	$264,455.35
	SUB TOTAL				**$264,455.35**
4	**Batter Construction**				
4.1	Batter material, including placement, shaping and compaction	72,820	$10.15	cum	$739,123.00
	SUB TOTAL				**$739,123.00**
5	**General Road access ramps through levee**				
5.1	Clay fill, including compaction and lime treatment	10,116	$13.55	cum	$137,071.80
5.2	Pavement construction subbase and top coat A/C	5,400	$60.10	sqm	$324,540.00
	SUB TOTAL				**$461,611.80**
6	**Project Management and generic project costs**				
6.1	Detail Design & Documentation	1	20%	unit	$855,962.58
6.2	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$427,981.29
	SUB TOTAL				**$1,283,943.87**
			TOTAL	Sydney	$3,661,074.57
	Local factor Rawlinson's (Deniliquin)	1.15	TOTAL	Deniliquin	$4,210,235.76
	Contingency			20%	$842,047.15
				TOTAL (Rounded to nearest $10,000)	**$7,680,000**

Preliminary Cost Estimate

Flood Management Option 2

- Temporary Levee to provide protection up to the 1% AEP flood event to North Darlington Point
- Located between Darlington Street and Beach Road, and along Whitton Darlington Point Road
- Refer to concept design for alignment used in the modelling

Reference:
Information by www.apexenvirocare.com.au

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1A	**Option A: Temporary levee of type "Aqua Barrier"**				
1.1	Supply of 1.2 metre high Aqua Barrier (30m lengths)	34	$13,500.00	units	$459,000.00
1.2	Supply of 0.9 metre high Aqua Barrier (30m lengths)	50	$10,000.00	units	$500,000.00
	SUB TOTAL Option A				**$959,000.00**
1B	**Option B: Temporary levee of type "Floodline"**				
1.1	Supply of 1.5 metre high Floodline	2,500	$950.00	m	$2,375,000.00
1.2	90 degree 1.5m high corner section	5	$2,000.00	units	$10,000.00
	SUB TOTAL Option B				**$2,385,000.00**
1C	**Option C: Temporary levee of type "NoFloods" twin tubes**				
1.1	Supply of 1.25 metre high water billed barrier	2,500	$400.00	m	$1,000,000.00
	SUB TOTAL Option C				**$1,000,000.00**
1D	**Option D: Temporary levee of type "Aquafence" fold out barrier**				
1.1	Supply of 1.2 metre high Aquafence	2,500	$1,500.00	m	$3,750,000.00
	SUB TOTAL Option D				**$3,750,000.00**
1E	**Option E: Temporary levee of type "Boxwall" moulded fence type barrier**				
1.1	Supply of 1.0 metre high Boxwall	2,500	$900.00	m	$2,250,000.00
	SUB TOTAL Option E				**$2,250,000.00**
2	**Project Management and generic project costs**				
2.1	Detail Design & Documentation	1	$2,000.00	unit	$2,000.00
2.2	Environmental Assessment	1	$2,000.00	unit	$2,000.00
	SUB TOTAL				**$4,000.00**
	Contingency		20%		Included in Totals
	Option A: TOTAL (Rounded to nearest $10,000)				**$1,160,000**
	Option B: TOTAL (Rounded to nearest $10,000)				**$2,870,000**
	Option C: TOTAL (Rounded to nearest $10,000)				**$1,200,000**
	Option D: TOTAL (Rounded to nearest $10,000)				**$4,500,000**
	Option E: TOTAL (Rounded to nearest $10,000)				**$2,700,000**

Preliminary Cost Estimate

Flood Management Option 3

- Spillway for the existing levee proposed for the South-Eastern side of Darlington Point
- Refer to concept design for location used in the modelling

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Spillway construction**				
1.1	Removal existing levee materials	1,640	$5.45	cum	$8,938.00
1.2	Reforming of spillway crest and compaction	2,128	$44.60	sqm	$94,908.80
1.3	Spillway surface material	494	$10.15	cum	$5,014.10
	SUB TOTAL				**$108,860.90**
2	**Project Management and generic project costs**				
2.1	Detail Design & Documentation	1	20%	unit	$21,772.18
2.2	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$10,886.09
	SUB TOTAL				**$32,658.27**
			TOTAL	Sydney	$141,519.17
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$162,747.05
	Contingency			20%	$32,549.41
		TOTAL (Rounded to nearest $10,000)			**$200,000**

Preliminary Cost Estimate

Flood Management Option 4

- Bypass channel through the stock route connecting Whitton-Darlington Point Rd and Kidman Way
- Refer to concept design for alignment and proposed works used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Stock Route Pathway upgrade**				
1.1	Remove cover vegetation and topsoil	59,000	$1.80	sqm	$106,200.00
1.2	Grade stock pathway	20,000	$5.45	cum	$109,000.00
1.3	Compact foundation	17,700	$3.55	sqm	$62,835.00
	SUB TOTAL				**$278,035.00**
2	**Channel and Embankment Construction**				
2.1	Excavate foundation channel	25,000	$32.40	cum	$810,000.00
2.2	Clay fill, including compaction and lime treatment	6,000	$13.55	cum	$81,300.00
2.3	Use of excavated material for batter	13,000	$10.15	cum	$131,950.00
2.4	Topsoil placement, raking and levelling	35,400	$6.00	sqm	$212,400.00
2.5	Turfing for slope stabilisation	35,400	$9.00	sqm	$318,600.00
	SUB TOTAL				**$1,554,250.00**
3	**Modular Bridge Construction**				
3.1	Removal of existing roads	800	$32.73	sqm	$26,184.00
3.2	Bulk earthworks	5,600	$21.90	cum	$122,640.00
3.3	Composite price for conventional low level 2-lane bridge (such as M-Lock by Rocla or HumeDeck by Humes)* *An indicative pricing; the bridge designs considered are likely less	800	$1,800.00	sqm	$1,440,000.00
	SUB TOTAL				**$1,588,824.00**
4	**Project Management and generic project costs**				
4.1	Detail Design & Documentation	1	20%	unit	$684,221.80
4.2	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$342,110.90
	SUB TOTAL				**$1,026,332.70**
			TOTAL	Sydney	$4,447,441.70
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$5,114,557.96
	Contingency			20%	$1,022,911.59
		TOTAL (Rounded to nearest $10,000)			**$6,140,000**

Preliminary Cost Estimate

Flood Management Option 5A

- Lowering a 700m stretch of Kidman Way directly south of the existing levee around Darlington Point
- Refer to concept design for extents used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal existing road base**				
1.1	Remove existing road layers	7,200	$32.73	sqm	$235,656.00
1.2	Excavation earthworks	14,091	$8.70	cum	$122,591.70
	SUB TOTAL				**$358,247.70**
2	**Forming new road layer at lower levels**				
2.1	Pavement construction subbase and top coat A/C	7,200	$60.10	sqm	$432,720.00
	SUB TOTAL				**$432,720.00**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$158,193.54
3.2	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$79,096.77
	SUB TOTAL				**$237,290.31**
			TOTAL	Sydney	$1,028,258.01
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$1,182,496.71
	Contingency			20%	$236,499.34
			TOTAL (Rounded to nearest $10,000)		**$1,420,000**

Preliminary Cost Estimate

Flood Management Option 5B

- Variation on FM5A where, rather than lowering the terrain universally, use bridges to span smaller extents of lowered terrain

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal existing road base**				
1.1	Remove existing road layers	1,200	$32.73	sqm	$39,276.00
	SUB TOTAL				**$39,276.00**
2	**New flow paths under road and road reconstruction**				
2.1	Excavation earthworks	2,100	$8.70	cum	$18,270.00
2.2	Composite price for conventional 2-lane bridge*	1,200	$1,800.00	sqm	$2,160,000.00
	*An indicative pricing; the bridge designs considered are likely less				
	SUB TOTAL				**$2,178,270.00**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	$40,000	unit	$40,000.00
3.2	Allowance for preliminaries, design, sediment control and property acquisition	1	$10,000	unit	$10,000.00
	SUB TOTAL				**$50,000.00**
			TOTAL	Sydney	$2,228,270.00
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$2,562,510.50
	Contingency			20%	$512,502.10
			TOTAL (Rounded to nearest $10,000)		**$3,080,000.00**

Preliminary Cost Estimate

Flood Management Option 6

- Removal of high terrain under the bridge crossing the Murrumbidgee River
- Refer to concept design for the proposed area for earthworks

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Excavation**				
1.1	Remove cover vegetation and topsoil	35,000	$1.70	sqm	$59,500.00
1.2	Bulk earthworks	68,738	$8.70	cum	$598,020.60
	SUB TOTAL				**$657,520.60**
2	**Project Management and generic project costs**				
2.1	Detail Design & Documentation	1	20%	unit	$131,504.12
2.2	Allowance for preliminaries, design, sediment control	1	20%	unit	$131,504.12
2.3	Environmental and site contingencies	1	30%	unit	$197,256.18
	SUB TOTAL				**$460,264.42**
			TOTAL	Sydney	$1,117,785.02
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$1,285,452.77
	Contingency			20%	$257,090.55
		TOTAL (Rounded to nearest $10,000)			**$1,540,000**

Preliminary Cost Estimate

Flood Management Option 7

- A series of large culverts through the embankment under the bridge crossing the Murrumbidgee River
- Refer to concept design for culvert locations used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal existing road base**				
1.1	Remove existing road layers	400	$32.73	sqm	$13,092.00
	SUB TOTAL				**$13,092.00**
2	**New culverts under road and road reconstruction**				
2.1	Excavation earthworks	8,400	$8.70	cum	$73,080.00
2.2	Laying new road layers	1,200	$60.10	sqm	$72,120.00
	SUB TOTAL				**$145,200.00**
3	**Drainage**				
3.1	Precast concrete box culvert including minimal site works	20	$54,000	unit	$1,080,000.00
	SUB TOTAL				**$1,080,000.00**
4	**Project Management and generic project costs**				
4.1	Detail Design & Documentation		20%	unit	$247,658.40
4.2	Allowance for preliminaries, design, sediment control		10%	unit	$123,829.20
4.3	Allowance for temporary structures and traffic control		10%	unit	$123,829.20
	SUB TOTAL				**$495,316.80**
			TOTAL	Sydney	$1,733,608.80
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$1,993,650.12
	Contingency			20%	$398,730.02
				TOTAL (Rounded to nearest $10,000)	$2,390,000

Preliminary Cost Estimate

Flood Management Option 8

- Clearing vegetation from the bridge crossing the Murrumbidgee River, along the creekline to the north for 4km
- Refer to concept design for the extent used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal of vegetation**				
1.1	Removal existing vegetation	326,000	$1.70	sqm	$554,200.00
	SUB TOTAL				**$554,200.00**
2	**Project Management and generic project costs**				
2.1	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$55,420.00
2.2	Environmental contingencies	1	30%	unit	$166,260.00
	SUB TOTAL				**$221,680.00**
			TOTAL	Sydney	$775,880.00
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$892,262.00
	Contingency			20%	$178,452.40
			TOTAL (Rounded to nearest $10,000)		**$1,070,000**

Preliminary Cost Estimate

Flood Management Option 9

- Lowering a 743m stretch of Hay Road directly south of the existing levee around Darlington Point
- Refer to concept design for extents used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal existing road base**				
1.1	Remove existing road layers	4,300	$32.73	sqm	$140,739.00
1.2	Excavation earthworks	5,600	$8.70	cum	$48,720.00
	SUB TOTAL				**$189,459.00**
2	**Forming new road layer at lower levels**				
2.1	Pavement construction subbase and top coat A/C	4,300	$60.10	sqm	$258,430.00
	SUB TOTAL				**$258,430.00**
3	**Project Management and generic project costs**				
3.1	Detail Design & Documentation	1	20%	unit	$89,577.80
3.2	Allowance for preliminaries, design, sediment control and property acquisition	1	10%	unit	$44,788.90
	SUB TOTAL				**$134,366.70**
			TOTAL	Sydney	$582,255.70
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$669,594.06
	Contingency			20%	$133,918.81
			TOTAL (Rounded to nearest $10,000)		**$800,000**

Preliminary Cost Estimate

Flood Management Option 10

- Doubling the dimensions of all culverts surrounding Darlington Point
- Refer to concept design for culverts updated in the modelling

Reference:

Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgetting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Given the lack of impact of this option the cost estimates were not pursued

Preliminary Cost Estimate

Response Management Option 7

- Raise Kidman Way to the north of Darlington to 1%AEP levels
- Include flowpaths under the road to allow natural water flow
- Refer to concept design for extents used in the modelling

Reference:
Rawlinsons 'Australian Construction Handbook' - Edition 36, 2018

Note: The preliminary costs estimates outlined below have been prepared for comparing and evaluating the feasibility of different floodplain risk management options. They are approximate only and should not be relied upon for budgeting purposes. Detailed costings can only be prepared once detailed design plans are prepared.

Cost estimates only include capital costs and no ongoing maintenance costs are included unless specifically noted. Values exclude GST, and costs associated with Insurance, Levies or any Permits/Fees have been omitted.

Item	Description	Quantity	Rate	Unit	Total
1	**Removal existing road base**				
1.1	Remove existing road layers	33,450	$32.73	sqm	$1,094,818.50
	SUB TOTAL				**$1,094,818.50**
2	**Forming new road layer at higher levels**				
2.1	Fill material, including placement, shaping and compaction	10,800	$10.15	cum	$109,620.00
2.2	Pavement construction subbase and top coat A/C	33,450	$60.10	sqm	$2,010,345.00
	SUB TOTAL				**$2,119,965.00**
3	**New flow paths under road and road reconstruction**				
3.1	Composite price for conventional 2-lane bridge*	800	$1,800.00	sqm	$1,440,000.00
	*An indicative pricing; the bridge designs considered are likely less				
	SUB TOTAL				**$1,440,000.00**
4	**Project Management and generic project costs**				
4.1	Detail Design & Documentation		20%	unit	$930,956.70
4.2	Allowance for preliminaries, design, sediment control		10%	unit	$465,478.35
	SUB TOTAL				**$1,396,435.05**
			TOTAL	Sydney	$6,051,218.55
	Local factor Rawlinsons (Deniliquin)	1.15	TOTAL	Deniliquin	$6,958,901.33
	Contingency			20%	$1,391,780.27
			TOTAL (Rounded to nearest $10,000)		**$8,350,000**

APPENDIX H

OPTIONS DETAILING AND MAPPING

H1 - Summary of Options Modelled

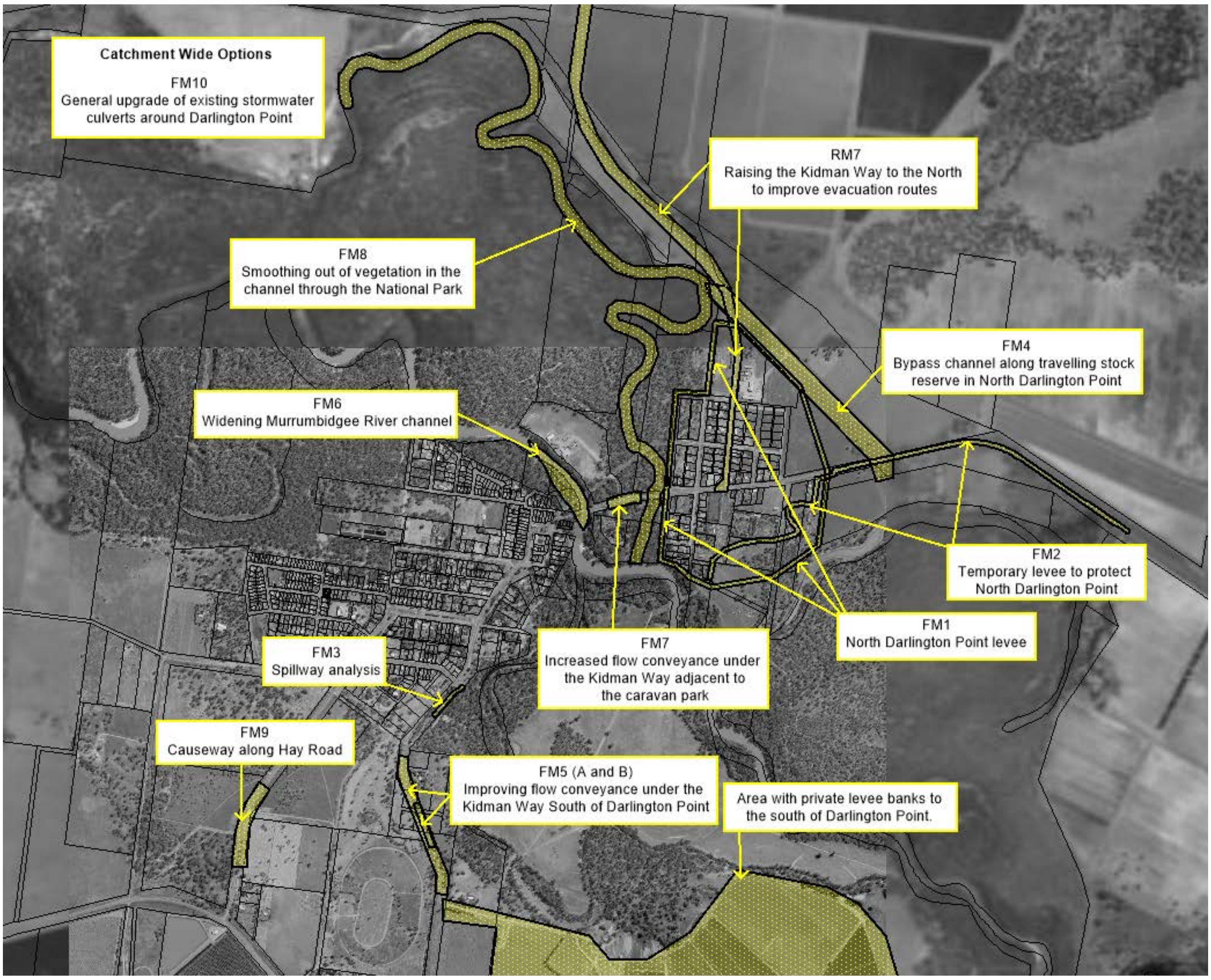


Plate H.1 - Overview of options that were included in an updated hydraulic model

1 FM Option 1 – North Darlington Point Levee

1.1 Concept Design of FM Option 1

Plate H.2 – FM Option 1 concept design

The potential location of the earthen levee is shown in **Plate H.2**. An earthen levee with an approximate length of 3.5 kilometres was included in the hydraulic model. As shown in **Plate H.2**, the concept design for the earthen levee incorporates:

- Levee crest level of the 1% AEP design flood level with a freeboard of one (1) metre added on top of the existing 1% AEP design flood level.
- Due to the topography of the area and the variation required for levee height, the design levee was broken down in to 3 different sections, as per **Table H.1**Error! Reference source not found. below.
- Where road crossings traversed the levee, a general rising road access along an approximate length either side of the levee of 100 metres was included in the design.
- A general levee crest width of three (3) metres with embankments at 3H:1V side slopes.

Table H.1 - North Darlington Point levee concept design details

Levee Section	Approximate length of levee section (metres)	Approximate height of levee section (metres)
1	1300 metres	Raised between 2 to 4 metres
2	1000 metres	Raised between 1 to 2 metres
3	1200 metres	Raised between 2 to 3 metres

1.2 Cost estimate of FM Option 1

A cost estimate was prepared for the levee around north Darlington Point and is included in **Appendix G**. This determined that the levee would cost approximately $7.68 million to build. The levee would have to be maintained into perpetuity, and so a minimum of 2% of the construction cost would need to be maintained on an annual basis to cater for future asset management requirements of a levee at north Darlington Point, equating to approximately $154,000 per year.

1.3 Hydraulic Impact of FM Option 1

The hydraulic benefits of the levee were quantified by including the levee in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the levee in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the levee. The difference mapping is presented in **Plate H.3, Plate H.4 and Plate H.5** for the 5% AEP and 1% AEP and 0.2% AEP events respectively.

The flood level difference mapping shows that the levee will reduce flood levels in north Darlington Point for all events up to and including the 0.2% AEP design flood event.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as:

Table H. 2 - Hydraulic Impact of FM Option 1

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	-1	-2
2% AEP	-9	-9
1% AEP	-15	-9
0.5% AEP	+4	-20
0.2% AEP	-21	-12
Extreme flood event	-14	-28

Despite the elimination of flooding at north Darlington Point up to the 1% AEP design flood event, the proposed levee would result in an increase in design flood levels at a number of other locations in the study area. The areas adversely impacted include immediately upstream in the Murrumbidgee River channel with flood depths increasing between 0.02 metres and 0.04 metres. Flood levels increase in the more rural areas to the north east of north Darlington Point by depths up to 0.06 metres and increase in the more rural areas downstream by depths up to 0.05 metres.

The proposed levee at north Darlington Point would impact the recently completed Darlington Point levee by increasing water levels adjacent to the upgraded earthen levee by approximately 0.04 metres. However, the flood level increases as a result of the levee at north Darlington Point would maintain the current level of protection to the existing Darlington Point levee (i.e. 1% AEP plus a freeboard of 0.75 metres).

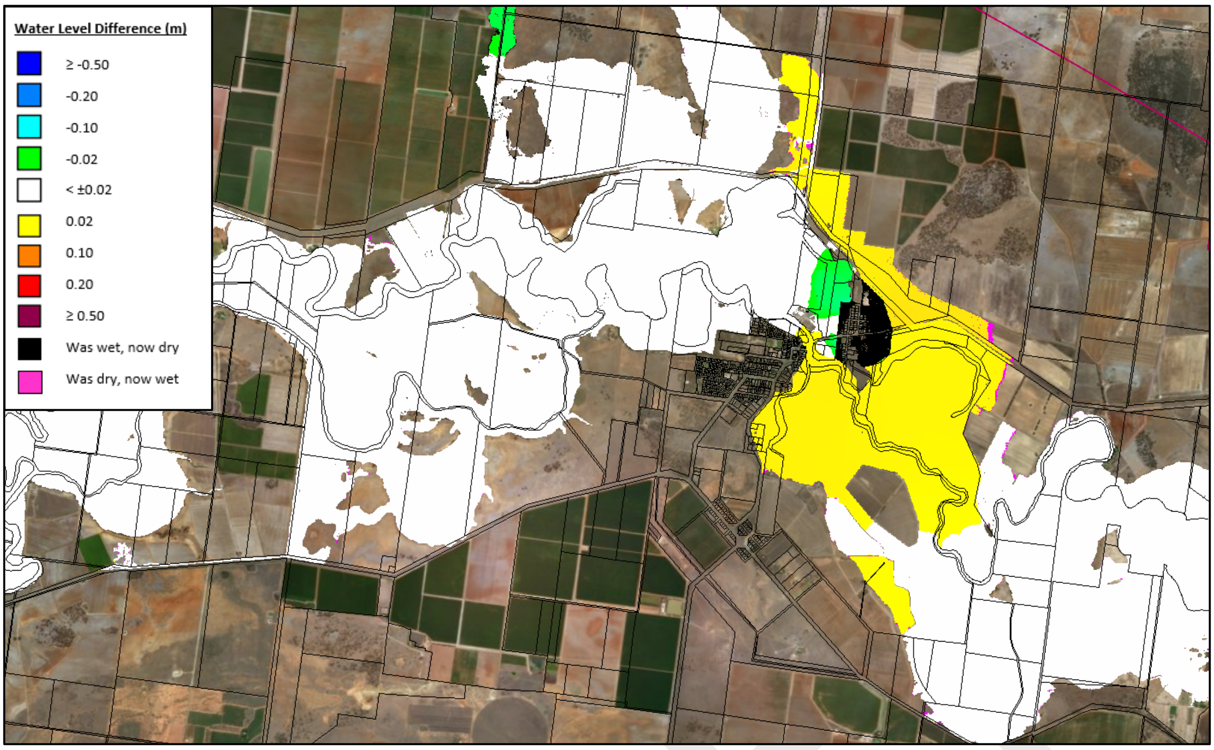


Plate H.3 – FM Option 1 floodwater level differences for the 5% AEP

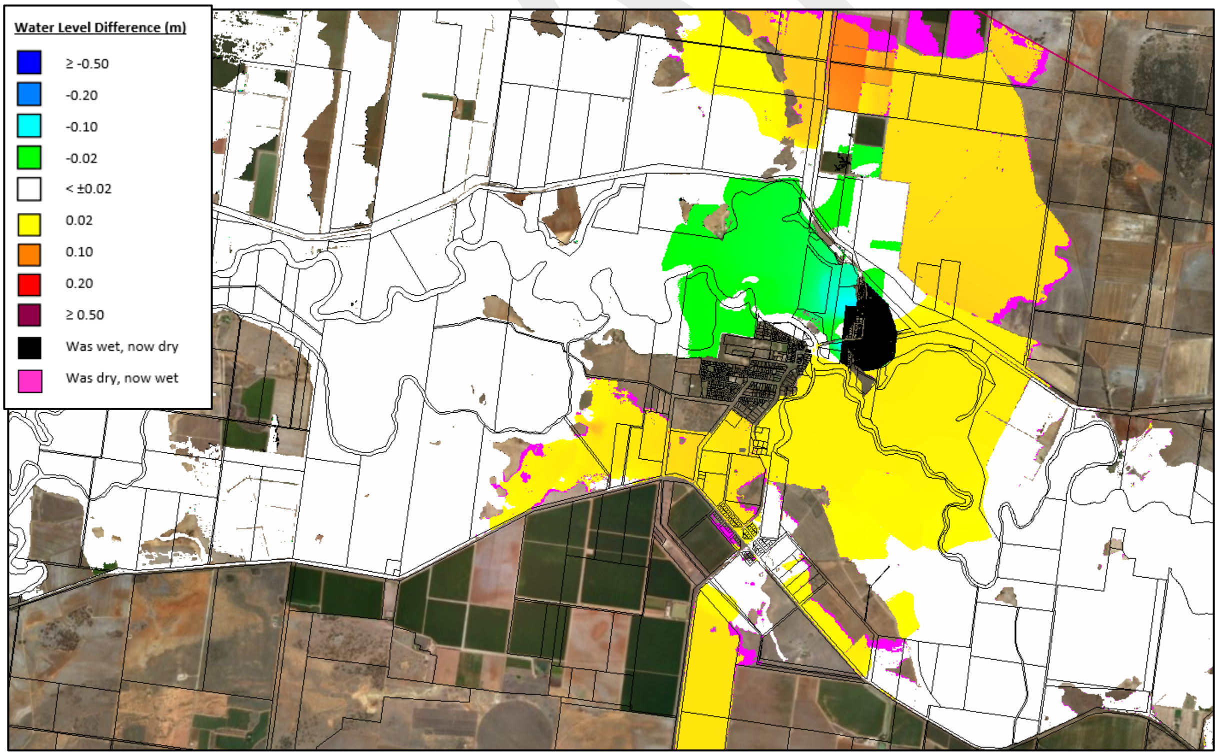
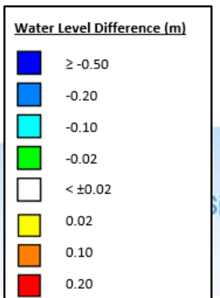


Plate H.4 – FM Option 1 floodwater level differences for the 1% AEP



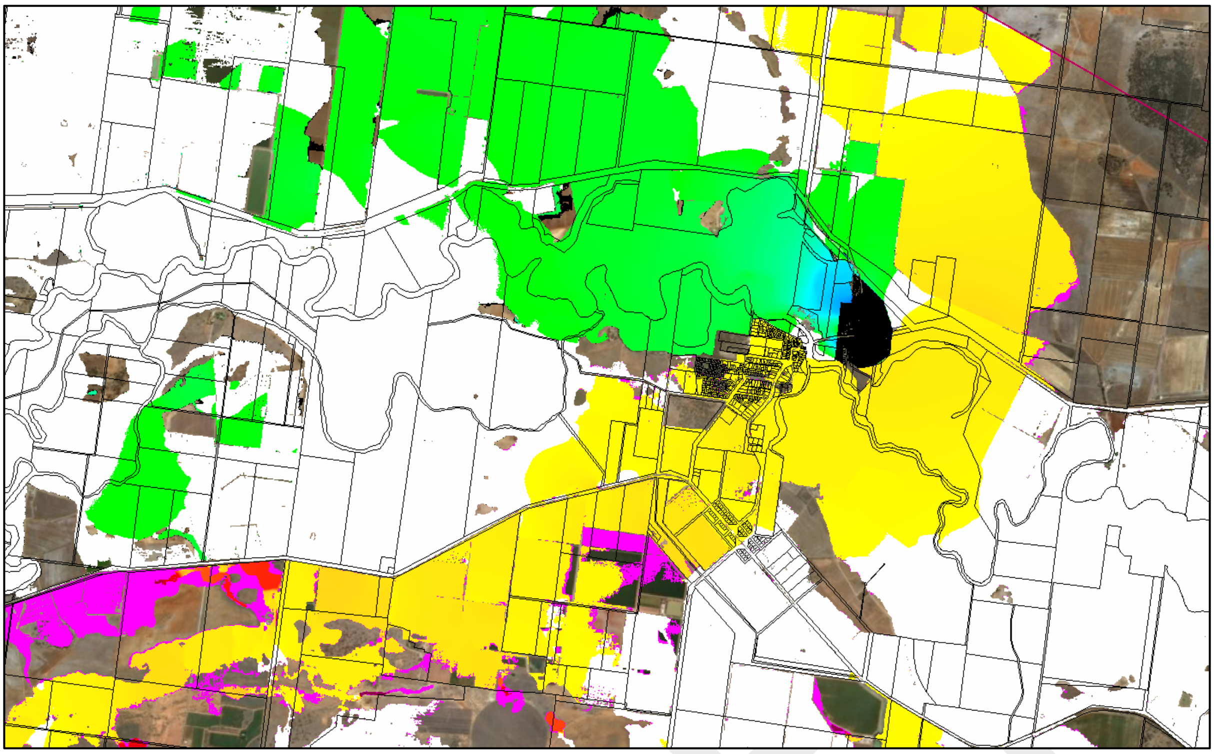


Plate H.5 – FM Option 1 floodwater level differences for the 0.2% AEP

1.4 Reduction in Flood Damages

The potential financial benefit associated with implementation of the north Darlington Point levee was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the levee in place. The outcomes of the revised damages assessment estimates that the north Darlington Point levee would reduce flood damage costs by $469,000 over the 50-year design life of the levee with an estimated reduction in annual average damages of approximately $34,000.

This yielded a preliminary benefit-cost ratio of less than 0.1.

Accordingly, the costs of construction of the levee outweigh the financial benefits anticipated as a result of its construction.

1.5 Comment on FM Option 1

The intention of a levee at north Darlington Point would be to protect existing development, not to facilitate future development. The flood damages assessment estimated 8 properties in the 2% AEP and 15 properties in the 1% AP design flood event would be impacted by over floor flooding. Over half of these properties are located in north Darlington Point.

The construction of a levee could encourage the residents of north Darlington Point to stay during a flood event rather than evacuate, when required and directed to do so. This would increase demand on the SES should the levee be overtopped, in addition to forcing these residents to potentially travel along roads that are inundated with flood waters. There would need to be significant and ongoing resources directed towards the education of the community of north Darlington Point regarding the residual risk associated with living behind a levee, including the potential that the levee maybe overtopped, or may fail during future flood events.

This option was generally supported by the community (over 50% of the community supported the option). In addition, the reduced inundation depths and extents across most of the north Darlington Point area would help reduce losses as a result of impacts to infrastructure, namely impacts to the roads. It may also afford some improvement to existing emergency response for the local area, however floodwaters are still predicted to inundate The Kidman Way to the north during the 0.5% AEP design flood event at Mirroool Creek and Whitton Darlington Point Road to the east. Therefore, although the roads in north Darlington Point are flood free up to the 1% AEP design flood event, vehicular access will not be possible to and from these roadways leading to north Darlington Point at floods greater than the 1% AEP design flood event.

There are a number of constraints the levee design and construction would need to take into consideration should this option be recommended, and these include:

- The terrestrial and biodiversity constraints and wetlands, as mapped in the Murrumbidgee LEP 2013. These constraints are currently mapped in or close to the general area where the levee embankment would potentially be located. If an earthen levee is recommended for north Darlington Point, the detail design would have to consider the terrestrial and biodiversity and wetland constraints as per the Environmental Planning and Assessment Act 1979 and the Murrumbidgee LEP 2013.
- There is currently one site of Aboriginal Heritage significance mapped in the northern parts of north Darlington Point identified as 'Kooba 111' on **Figure 6**. If an earthen levee is recommended for north Darlington Point, an Aboriginal Heritage Assessment (or similar) will need to be carried out to verify if there are additional unmapped sites of Aboriginal Heritage significance that would be impacted by the construction of the levee. Any proposed works would have to take into consideration the requirements of the National Parks and Wildlife Act 1974 and the Environmental Planning and Assessment Act 1979.
- There is currently one General Heritage Site mapped in north Darlington Point, as identified **Figure 6**. If an earthen levee is recommended for north Darlington Point, any proposed works would have to take into consideration the requirements of Murrumbidgee LEP 2013 and the Environmental Planning and Assessment Act 1979 related to heritage.
- Geotechnical investigations undertaken as part of the 2009 Worley Parsons Report (*Darlington Point Levee Rehabilitation Project: Phase A – Geotechnical Investigations and Options Assessment)* give a general understanding of the geotechnical conditions at north Darlington Point based on an assumed alignment. The report stated that the existing ground conditions and geotechnical characteristics would be suitable for use as foundation material for a new levee at north Darlington Point. Therefore, the assumptions included in the cost estimates undertaken as part of this study for a potential levee around north Darlington Point have used these same assumptions. A detailed geotechnical survey would have to be carried out on the proposed alignment to confirm

these assumptions should this option be recommended for further analysis and detail design.

- Almost the entire levee alignment would be located on land that is currently in private ownership. A minor allowance has been included in the cost estimate of this option for the acquisition of land based on acquiring the width for the levee embankment only (no allowance for access track land requirements), however this amount is subject to variation and could influence the final estimated cost of this option. If this option is recommended for further investigation, then a detailed valuation should be undertaken on costs to acquire the land or easement for the levee to provide required access requirements as a very preliminary allowance has been made in these cost estimates.
- No allowance was made for the upgrade of internal stormwater drainage requirements for areas behind the levee.
- No allowance has been made for the relocation of existing infrastructure, such as underground pipes or conduits. A Dial-Before-You-Dig investigation query was lodged and there are a number of assets in north Darlington Point that may be impacted by the construction of a levee, these include:
    - *NBN in Narrand Street / Whitton Darlington Point Road, Darlington Street, Uri Street/Kidman Way.*
    - *Essential Energy in Narrand Street / Whitton Darlington Point Road, Darlington Street, Tubbo StreetUri Street/Kidman Way and the sub-station in the northern parts of north Darlington Point on Kidman Way.*

  If any further investigations are undertaken related to the construction of a permanent levee around north Darlington Point, a detailed services search should be undertaken during the initial stages of that work, to gain a greater understanding of the impacts on, and potential costs related to, infrastructure and services. These may also influence the alignment and footprint size of the levee in particular locations.

Protection from all flooding up to and including the 1% AEP design flood event (and potentially greater floods) would provide a boost to the residents of north Darlington Point. The questionnaire responses (received as part of the stage 1 community consultation) revealed the sentiment, by some respondents, that north Darlington Point does not receive the same priority as Darlington Point from government agencies and investors alike, as a result of its vulnerability to flooding.

Overall, the north Darlington Pont levee appears to afford some benefits, however these come at a significant financial cost. The levee does not provide a significant reduction in flood damages due to the small number of properties that currently experience over floor flooding that would be beneficially impacted by this option. The levee would afford the additional benefit of providing flood free access around the north Darlington Point road network, however there is potential for the roads beyond this area to be inundated with floodwaters. Further investigations are not recommended.

1.6 Evaluation of FM Option 1

Table H.3 - Evaluation outcomes on the north Darlington Point levee option

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**+1**	Beneficial reductions in flood levels and extents across north Darlington Point, however some minor increases in flood levels anticipated at the existing Darlington Point levee and properties to the east of north Darlington Point.
Inundated Buildings	**+1**	15 buildings no longer inundated above floor level during 1% AEP design flood event.
Emergency Response	**0**	Reduced inundation depths across most of north Darlington Point including road access, however roadways to the north and east would still be inundated during flood events greater than the 1% AEP design flood event. May encourage residents to stay in their homes, increasing demand on SES if levee is over topped.
Technical Feasibility	**-1**	There may be some technical limitations associated with the acquisition of the land/easement for the full length of the levee that is required. There may be issues associated with the footprint of the required levee due the location of the existing buildings and infrastructure.
Environmental Impacts	**-1**	May involve removal of some vegetation to implement. Maybe opportunities to reinstate vegetation after construction in some areas.
Economic Feasibility	**-2**	Low BCR with a high capital cost and relatively high ongoing maintenance costs.
Community Acceptance	**+1**	Just over 50% of the community indicated support for this option.
SCORE	**-1**	

1.7 Summary of FM Option 1 Assessment

Option 1 is not recommended for further investigation.

2 FM Option 2 – Temporary Levee to Protect North Darlington Point

2.1 Concept Design of Option 2

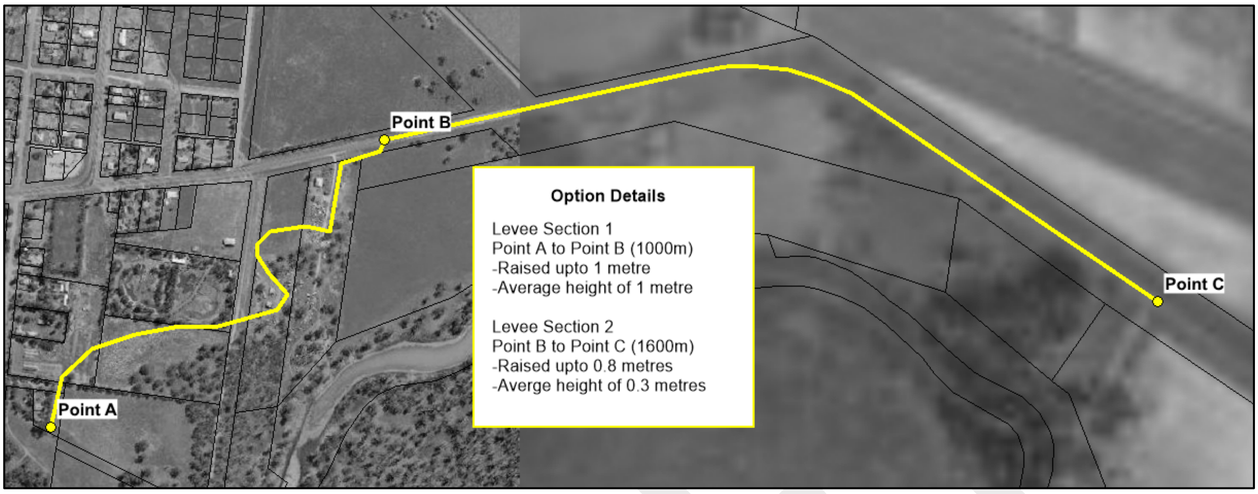


Plate H.6 – FM Option 2 concept design

The option of a temporary levee was also investigated for North Darlington Point. Once the cost and cost benefit ratio was determined for a permanent earthen levee around Darlington Point, the opportunity to provide a temporary levee was investigated to determine whether the benefit cost ratio for a levee protecting the properties of north Darlington Point could be improved.

The alignment of the temporary levee has been refined based on the location of existing development and structures in the area and the characteristics of the floodwaters as they travel into and around north Darlington Point. The earthen levee investigated as part of the options analysis involved significant costs and land / easement acquisitions. The floodwaters can remain around north Darlington Point for a number of weeks and months, so a temporary flood levee would only be in place and provide protection until these floodwaters started to recede.

The potential location of the temporary levee is shown in **Plate H.6**. This temporary levee would essentially be in two sections that overlap in the middle. The first section would run from the southern extent of Darlington Street and progress in an easterly direction along an alignment that would follow the lower topography of the lots towards Beach Road, before travelling in a north-westerly direction to Narrand St/Whitton Road. There are three (3) dwellings that this levee would traverse around. This section of temporary levee would have an approximate length of 900 metres. At Narrand Street/Whitton Road, the temporary levee could be placed on the road carriageway for an approximate length of 1.5 kilometres. Thus, a different type of temporary levee could be employed along this straighter, flatter section. Alternatively, a small permanent style of levee could be built along this section in the road verge area, with the temporary levee section employed through the private properties to the west of this levee during flood events only.

The concept design for this temporary levee arrangement includes:

- Temporary levee crest level along the section between Darlington Street and Beach Road of approximately one (1) metre high that traverses open space on the private properties. This would provide almost 0.50 metres freeboard to the highest 1% AEP design flood level in this section and approximately 0.25 metres freeboard to the 0.2% AEP design flood level. Based on the existing flood levels, it is anticipated that the crest of the temporary levee would be overtopped by floodwaters in the extreme flood event up to a maximum of 0.03 metres.
- Temporary levee along Narrand Street / Whitton Road would have an approximate height of 0.50 metres.

A second sequence of modelling was undertaken by increasing the temporary levee height by one (1) metre.

There are a number of styles of temporary levees that could be employed for this situation. Each of these example levee types below are reusable. Some examples of temporary levees include –

- Floodline - Aluminium A-Frame base with giant panels with a wraparound membrane out over it - https://www.floodingsolutions.com.au/single-post/2016/07/06/Floodline;
- Portable Cylinder Flood Barriers – Glass Reinforced Plastic sheet that is formed into a cylinder and waterbag liners fit inside the cylinder and filled with water. Plastic membranes placed along the line of cylinders and the front held in place with plastic bags - http://www.floodcontrolinternational.com.au/PRODUCTS/FLOOD-BARRIERS/pcfb.php
- Flexible tubes that are only filled with water once tubes are in place- https://www.apexenvirocare.com.au/aqua-barrier/aqua-barrier-water-inflated-dam.html#aqua-barriers https://www.bluemont.com.au/flood-prevention/mobile-flood-barrier-tubes-by-nofloods/

2.2 Cost Estimate of Option 2

A cost estimate was prepared for the temporary levee around the southern part of north Darlington Point and is included in **Appendix G**. It is to be noted that the cost estimate for the temporary levee component was based on an average of the estimated costs provided by suppliers of the temporary levee propriety devices as listed above. This estimated that the temporary levee would cost on average approximately $2 million to supply. There are several propriety devices that could be supplied for approximately $1.2 million (Bluemont NoFlood barrier and Aqua Barrier by Apex Envirocare). This levee would only be paced in location during a flood event and could be stored at Murrumbidgee Council depot in Darlington Point in non-flood times. No allowance for ongoing maintenance costs have been included in the cost estimate for this option. It is assumed that the post flood clean-up of council assets would involve cleaning of the temporary flood barriers (primarily involves hosing down the outside of the temporary levee infrastructure) and packing away.

Some proprietaries of these devices have indicated that the temporary levee components could be hired for the duration of the flooding, rather than bought outright. Hiring the levee components, which includes resources from the propriety owner for the set-up of the infrastructure, could provide significant cost savings. The costs involved with the hire of the devices only was not pursued as part of this study. If the option of a temporary levee is supported by the floodplain management committee, then further details on the hiring of the infrastructure can be investigated.

2.3 Hydraulic Impact of Option 2

The hydraulic benefits of the levee were quantified by including the temporary levee in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the temporary levee in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the basin. The difference mapping is presented in **Plate H. 7 and Plate H. 8** for the 5% AEP and 1% AEP events respectively. **Plate H.9** and **Plate H.10** indicate the results for the levee with the additional height of one (1) metre applied to the levee crest.

The flood level difference mapping shows that at the proposed height, the temporary levee will lead to a reduction in the existing flood levels downstream in most parts of north Darlington Point of approximately 0.25 metres with some minor increases in the western side of north Darlington Point of between 0.03 metres and 0.07 metres. There will however be an increase in flood levels immediately upstream of the temporary levee of up to 0.11 metres. Ultimately, the increase in flood levels in this vicinity would result in in the temporary levee being overtopped, causing floodwaters to inundate north Darlington Point.

This option also leads to a significant reduction in the depths of floodwaters on the Kidman Way in the northern section of north Darlington Point, reducing depths of flooding across this section of road to less than 0.30 metres during the 1% AEP design flood event. This provides a vastly improved emergency access opportunity north to Griffith during the larger flood events should vehicles need to travel through the inundated road.

The flood level difference mapping also indicates that floodwater depths are estimated to increase across the floodplain for approximately 1.5 kilometres wide upstream of the levee. These increases are generally in the range of 0.02 metres to 0.03 metres, with some localised increases of between 0.15 metres to 0.20 metres estimated to occur adjacent to the Kidman Way and Hay Road (close to the junction with The Sturt Highway). These impacts appear greatest immediately downstream of Hay Road where there is existing development. These areas are currently zoned RU1 – Primary Production and generally covered with biodiversity constraints.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation (for the higher of the two temporary levee formations) are predicted as follows:

Table H. 4 - Hydraulic Impact of FM Option 2

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	0
2% AEP	-5	-1
1% AEP	-11	-8
0.5% AEP	+24	+3
0.2% AEP	+31	+4
Extreme flood event	+40	-39

Plate H. 7 – FM Option 2 floodwater level differences for the 5% AEP

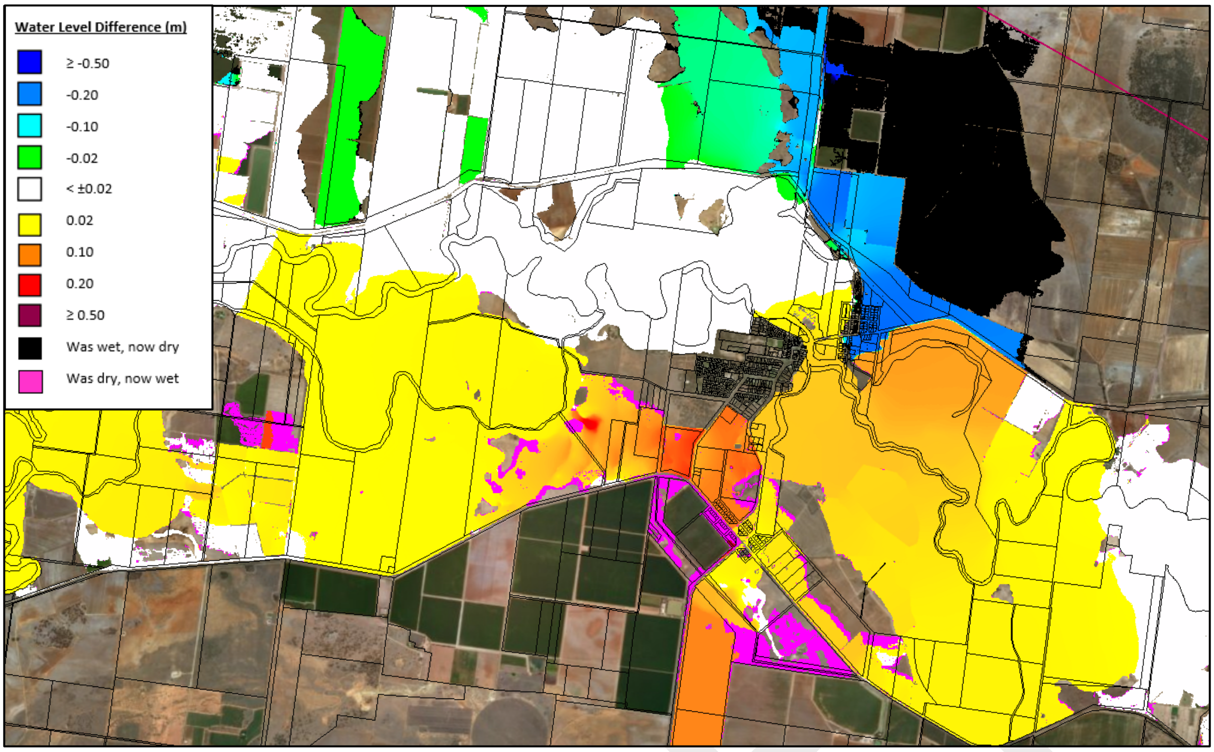


Plate H. 8 – FM Option 2 floodwater level differences for the 1% AEP

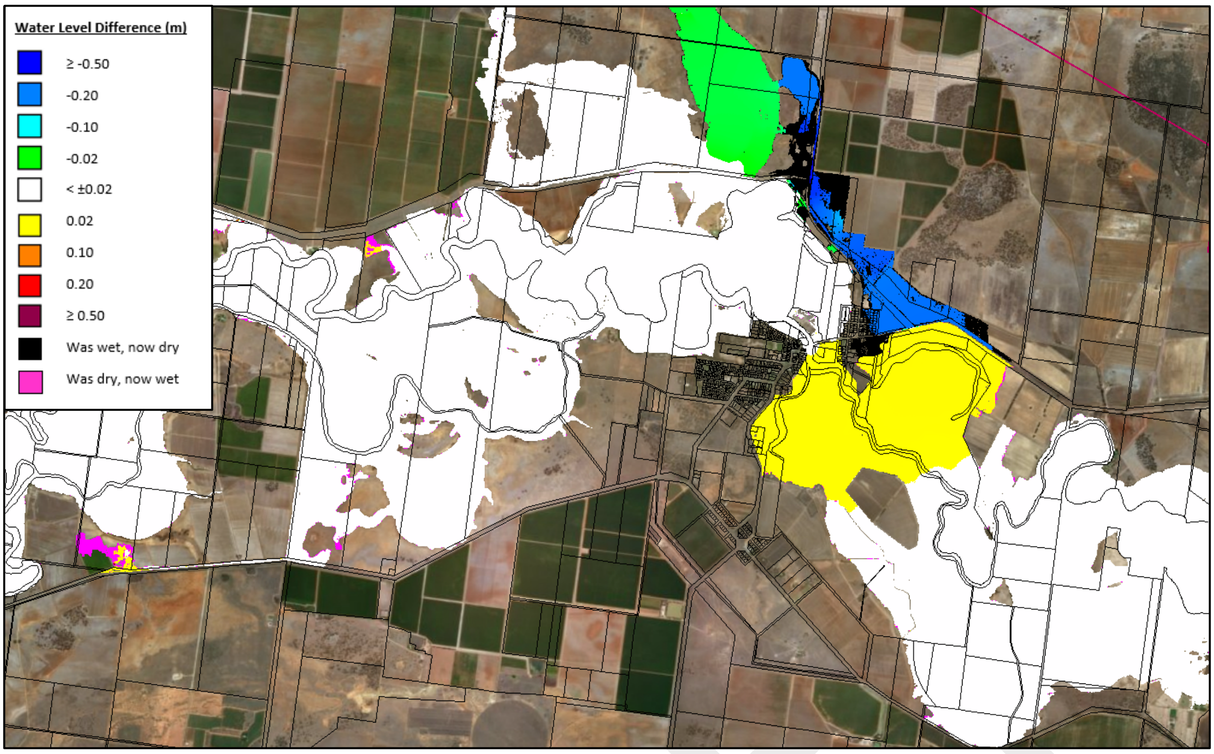


Plate H. 9 – FM Option 2 (with an additional 1m height) floodwater level differences for the 5% AEP

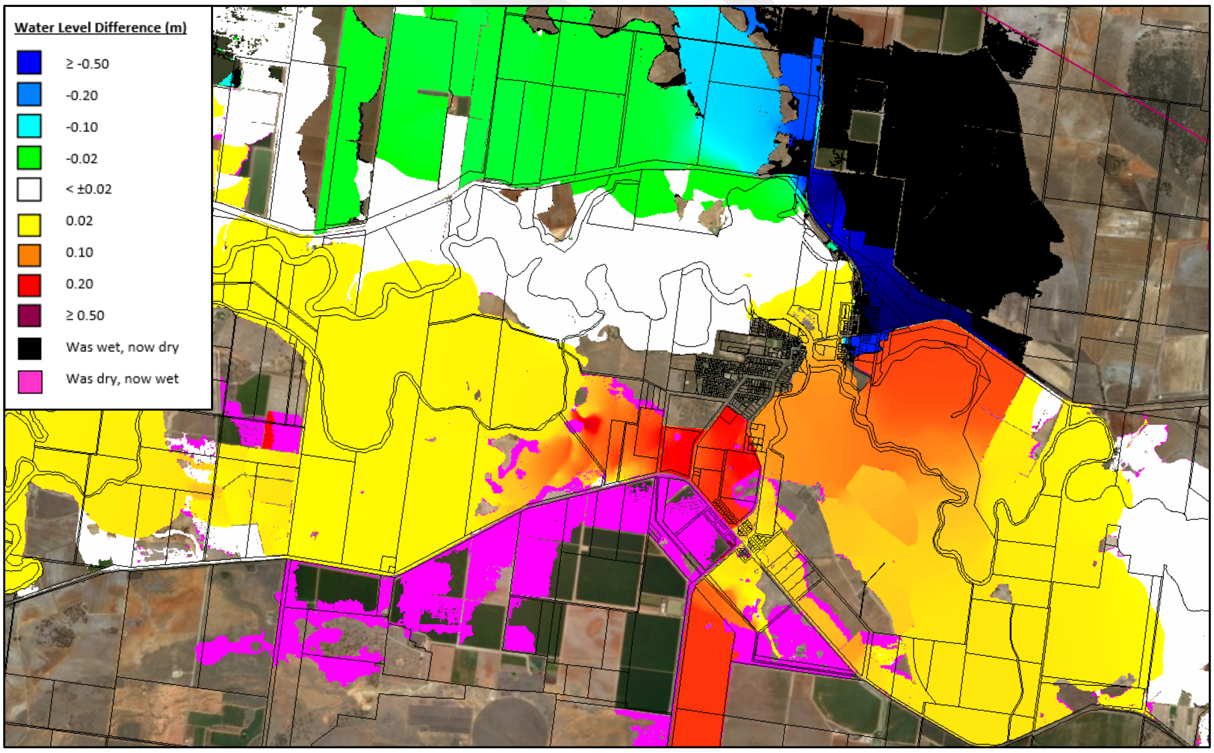


Plate H. 10 – FM Option 2 (with an additional 1m height) floodwater level differences for the 1% AEP

2.4 Reduction in Flood Damages

The potential financial benefit associated with implementation of a temporary levee to help protect north Darlington Point was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the temporary levee in place. The outcomes of the revised damages assessment estimates that the north Darlington Point temporary levee would reduce flood damage costs by $26,000 over a 50-year period. This 50-year period has been selected so that this option can be compared to other floodplain risk management options in this study.

These estimates yielded a preliminary benefit-cost ratio less than 0.1.

Accordingly, the costs associated with the implementation of a temporary levee significantly outweigh the financial benefits anticipated as a result of its implementation. If a more detailed analysis of this option is supported, then a more detailed financial estimate can be made based on the life cycle costs of the type of temporary levee selected to better inform the benefit cost ratio.

2.5 Comment on FM Option 2

The option of a levee around North Darlington Point was generally supported by the community however the option of providing this levee structure as a temporary one, rather than a permanent one, was not promoted at the time of the stage 1 community consultation. Therefore, it is not clear what the community support is for a temporary levee protecting North Darlington Point.

A temporary levee would facilitate a reduction of floodwater inundation depths across most of the north Darlington Point area. This would greatly assist existing emergency response utilising the Kidman Way north towards Griffith during flood events. Floodwaters are still predicted to inundate The Kidman Way to the north at Mirrool Creek in the 0.5% AEP design flood event. Floodwaters are also expected to inundate Whitton Darlington Point Road to the east, thus indicating vehicular access will not be possible along these roadways at the peak of the larger flood events.

There are a number of constraints a temporary the levee design and construction would need to take into further consideration should this option be considered further, and these include:

- Temporary levees have a much shorter guarantee for their length of service life than a more permanent structure. The life span of some of the temporary levee infrastructure components is 10 + years. Therefore, despite having a reasonable up-front cost, the ongoing costs may be higher and would require the renewal of the temporary levee infrastructure every 10 or so years These costs have not been included in the costs estimates for this analysis, potentially leading to a significantly reduced BCR.
- There is the possibility that there may be periods of 10 years or more with no major flooding experienced at Darlington Point, therefore the temporary levees would not be required and would most likely have to be replaced before it was deployed once.
- Third party impacts associated with the failure of the temporary infrastructure during a flood event is not clear. This may also include failure associated with the storage or non-

use of the infrastructure during non-flood times and the impacts on existing properties should flooding be exacerbated as a result of the failure of the temporary levee.

- The construction of a levee could encourage the residents of north Darlington Point to stay during a flood event rather than evacuate before flood waters reach the area, if directed to do so by the SES. Therefore, there could be additional demand placed on the SES to evacuate people after the area is inundated, should the levee be overtopped during a flood event. Thus, if this option is recommended, there would need to be significant and ongoing community education directed towards the residents of north Darlington Point regarding the residual risk associated with the implementation of a temporary levee during a flood event.
- Footprint or location of where the temporary levee would traverse would almost wholly be on private property. Thus, there would be an ongoing onus on Council and the SES to ensure this footprint remains free of permanent or non-moveable obstacles so that the levee cold be installed when required.
- The installation of the levee along the lower sections of properties may introduce local flooding issues behind the levee where water from the local overland flooding cannot escape into the Murrumbidgee River.
- The alignment of the levee itself would be only confirmed when on site during the deployment of the temporary levee infrastructure. Therefore, the alignment would be reliant on the intuition of the people deploying it and may vary from what has been modelled.
- The supplier of each of the proprietary devices listed in this analysis provides assertions to its performance during a flood event if the product is employed within its guarantee period and used as per its design intent. However, neither of these details can be guaranteed as part of the implementation of the recommendations from this study for a future flood event.
- As with any large scale and essential infrastructure that requires installation, there needs to be someone with knowledge on the correct installation methods for when the temporary levee would be required for use in a flood. Therefore, Council and the SES would have to ensure there is ongoing training to support these needs.
- There is the possibility that the structure may be deployed during rainfall events as elevated water levels are predicted along the Murrumbidgee River, however those levels may not be reached. Therefore, resources would be used deploying the structure, which does not result in the structure being used during the flood.
- There is potential that the footprint of the temporary levee may be close to terrestrial and biodiversity constraints, as mapped in the Murrumbidgee LEP 2013. Therefore, if a temporary levee is recommended as part of the flood risk management options of this study, the feasibility assessment would have to consider the terrestrial and biodiversity constraints as per the Environmental Planning and Assessment Act 1979 and the Murrumbidgee LEP 2013.

Although benefits of this option have been quantified in terms of a reduction in flood damage to properties, this potential damage reduction could vary depending on the performance of the temporary levee. Each supplier of a proprietary levee device provides assertions to its performance during a flood event if the product is within its guarantee period and used as per its design intent. However, neither of these details can be guaranteed to be undertaken during a flood event. As such, this option should be considered in the context of being able to provide a positive impact on the trafficability of the roads in and around north Darlington Point, particularly The Kidman Way, during extended inundation times from floodwaters. This option provides a significant reduction in floodwaters that inundate The Kidman Way going north to Griffith, which is identified in the SES Local Flood Plan as an evacuation route. The potential benefits this provides are difficult to provide with a quantifiable and tangible value.

A freeboard has not been applied to the temporary levee as applied to the design of a "standard earthen" levee. The exclusion of a freeboard mount reduces the effective level of protection the levee provides. Therefore, the level of protection provided by the temporary levee cannot be directly compared to the levee crest level that has been modelled.

Overall, the temporary levee around north Darlington Pont appears to afford some benefits, however these come with adverse impacts in other parts of the catchment and with fairly substantial financial impact. However, it does appear to alleviate some of the flooding issues from the north Darlington Point area in the larger flood events and assist with improving the trafficability of the Kidman Way for the duration of longer flood events (which can last for several months). Despite these benefits, this option has a very low cost-benefit ratio which makes it difficult to support for further investigation.

2.6 Evaluation of FM Option 2

Table H.5 - Evaluation outcomes on the north Darlington Point temporary levee option

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**+1**	Beneficial reductions in flood levels and extents across north Darlington Point and to the trafficability of the Kidman Way to Griffith, however some minor increases in flood levels anticipated upstream and adjacent to the Kidman Way and Hay Road south of Darlington Point,
Inundated Buildings	**+1**	11 buildings no longer inundated above floor level during 1% AEP event
Emergency Response	**+1**	Reduced inundation depths across most of north Darlington Point and close to elimination of floodwaters from access along the Kidman Way north to Griffith for floods up to and including the 0.2% AEP design flood event. Potentially very minor increase in flood depths across the Kidman way to the south of Darlington Point when in place. Would also afford additional evacuation time to the north, should floods greater than the 1% AEP design flood event be predicted.
Technical Feasibility	**-1**	Placement of structure during an event may not be in exact locations as included in the model, therefore potential for variation in outcomes of flood impacts. Acquisition and long-term maintenance of a temporary levee mechanism is costly. Potential to rent the device for the duration of flooding may reduce ongoing maintenance requirements and asset depreciation. Liability issues should the levee fail.

Evaluation Criteria	Rating	Comments
Environmental Impacts	**0**	Should involve minimal disturbance to vegetation and biodiversity constraints. Would only be in place during a flood event, so any impacts are temporary.
Economic Feasibility	**-2**	Low BCR with a reasonable capital cost and relatively high ongoing costs. Potential to rent the device for the duration of flooding may reduce ongoing maintenance requirements and asset depreciation.
Community Acceptance	**0**	Over 50% of the community indicated support for a permanent levee around north Darlington Point, however the support for a temporary levee is not known.
SCORE	**0**	

2.7 Summary of FM Option 2 Assessment

Option 2 is not recommended for further investigation.

3 FM Option 3 – Spillway Analysis

3.1 Concept Design of FM Option 3

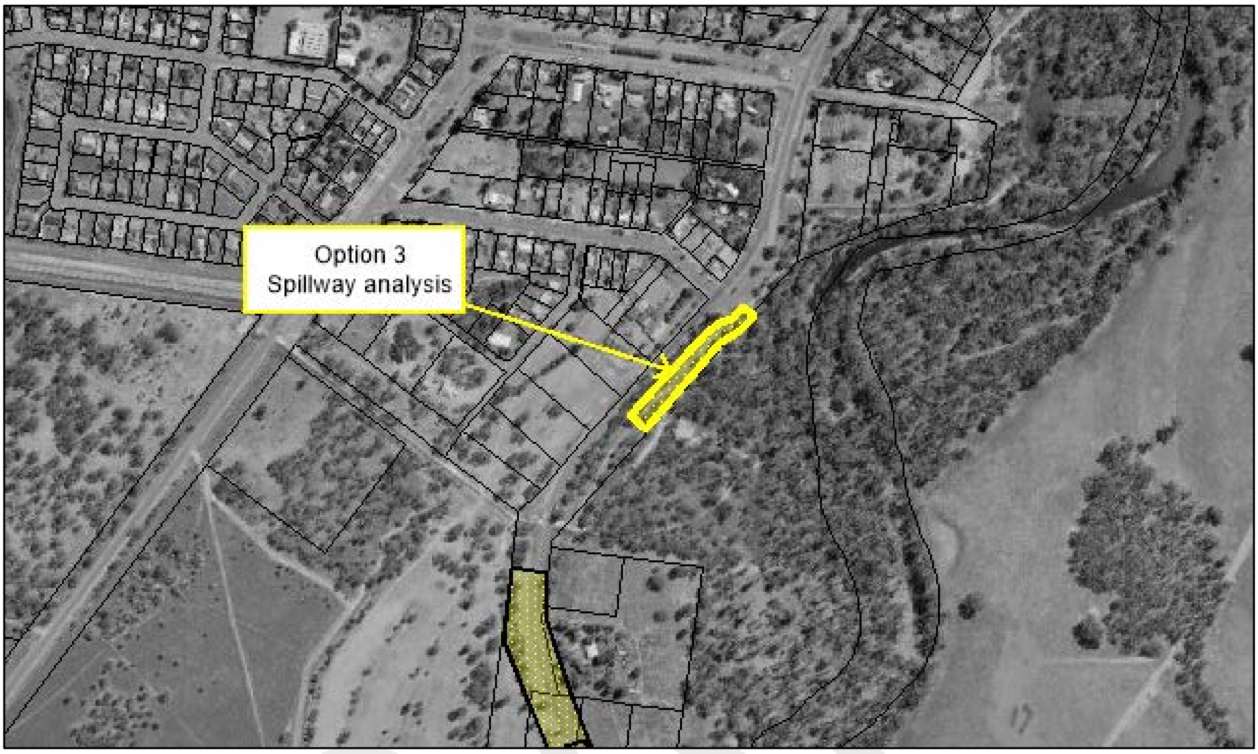


Plate H.11 – FM Option 3 – Location of spillway

The option of incorporating a formal spillway into the existing levee was investigated. This option considered the characteristics, location and impacts of the spillway included in the 2018 flood study and the factors considered in the freeboard analysis discussed in **Section 4.3** of the floodplain risk management study.

The primary benefit of introducing a spillway is that the area behind the levee is flooded in a slow and controlled manner. Without a spillway, the location of a breach that may occur during a flood is largely unknown. A breach may develop rapidly, leading to high hazard water pouring through the levee and into the town in locations that are not prepared for this rapid onset of floodwater and hazardous flooding conditions. A spillway will also assist in maintaining the structural integrity of the levee structure itself, controlling the flow over it.

Plate H.12 outlines the range of design flood heights that are estimated to occur adjacent to the existing levee, generally parallel to Stock Street. This plate outlines the limited flood range between all flood events, with the following differences estimated on average:

- between the 1% AEP and 0.5% AEP design flood events – 0.08 to 0.10 metres
- between the 1% AEP and 0.2% AEP design flood event – 0.15 metres
- between the 1% AEP and extreme flood event – 0.40 to 0.50 metres.

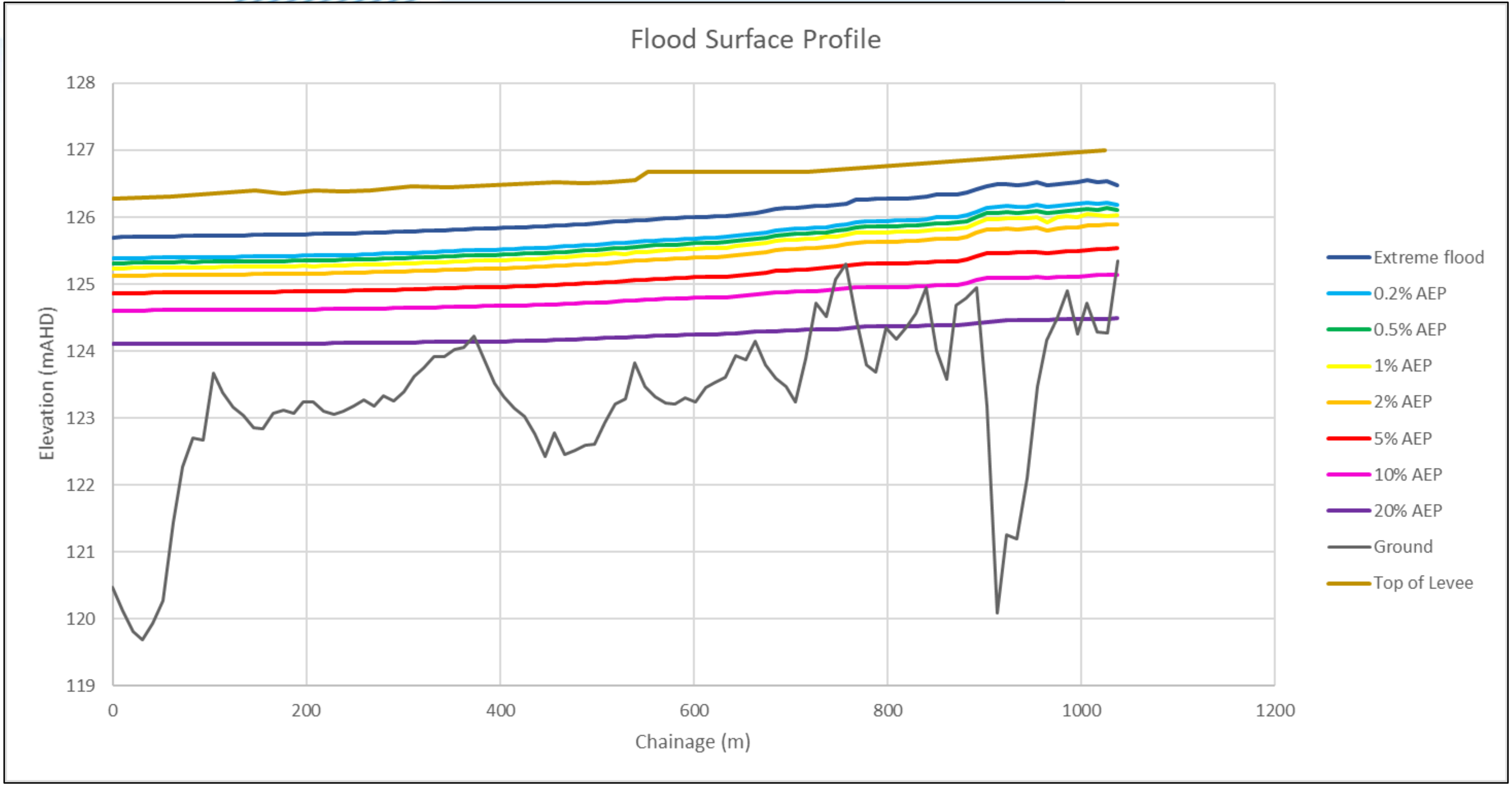


Plate H.12 -Flood surface profiles along the levee embankment parallel to Stock Street, Darlington Point

The level of the spillway was based on the freeboard determined during the freeboard analysis and the updated 1% AEP design flood level estimated in this study. This analysis determined that the spillway could be located at the 1% AEP design flood level with a freeboard of 0.45 metres, and with a width of 200 metres. The 200 metre width was used in the 2018 flood study and there was no obvious need to modify this width. This would enable the spillway to be approximately 0.30 metres below the general crest level of the upgraded levee.

The location of the spillway was also based on the spillway included in the 2018 flood study. As stated in that report, a spillway located at the downstream end of Darlington point, closer to the water treatment plant, would not provide the same efficiencies as a spillway located at the upstream sections of Darlington Point. Locating a spillway at the downstream end of the existing levee may not facilitate an efficient infilling of the area behind the levee to reduce the likelihood of hazardous conditions should the levee be breached during a flood event.

The potential location of the spillway is shown in **Plate H.11**. For the assessment of this option, this spillway was assumed to be of a generic broad crested weir shape made of reinforced clay, with associated erosion control measures implemented immediately downstream.

3.2 Cost Estimate of FM Option 3

A cost estimate was prepared for the spillway and is included in **Appendix G**. This determined that the construction of spillway in the existing levee would cost approximately $200,000.

No allowance for ongoing maintenance costs has been included in the cost estimate for this option as it has been assumed these would be included in councils existing asset management of the levee.

3.3 Hydraulic Impact of FM Option 3

The hydraulic benefits of the spillway were quantified by including the spillway in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, velocities and hazard with the spillway in place were determined for the 0.5% AEP, the 0.2% AEP and extreme flood events. Floodwater level difference mapping as a result of this option are include on **Plate H.13 and Plate H.14** for a spillway width of 200 metres**.**

A smaller spillway of 100 metres width was also modelled to determine the sensitivity of the flood characteristics with a smaller spillway. Floodwater level difference mapping as a result of this option are included on **Plate H.15 and Plate H.16** for a spillway width of 100 metres.

Some flood level differences were observed between the design flood events and the flood levels once this formalised spillway was implemented. Ultimately, the area behind the levee would be inundated during the flood events greater than the 0.2% AEP design flood event only, should a spillway be introduced at a level of 0.45 metres above the 1% AEP design flood level (approximately 0.30 metres below the top of the existing levee).

Analysis of these results to determine the cost-benefit ratio of this option has not been undertaken as the same number of properties would be impacted by floodwaters with or without the spillway, albeit in a more controlled manner with the spillway in place.

The option of constructing a spillway was not included as a specific or individual option included in the community survey undertaken during stage 1 of this study. Therefore, it is difficult to assign a qualitative score for the community acceptance of this option. Discussions carried out during floodplain committee meetings about the possibility of a spillway yielded generally negative responses from the committee members.

3.4 Reduction in Damages

A spillway would inundate areas behind the levee for events greater than the 0.2% AEP design flood event. As such, there would be no changes to the number of properties impacted by flooding in the scenario with a spillway in the levee and flood damages to the properties behind the levee from the existing scenario (with a breach estimated to occur in the current design flood modelling).

As this option will not impact on properties outside of the levee, there would be no changes to flood damages to properties outside of the levee.

3.5 Comment on FM Option 3

There are a number of considerations that require further refinement should a spillway be considered further, including:

- The existing levee is generally around 0.8 – 1.0 metres above the 1% AEP design flood level. Therefore, there is still approximately 0.65 metres freeboard in the 0.2% AEP design flood event and 0.3 – 0.4 metres freeboard in the extreme flood event. The 0.5% AEP design flood event and larger design flood events produce flood levels that are within the minimum freeboard (when modelled without a breach) and therefore have been modelled assuming a breach of the levee.
- However, in the freeboard analysis undertaken for this study (**Appendix D**), there are some conservative assumptions, such as 0.3 metre inclusion for model uncertainty where other studies within NSW have used 0.2 metres for similarly accurate models. Therefore, it is conceivable that for the 0.5% AEP and 0.2% AEP design flood events, the levee would not be breached. In these instances, the spillway may induce flooding within Darlington Point which may not have occurred if no spillway were constructed.
- Given this possibility, and that there would only be a benefit for events greater than the 0.2% AEP, such as the extreme flood, a spillway is not recommended.
- Location of the spillway and the potential impacts immediately downstream of the spillway, particularly as there are existing developments in the vicinity of the spillway included in this analysis.
- Performance of a spillway versus the likelihood and performance of the upgraded levee being overtopped without a spillway in place. The levee crest levels indicate there is 0.75 metres freeboard to the 1% AEP design flood level. This implies that the levee may only breach in events greater than the 0.5% AEP design flood event. This is approximately the same level that a spillway was recommended to be located at.
- The levee crest levels indicate there is 0.75 metres freeboard to the 1% AEP design flood level, approximately 0.65 metre freeboard to the 0.5% AEP design flood level, 0.55 metres to the 0.2% AEP design flood level and between 0.35 and 0.25 metre freeboard to the extreme flood event.

- Construction of a spillway in a levee and embankment in a section of levee that has recently been completed.
- It is possible that an uncontrolled breach may occur in a different location and that in the extreme event, a breach is likely to occur regardless of the existence and location of the spillway.
- Emergency management of Darlington Point would involve evacuation should a flood greater than the design flood height of the upgraded levee (1%AEP design flood event) be forecast. Therefore, the introduction of a spillway would not reduce the risk to life or flood damage to property expected behind the levee. If anything, it would have the potential to increase the potential flood damage to properties by facilitating the inflow of floodwaters at a lower level than the current levee breach height.

Overall, this analysis has not exposed a clear hydraulic benefit to introduce a spillway into the upgraded levee at Darlington Point. The current levee provides a justifiable level of protection to the 1% AEP design flood event with a 0.75 metre freeboard.

It is to be noted that the spillway analysis and a freeboard analysis of the existing levee was carried out in this study and summarised in **Section 4** of the floodplain risk management study. The assumptions included in the freeboard analysis include a maintenance regime for the levee. This would involve the levee being appropriately maintained as per current best practice and general asset management principles, and as Council currently undertakes for infrastructure throughout the LGA. This will ensure that the levee will continue to function as designed and will safeguard the results and recommendation of the spillway analysis presented here.

3.6 Evaluation of FM Option 3

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**0**	No changes in flood levels and extents for the areas behind the levee to existing design flood events. A spillway may facilitate less hazardous flooding conditions for the areas behind the levee should the levee be breached.
Inundated Buildings	**0**	No changes to buildings inundated above floor once the levee or spillway is breached.
Emergency Response	**0**	No changes to emergency response requirements as the levee maintains a level of protection of the 1% AEP design flood level plus a freeboard. Flooding predicted in excess of the 1% AEP design flood would still require the evacuation of Darlington Point.
Technical Feasibility	**-1**	Challenges associated with construction of a spillway in the recently upgraded levee embankment
Environmental Impacts	**0**	Negligible environmental impacts.
Economic Feasibility	**-1**	BCR not determined however can be costly to implement. Repair costs to levee would vary if a spillway was not

Evaluation Criteria	Rating	Comments
		introduced and the levee was breached in alternate and unknown location/s.
Community Acceptance	**0**	Appears to neither have support or critics from the community
SCORE	**-2**	

3.7 Summary of FM Option 3 Assessment

Option 3 is not recommended for further investigation.

Plate H.13 – FM Option 3 (with a 200m wide spillway) floodwater level differences for the 0.5% AEP

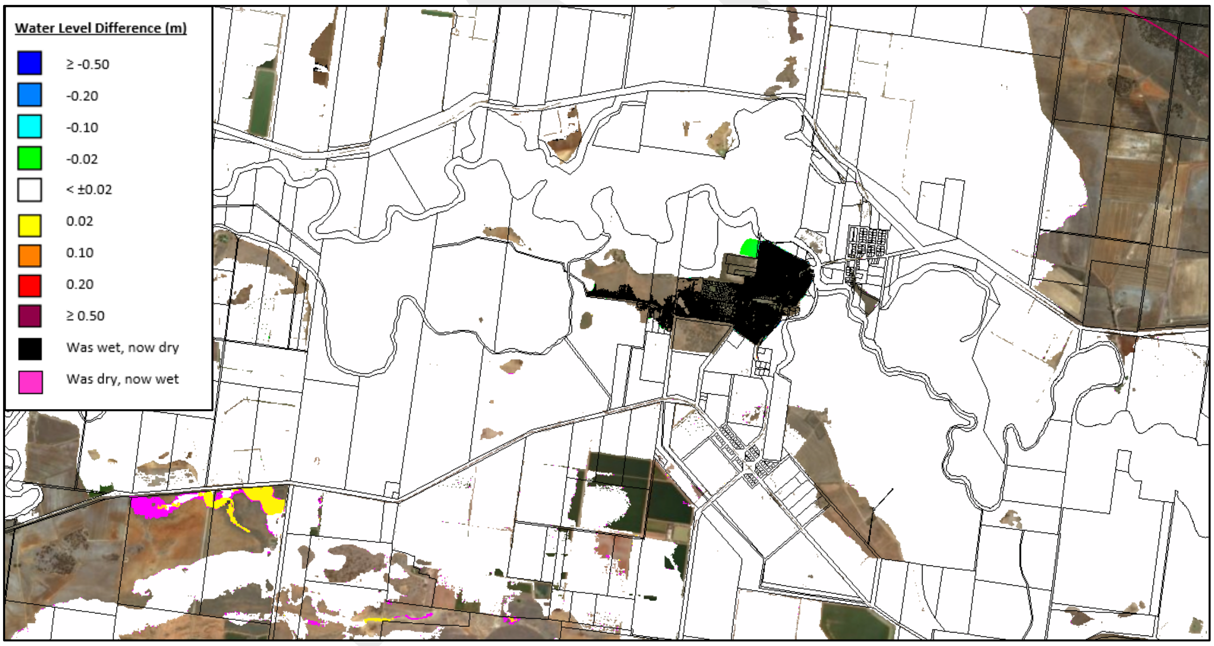


Plate H.14 – FM Option 3 (with a 200m wide spillway) floodwater level differences for the 0.2% AEP

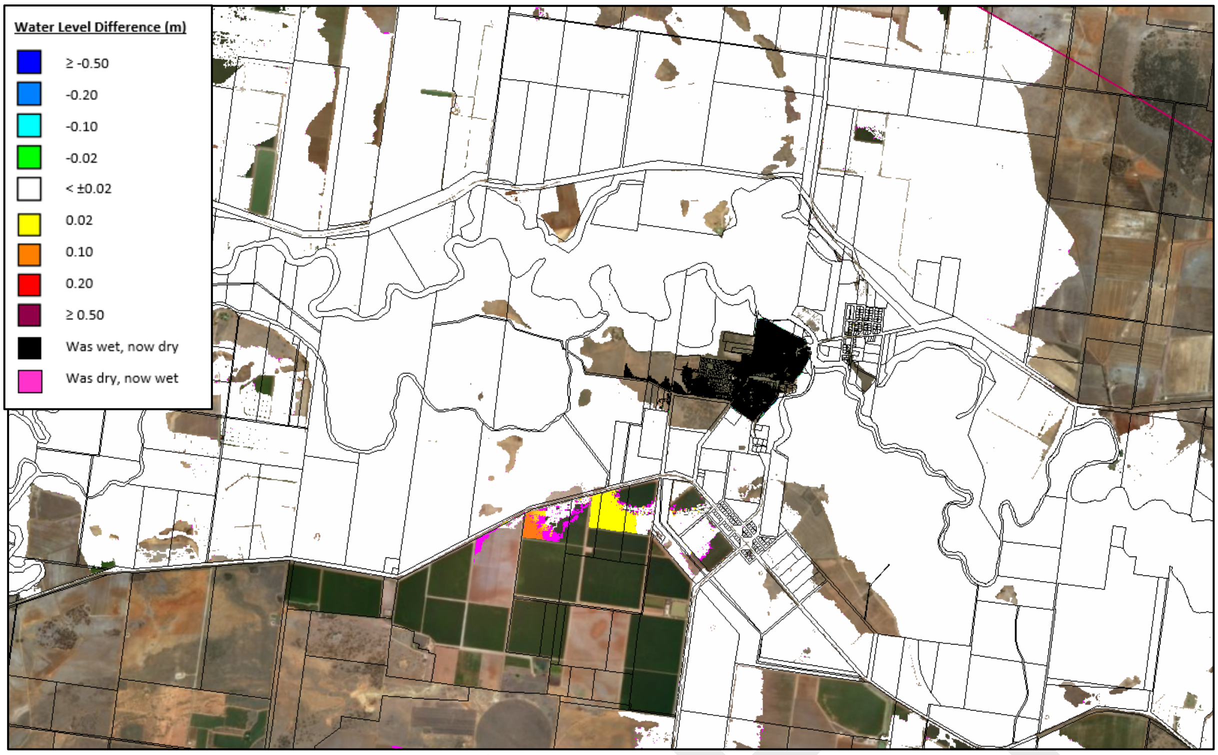


Plate H.15 – FM Option 3 (with a 100m wide spillway) floodwater level differences for the 0.5% AEP

Plate H.16 – FM Option 3 (with a 100m wide spillway) floodwater level differences for the 0.2% AEP

4 FM Option 4 – Bypass Channel Along Travelling Stock Reserve in North Darlington Point

4.1 Concept Design of FM Option 4

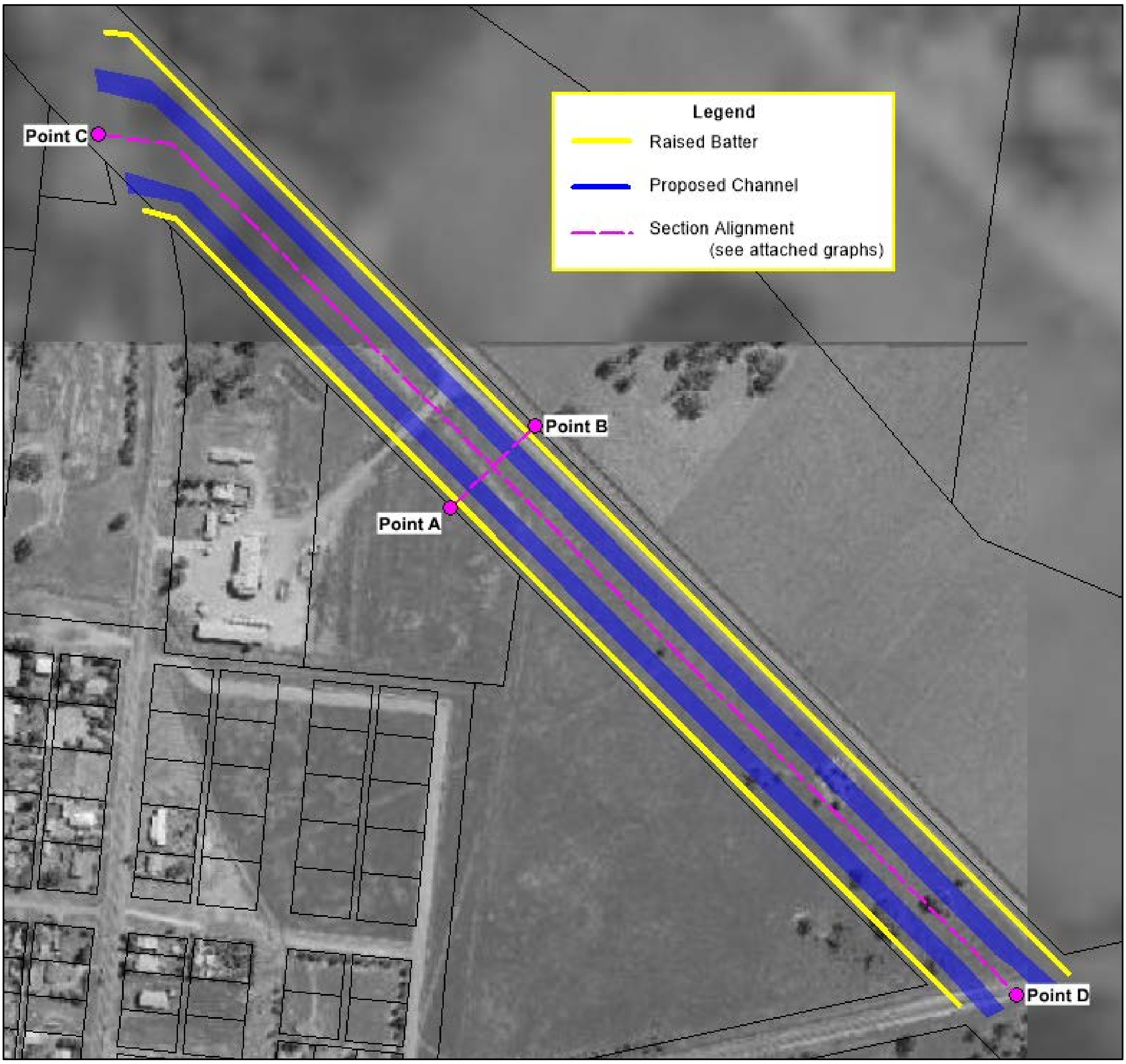


Plate H. 17 – FM Option 4 concept design

The opportunity to use Travelling Stock Reserve in the eastern section of north Darlington Point as a flowpath to help redirect floodwaters around north Darlington Point was assessed. The design flood modelling indicates floodwaters inundate this area initially as a result of elevated water levels in the Murrumbidgee River. Water overflows from Darlington Lagoon, across Whitton Darlington Point Road and travels northwards, inundating the roads and private property in the eastern section of north Darlington Point, before re-joining the Murrumbidgee

River floodplain downstream of north Darlington Point, through channels in the National Park area.

The Travelling Stock Reserve is approximately 100 metres wide. The relief floodway would aim to provide an additional flow path starting at the culverts under Whitton Darlington Point Road, travelling northwards to the area adjacent to the electricity sub-station on Kidman Way (north-western section of north Darlington Point). The culverts would be upgraded at the upstream and downstream extents of this flowpath under each of the roadways to assist with the passage of floodwaters under each road crossing.

Key features of the Travelling Stock Reserve relief floodway are shown in **Plate H.18** and includes:

1. Two channels, each with a width of approximately 15 metres utilising part of the Travelling Stock Reserve cross sectional area, from Whitton Darlington Point Road to The Kidman Way.
2. Preservation of an approximate 20 metre wide corridor for stock, maintaining existing pathway characteristics (dirt, graded) between the two channels.
3. Installation of two low level bridges at the upstream and downstream extents of the flowpath. One bridge to facilitate the passage of floodwaters under Whitton Darlington Point Road and one under The Kidman Way.

As discussed in floodplain risk management study**Error! Reference source not found.**, the area around Narrand Street/ Whitton Darlington Point Road in north Darlington Point, is vulnerable to flooding in events as frequent at the 5% AEP design flood event. This flooding is primarily driven from floodwaters first inundating land on the eastern side of north Darlington Point as floodwater overflows from Darlington Lagoon. As the flooding becomes more severe, these floodwaters traverse Narrand Street / Whitton Darlington Point Road and travel northwards, until they join back into the floodplain of the Murrumbidgee River via the channels that flow through the National Park to the west of the Kidman Way.

The alignment of the existing Travelling Stock Reserve in this area is advantageous as it is in the same direction floodwaters naturally travel, therefore provides an opportunity for use as a more formal overland flowpath. Floodwaters naturally enter this area from Darlington Lagoon in the south, and travel northwards on the eastern side of north Darlington Point along the existing grade of the land. This option also provides an opportunity to return these overland floodwaters into the Murrumbidgee River floodplain on the western side of The Kidman Way at an earlier location that naturally occurs, where it currently adds to the flood hazards associated with flooding around the junction of The Kidman Way and Murrumbidgee River Road.

The NSW Government has classified the Travelling Stock Reserve as a medium conservation value in this area. Discussions would have to be held with Local Land Services as to the viability of reshaping part of this Travelling Stock Reserve for flood mitigation purposes.

The potential location and characteristics of the flowpath along the Travelling Stock Reserve are shown in **Plate H. 17**. One open channel with an approximate width of 15 metres was included on the eastern side of the pathway, and one on the western side.

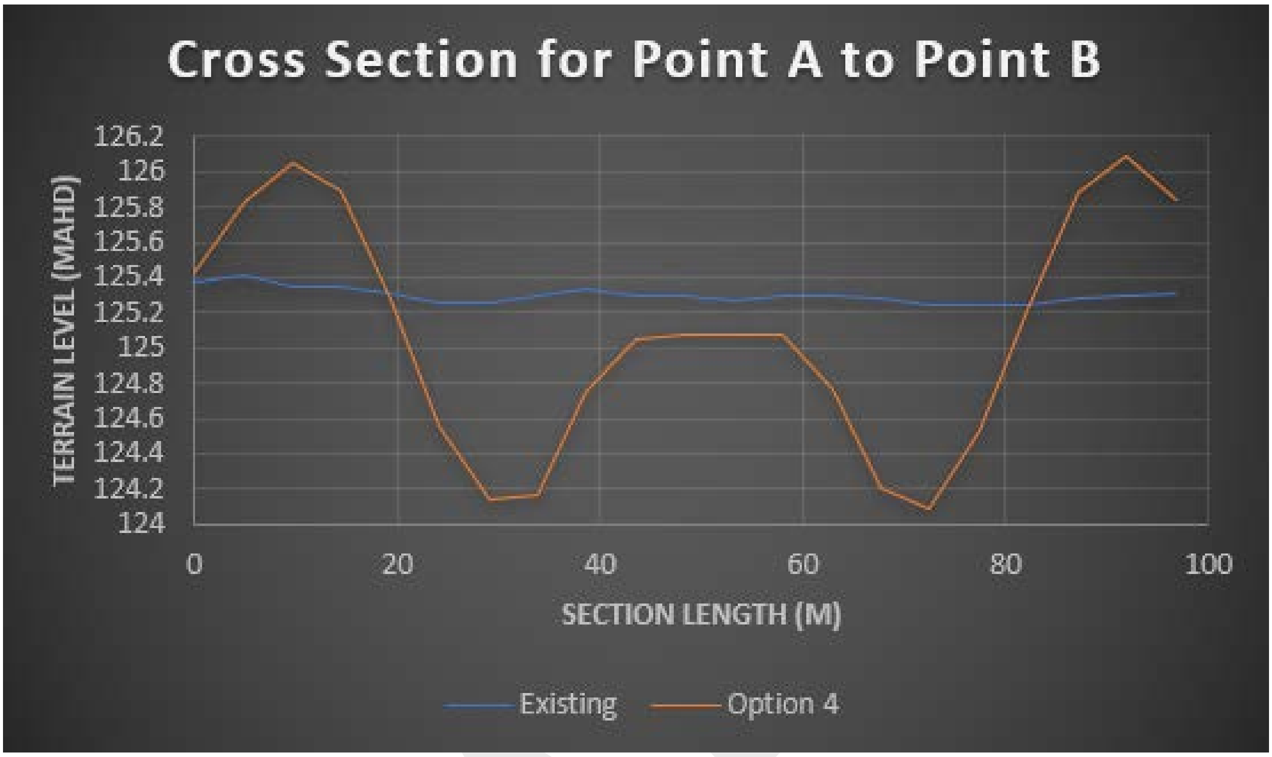


Plate H.18 - FM Option 4 Cross Section A - B

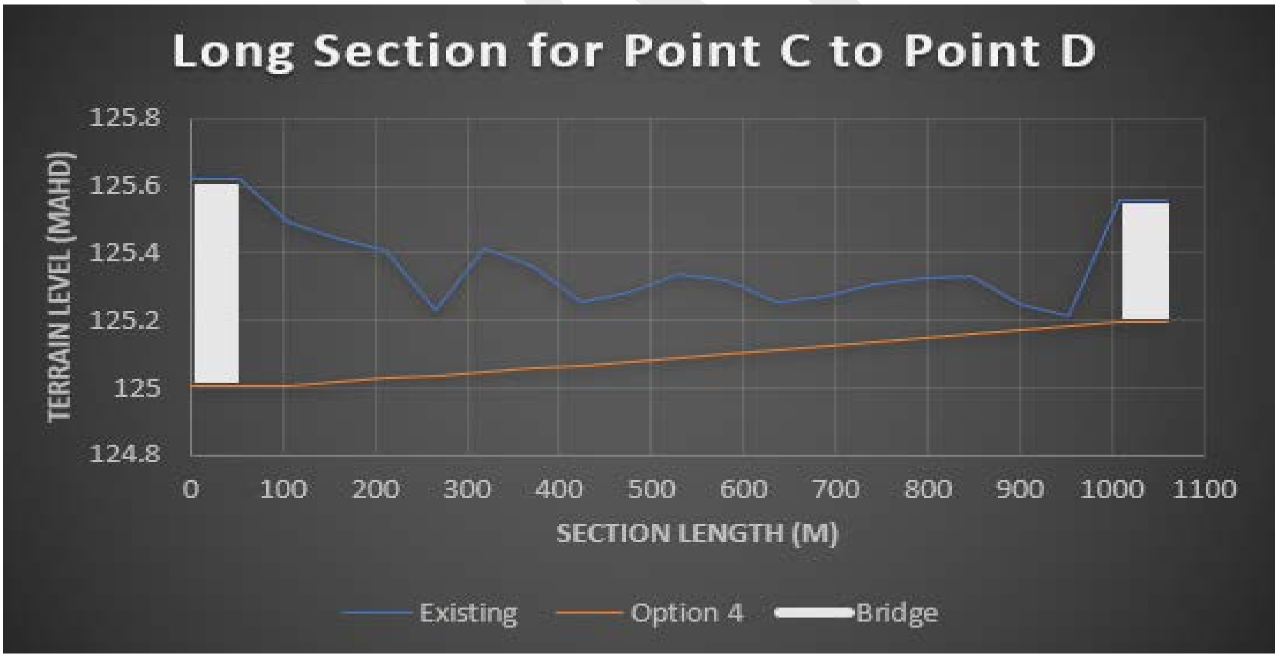


Plate H. 19 - FM Option 4 Long Section C – D

A low levee one (1) metre high levee bordering the eastern and western sides of the Travelling Stock Reserve is included. These channels will help mitigate the overflow of floodwaters into the surrounding overbank areas. As shown in **Plate H.** 17, **Plate H.18** and **Plate H.19** , the concept design for the earthen levee incorporates:

- Two open channels with 15 metres width, with side embankments slopes of approximately 3H:1V to one (1) metre depth.
- Side levee embankments along the length of the Travelling Stock Reserve of one (1) metre height, with side embankments slopes of approximately 3H:1V.
- Turfing of embankments to help manage slope stabilisation.
- Excavation at southern end of Travelling Stock Reserve to provide a continuous downward grade from the south to the north of the flowpath.
- Low level bridge structure at Narrand Street/ Whitton Darlington Point Road crossing.
- Low level bridge structure at The Kidman Way crossing.

4.2 Cost Estimate of FM Option 4

A cost estimate was prepared for the flowpath along the Travelling Stock Reserve and is included in **Appendix G**. This determined that construction of the flowpath along the Travelling Stock Reserve would cost approximately $6.1 million. A significant proportion of these costs are associated with the supply of low-level bridge structures included at the upstream and downstream extents of the flowpath.

4.3 Hydraulic Impact of FM Option 4

The hydraulic benefits of the flowpath along the Travelling Stock Reserve were quantified by including the upgraded flowpath in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the flowpath in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the basin. The difference mapping is presented in **Plate H.20**, **Plate H.21** and **Plate H.22** for the 5% AEP and 1% AEP and 0.2% AEP events respectively.

The flood level difference mapping shows that the flowpath along the Travelling Stock Reserve will help to alleviate flooding to the east of the flowpath by significantly reducing flood levels in this areas by up to 0.50 metres in the 1% AEP design flood event. However, it would also lead to increases flood levels to the western section of north Darlington Point of approximately 0.02 metres. Larger increases of up to 0.20 metres are expected immediately downstream of the opening under the Kidman Way however these impacts extend over a very small area and are very localised. The increase in flood levels did not extent past the floodplain sections of the National Park. The reduction in flood levels continue several kilometres northwards.

The reduction in volume of floodwaters reaching the intersection of the Kidman Way and Murrumbidgee River Road would help to alleviate the inundation of the roadway in this area during flood events.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as follows:

Table H. 6 - Hydraulic Impact of FM Option 4

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	0
2% AEP	0	0
1% AEP	0	0
0.5% AEP	0	0
0.2% AEP	0	2
Extreme flood event	+1	1

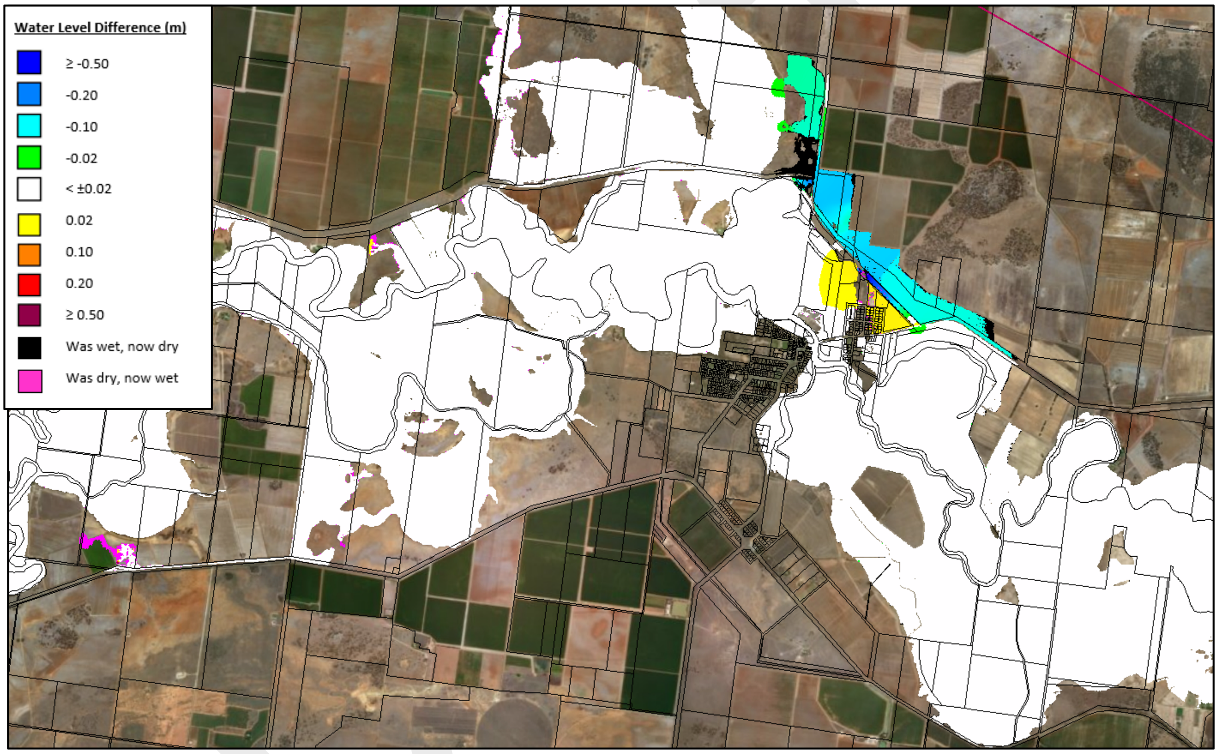


Plate H.20 – FM Option 4 floodwater level differences for the 5% AEP

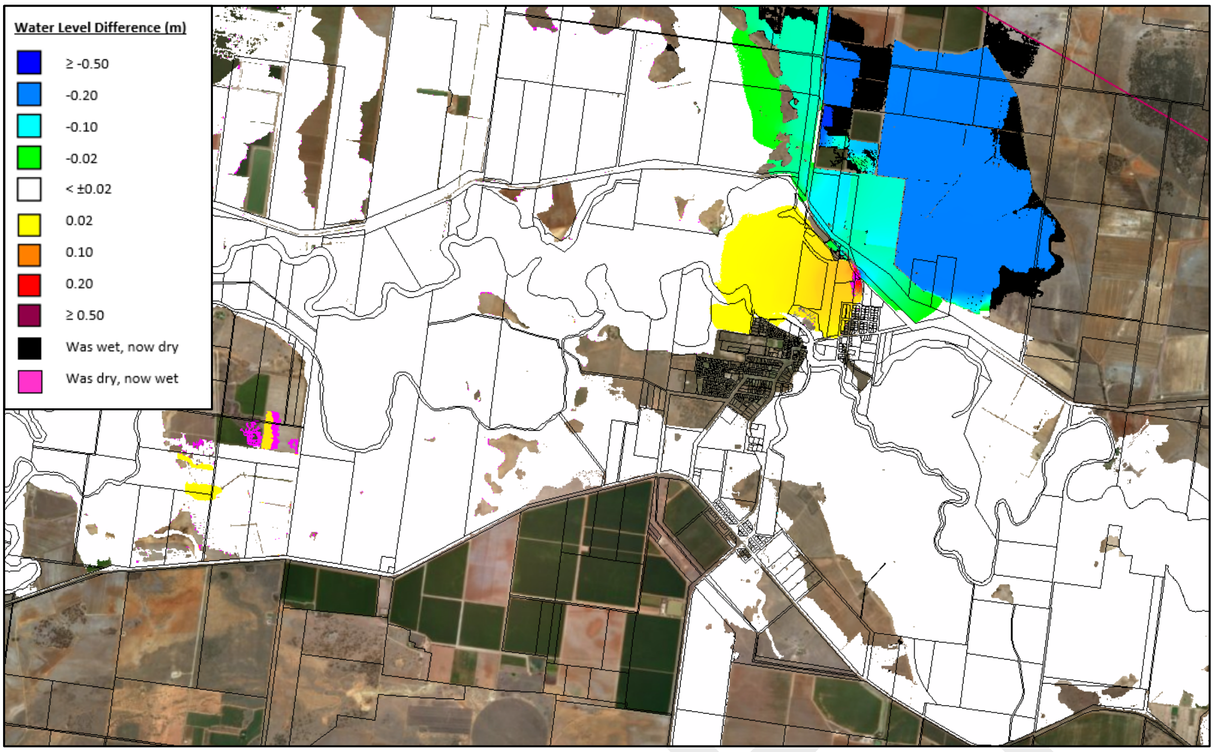


Plate H.21 – FM Option 4 floodwater level differences for the 1% AEP

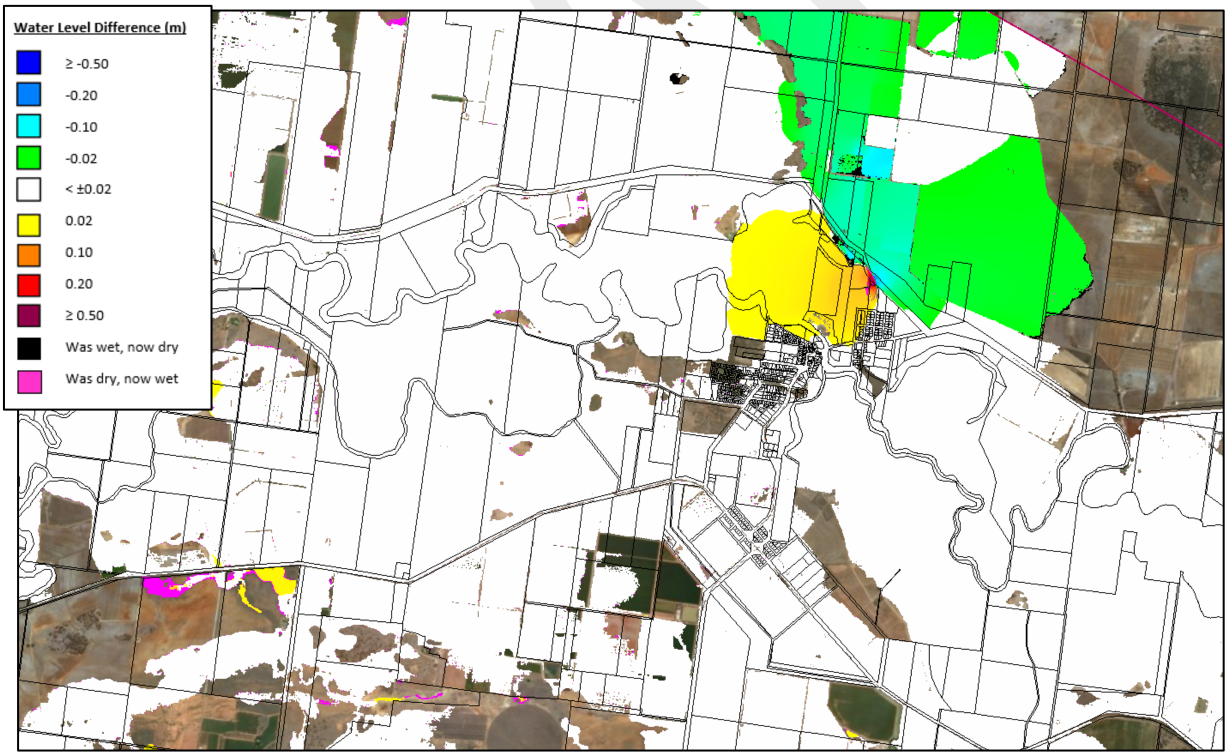


Plate H.22 – FM Option 4 floodwater level differences for the 0.2% AEP

4.4 Reduction in Flood Damages

A review of the results of all design flood simulations indicate there is no difference with the number of properties subject to above floor inundation compared to existing conditions. The outcomes of the revised damages assessment estimates that the flowpath along the Travelling Stock Reserve would not reduce flood damages when considering flood damage to property only. Accordingly, there is minimal potential financial benefit associated with implementation of the flowpath along the Travelling Stock Reserve in north Darlington Point. Based on the reduction in flood damages, there would be a benefit cost ratio of 0.

4.5 Comment on FM Option 4.

This option was not included in the suite of options presented to the community as part of the community survey undertaken during stage 1 of this study. However, the option to upgrade roads so they are less susceptible to flooding had a positive support response rate of 75% from the community. Additionally, discussion during the FRMC meetings suggested that the community was supportive of work to increase flow along the Travelling Stock Reserve.

There are a number of constraints the flowpath along the Travelling Stock Reserve would need to take into further consideration should this option be considered further, and these include:

- The NSW Government has classified the Travelling Stock Reserve (TSR) as a medium conservation value in this area. Discussions would have to be held with Local Land Services as to use of this TSR as a formal flowpath, and to the viability of reshaping part of this TSR for flood mitigation purposes whilst maintaining its standard of service for stock travel.
- This option also required some earthworks to form small channels from the culverts under the roadways at either end (the Kidman Way in the north and Whitton Darlington Point Road in the south) to ensure floodwaters were not impacting on adjacent properties.
- The effectiveness of this option was highly influenced by the size of the openings at the upstream and downstream ends of the flowpath. Culverts were initially included in the design modelling, however, were found to be ineffective at conveying floodwaters through them efficiently. Therefore, there is potential to reduce the costs of this option if alternate culverts or bridge openings are utilised for the crossings of the Kidman Way and Whitton Darlington Point Road.
- The terrestrial and biodiversity constraints, as mapped in the Murrumbidgee LEP 2013. These constraints are currently mapped along sections of the Travelling Stock Reserve. If the TSR is to be formed into a formal flowpath for floodwaters, the detail design would have to consider the terrestrial and biodiversity constraints as per the Environmental Planning and Assessment Act 1979 and the Murrumbidgee LEP 2013.

Overall, the use of the Travelling Stock Reserve as a formal flowpath for floodwaters appears to afford some benefits in terms of flood depths and extents across the floodplain in this location. These outcomes come with financial costs that are not matched by any quantifiable reduction in the flood damages to the existing properties.

4.6 Evaluation of FM Option 4

Table H. 7 - Evaluation outcomes on the flowpath along Travelling Stock Reserve in north Darlington Point

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+1	Beneficial reductions in flood levels and extents across the eastern sections of north Darlington Point and to the trafficability of the Kidman Way to Griffith, however some minor increases in flood levels anticipated upstream and adjacent to the Kidman Way.
Inundated Buildings	0	No change in buildings inundated above floor level during 1% AEP design flood event
Emergency Response	+1	Improvements in the trafficability of flood depths on Whitton Darlington Point Road and The Kidman Way going north. Reduced inundation depths across most of north Darlington Point local roads and properties.
Technical Feasibility	-1	Approval from Local Land Services to reshape the Travelling Stock Reserve to construct the channel may be difficult.
Environmental Impacts	0	Should involve minimal disturbance to vegetation and biodiversity constraints, however area has terrestrial and biodiversity constraints mapped along in on Murrumbidgee LEP 2013. The flowpath would only be active during a larger flood event, so any impacts as a result of floodwater inundation are anticipated to be temporary.
Economic Feasibility	-2	BCR = 0 as no changes in quantifiable flood damages.
Community Acceptance	+1	Over 70% of the community indicated support to upgrade roads so they are less susceptible to flooding.
SCORE	**0**	

4.7 Summary of FM Option 4 Assessment

Option 4 is not recommended for further investigation.

5 FM Option 5 – Improving Flow Conveyance Under the Kidman Way South of Darlington Point

5.1 Concept Design of FM Option 5

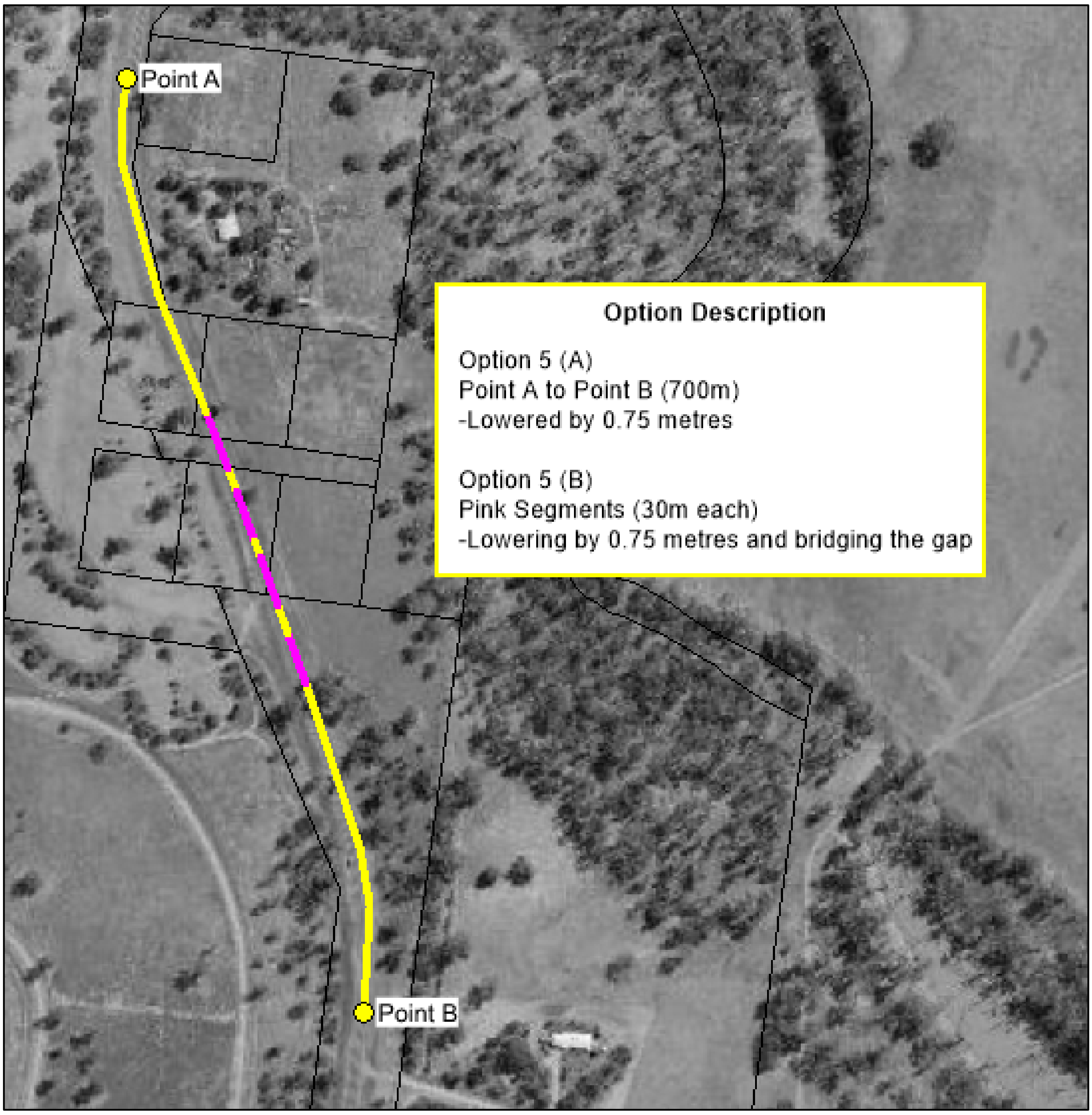


Plate H.23 – FM Option 5 (A) and Option 5 (B) concept designs

The design event modelling for floods greater than the 2% AEP design flood event revealed what appeared to be a high level flowpath that breaks westward out of the Murrumbidgee River floodplain and travels across The Kidman Way south of Darlington Point. In the 1% AEP design event flood, floodwater depths through this flowpath are between 0.25 and 0.5 metres deep.

Opportunity to utilise and expand upon this high level flowpath to help alleviate flood impacts at Darlington Point was assessed.

The potential location of the flowpath is shown in **Plate H.23**. This option started off by lowering the crest levels of The Kidman Way, effectively forming a causeway for this stretch of roadway. This option was refined as the modelling progressed, with the two different design scenarios detailed below.

The option was initially design as a 700-metre-wide causeway along the southern sections of the Kidman way. This extreme design enabled a complete assessment of the ultimate benefits channels works could have in alleviating flood hazards through these southern sections of Darlington Point. This option is referred to as **Option FM 5A**.

The causeway was modified, to try to maintain flow conveyance in this area from east to west, whilst also providing vehicular access along the Kidman Way south of Darlington Point. A series of low-level culverts along a length of approximately 100 metres of the lowest section of the Kidman Way were included in the model to replace the causeway. This option is referred to as **FM Option 5B**. The concept design for the flowpath incorporating a series of culverts under The Kidman Way incorporates:

- Eight (8) concrete culverts with the dimensions of 600mm wide x 450mm high
- Appropriate earthworks to construct adequate foundation and bedding for the concrete culverts.
- Reconstruction of the road pavement to match existing conditions.

5.2 Cost Estimate of FM Option 5

5.2.1 FM Option 5A

A cost estimate was prepared for the construction of the causeway along the Kidman Way is included in **Appendix G**. This determined that the road and civil works would cost approximately $1.42 million to construct. As this road forms part of Councils existing road network, there would not be a significant variation to the ongoing maintenance costs for this option as it would be included on Councils existing asset management regime.

5.2.2 FM Option 5B

A cost estimate was prepared for the construction of the floodway under the Kidman Way is included in **Appendix G**. This determined that the road and civil works would cost approximately $3.08 million to construct. As this road forms part of Councils existing road network, there would not be a significant variation to the ongoing maintenance costs for this option as it would be included on Councils asset management plan. This design also assumes a certain waterway area through the culverts. Therefore, regular maintenance of the culvert inlets and outlets would need to be undertaken to ensure debris or rubbish do not collects within or adjacent to them.

5.3 Hydraulic Impact of FM Option 5

5.3.1 FM Option 5A

The hydraulic benefits of the 700m-wide-causeway were quantified by including the causeway in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the high level flowpath / causeway in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the construction of a 700m wide causeway at this location. The difference mapping is presented in **Plate H.24**, **Plate H.25** and **Plate H.26** for the 20% AEP and 1% AEP and 0.2% AEP events respectively.

This 700-metre-wide causeway resulted in significant changes in flood impacts both downstream in the Murrumbidgee River channel and to the west of this high flow channel through the rural area. Flood level increases up to 0.37 metres were anticipated immediately downstream of the causeway, reducing to 0.20 metres a further 2 kilometres downstream. Minor increases in flood levels continued for 10 kilometres or so downstream. It is estimated there are flood level reductions of approximately 0.25 metres in the Murrumbidgee River channel and up to 0.19 metres around north Darlington Point during the 1% AEP design flood event. This option resulted in greater depths of floodwaters inundating The Kidman Way south of Darlington Point during all design flood events.

A review of the results of all design flood simulations indicate that there are a significant number of properties who are currently subject to above floor inundation that are predicted to no longer be impacted. However, the severity of flooding will increase for properties downstream of the Kidman Way in the immediate vicinity of the works where there are existing residential dwellings.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as:

Table H. 8 - Hydraulic Impact of FM Option 5A

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	+2	+1
2% AEP	-5	+3
1% AEP	-4	0
0.5% AEP	-142	-80
0.2% AEP	-123	-21
Extreme flood event	-40	+9

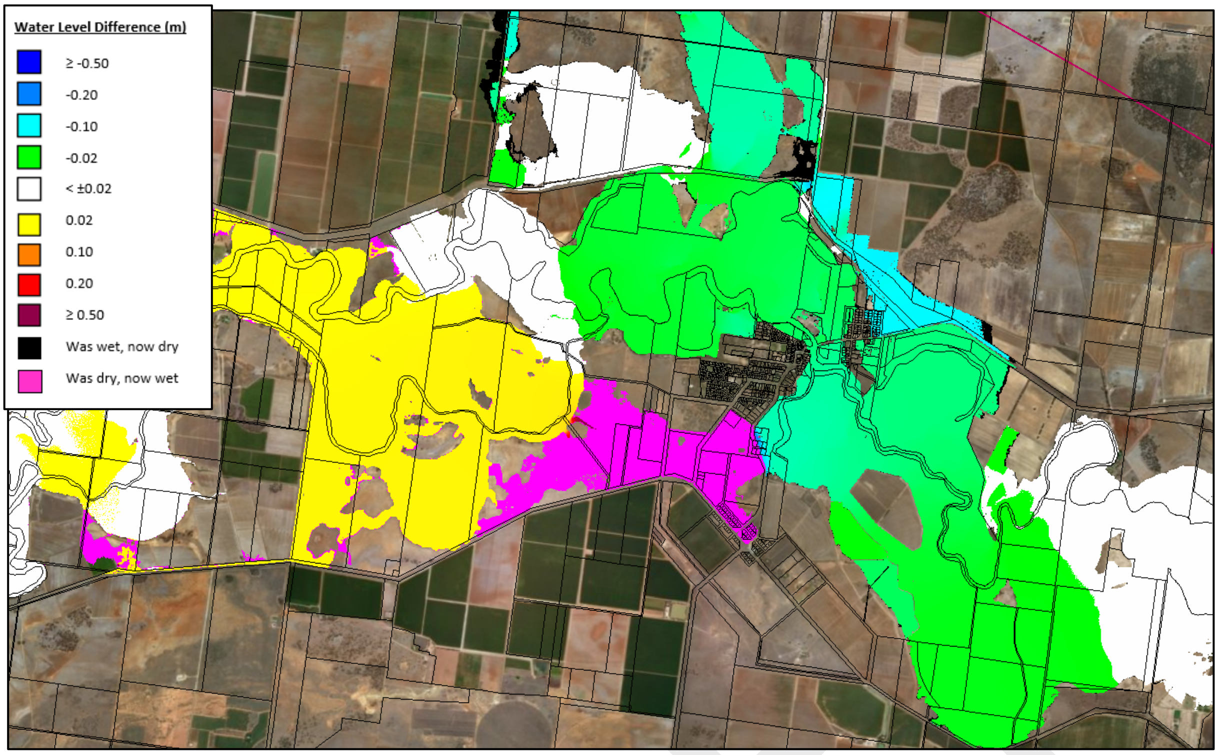


Plate H.24 – FM Option 5 (A) floodwater level differences for the 5% AEP

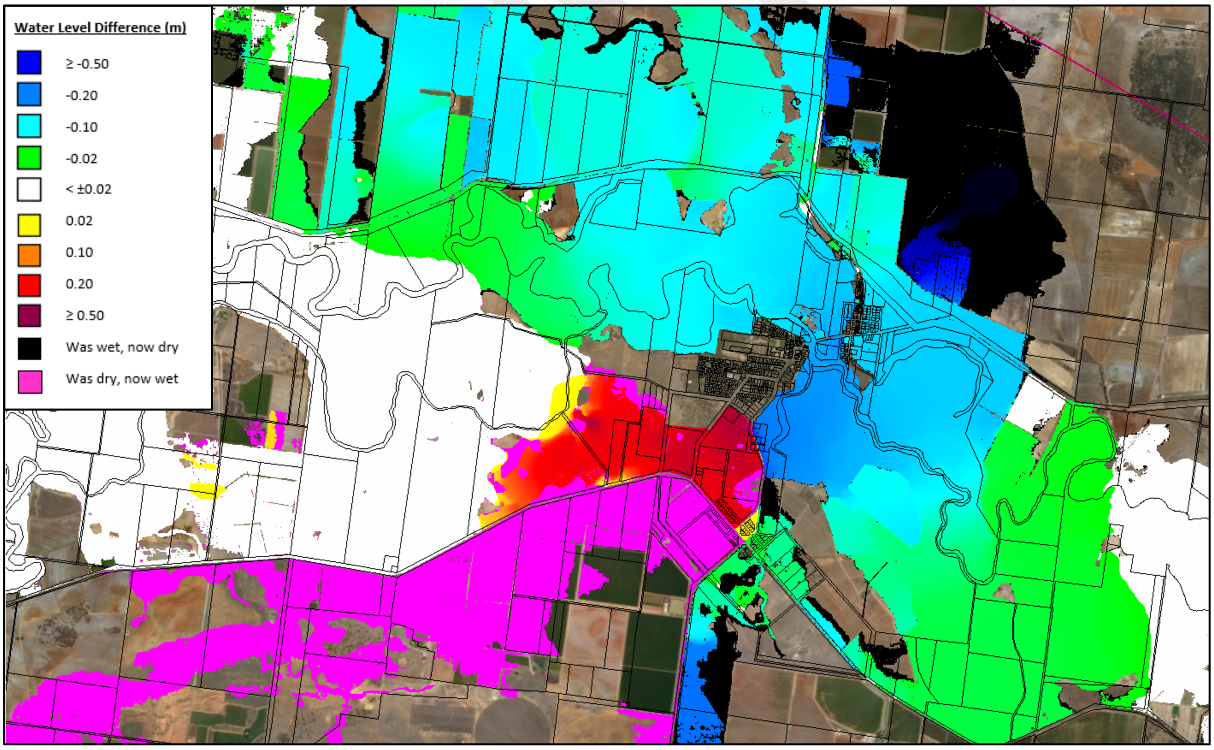


Plate H.25 – FM Option 5 (A) floodwater level differences for the 1% AEP

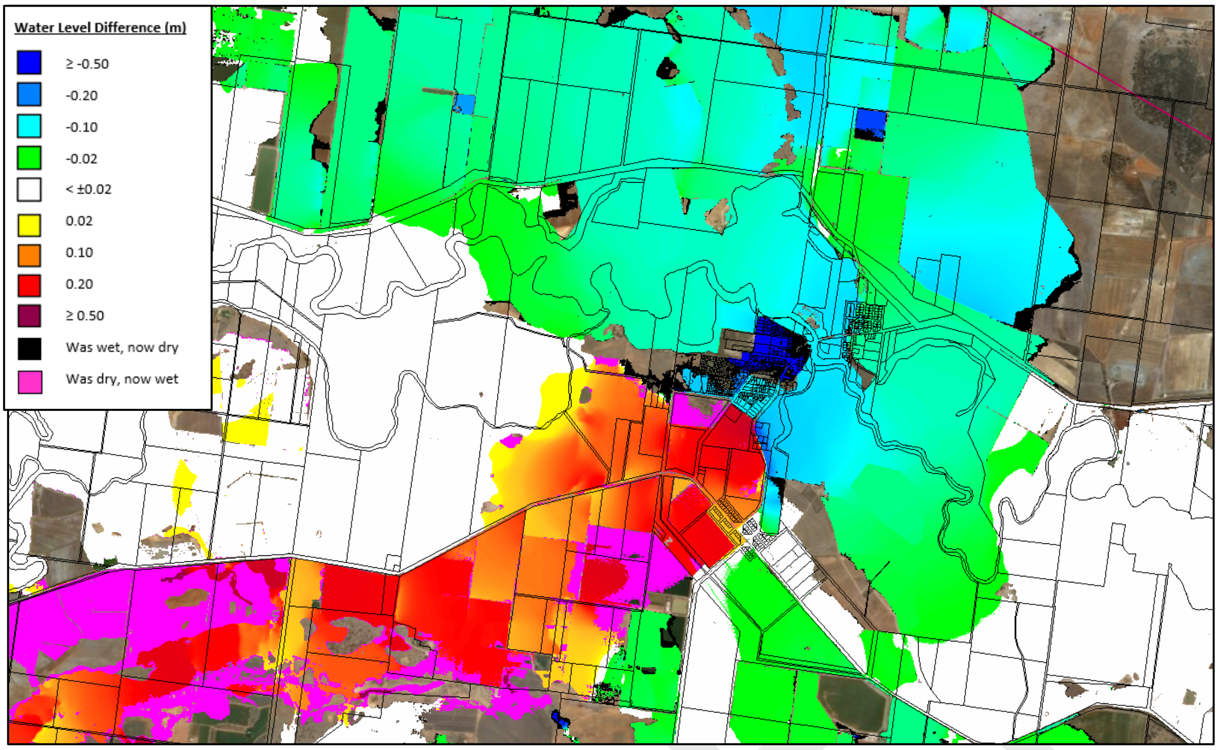


Plate H.26 – FM Option 5 (A) floodwater level differences for the 0.2% AEP

5.3.2 FM Option 5B

The hydraulic benefits of the culverts under The Kidman way were quantified by including the series of culverts under the Kidman Way in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the culverts in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the implementation of culverts under the Kidman Way. The difference mapping is presented in **Plate H.27**, **Plate H.28** and **Plate H.30** for the 20% AEP and 1% AEP and 0.2% AEP events respectively.

This implementation of the series of culverts under the low point of The Kidman Way impacted flood levels over a length of almost 20 kilometres in the Murrumbidgee Channel in the 1% AEP design flood event. These reductions were very minor (approximately 0.01 metres) extending from around 7 kilometres upstream and 9 kilometres downstream of north Darlington Point. However, flood levels immediately downstream of The Kidman Way increased by approximately 0.20 metres in the 1% AEP design flood event, with some areas impacted by changes up to 0.50 metres. These impacts were magnified during the 5% AEP design flood event, with increases of up to 0.50 metres expected downstream of The Kidman Way, with only minor decreases of up to 0.02 metres expected in the Murrumbidgee River and north Darlington Point.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as:

Table H. 9 - Hydraulic Impact of FM Option 5B

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	+2	+2
2% AEP	-3	+2
1% AEP	0	-2
0.5% AEP	-61	+11
0.2% AEP	-3	-1
Extreme flood event	-5	+4

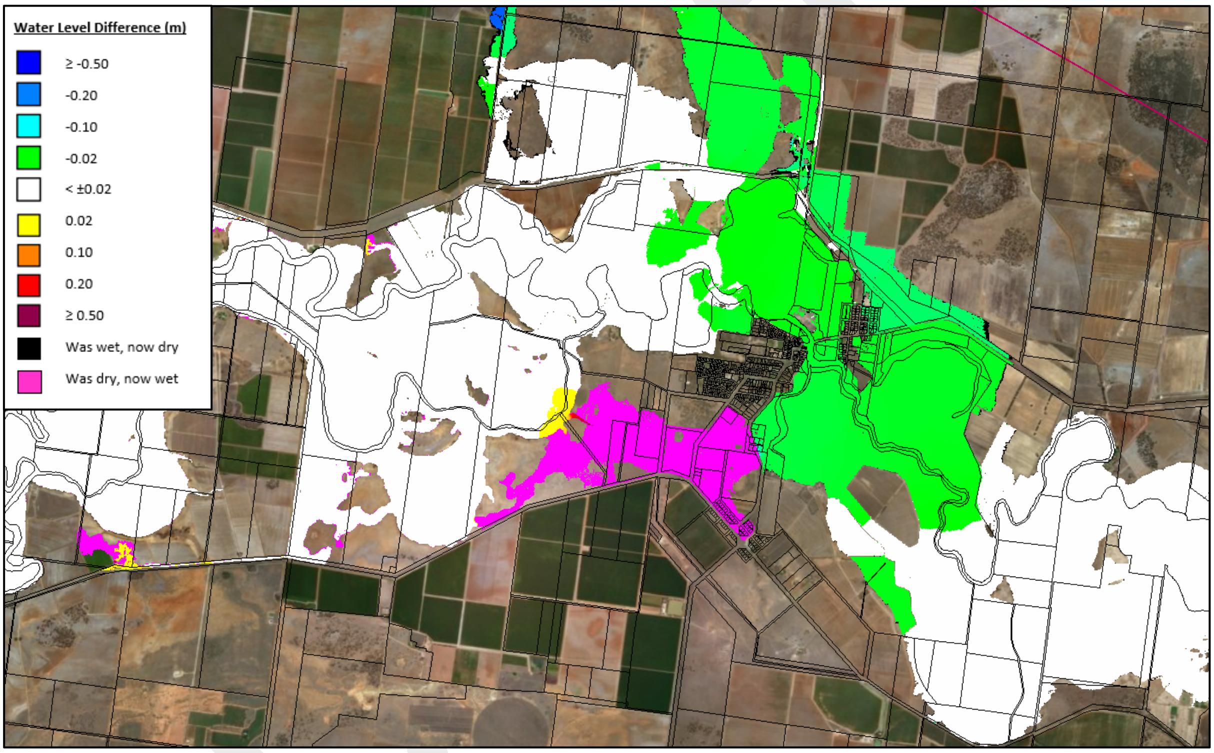


Plate H.27 – FM Option 5 (B) floodwater level differences for the 5% AEP

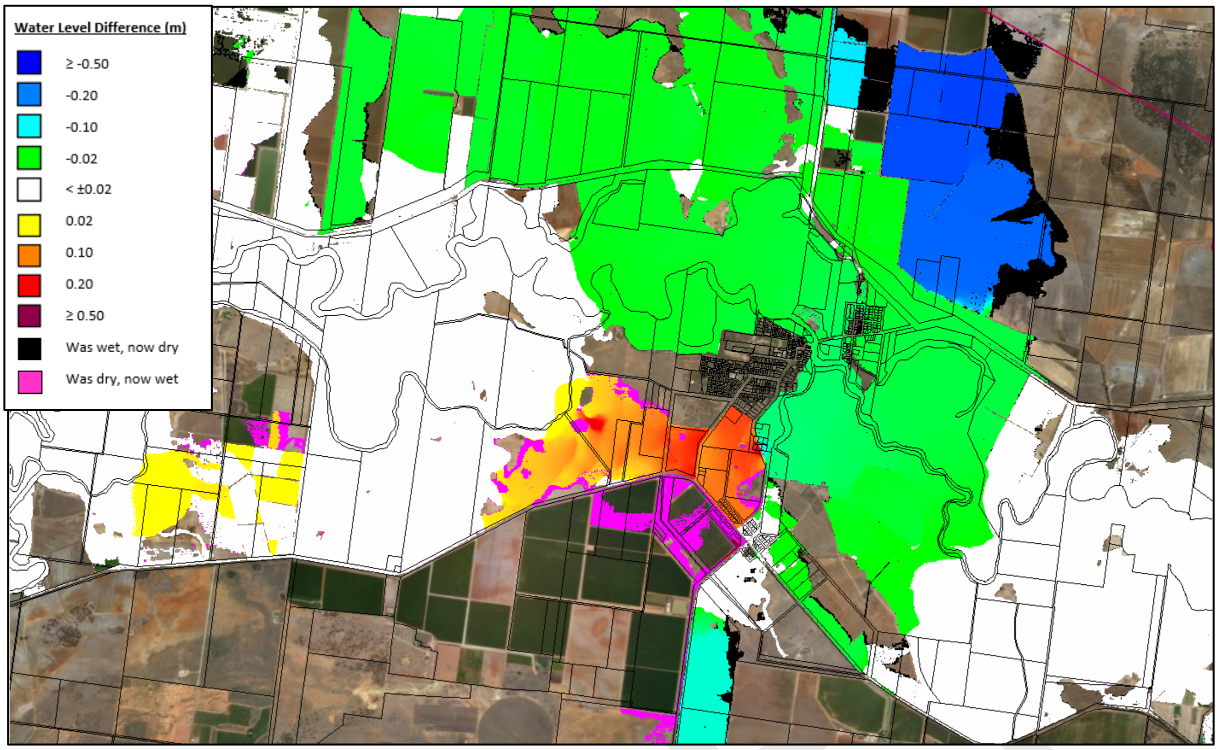


Plate H.28 – FM Option 5 (B) floodwater level differences for the 1% AEP

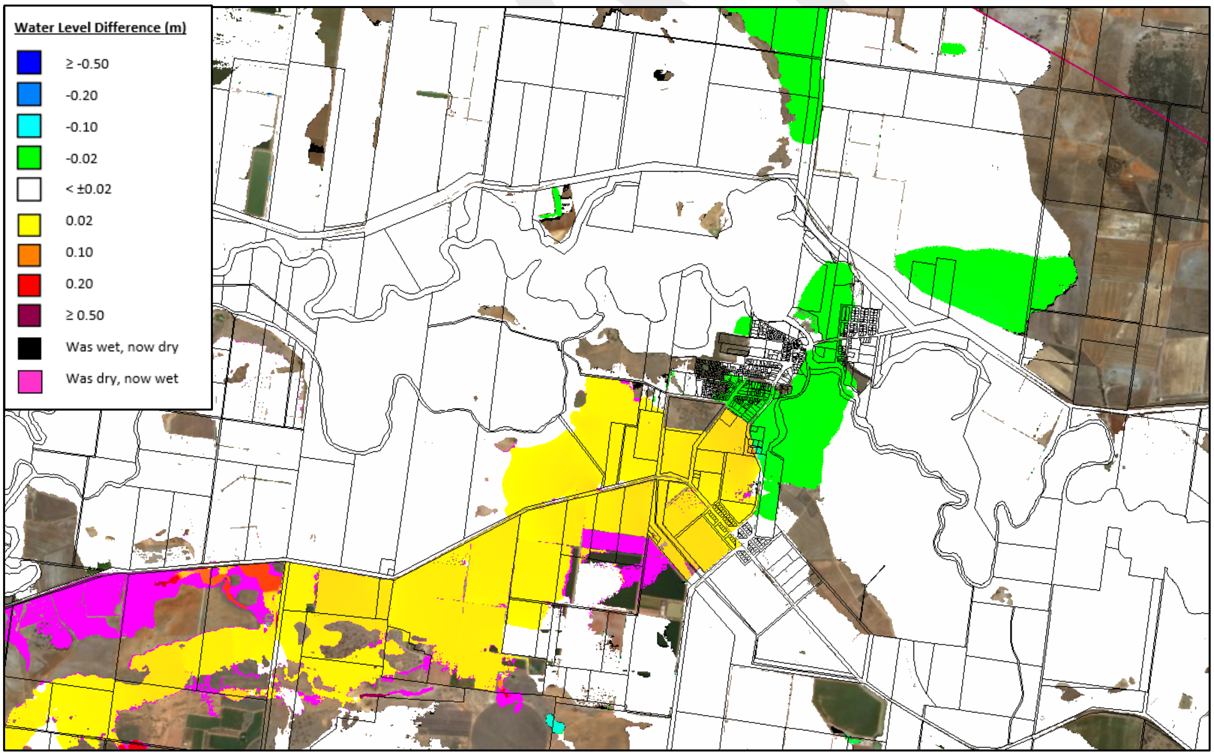


Plate H.29 – FM Option 5 (B) floodwater level differences for the 0.2% AEP

5.4 Reduction in Flood Damages

5.4.1 FM Option 5A

The outcomes of the revised damages assessment estimates that the lowering of the Kidman Way would decrease flood damage costs by $1.05 million over the 50-year design life of the calculations. This yielded a preliminary benefit-cost ratio less than 0.8.

5.4.2 FM Option 5B

The potential financial benefit associated with implementation of the flowpath under the Kidman Way was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the causeway and culverts in place. The outcomes of the revised damages assessment estimates that the flowpath under the Kidman Way incorporating a series of culverts would decrease flood damage costs by $221,000 over the 50-year design life of the calculations. This yielded a preliminary benefit-cost ratio less than 0.1. this is primarily associated with the high capital costs of the culverts. Alternative options could be explored.

5.5 Comment on FM Option 5

This specific option was not included in the suite of options presented to the community as part of the community questionnaire undertaken during stage 1 of this report. The intent of this options was to assist with the alleviation of flood impacts at north Darlington Point, however it would also provide opportunity for increase flood free access south from Darlington Point to the Sturt Highway.

There are a number of constraints providing the high level flowpath with culverts and associated road and civil earthworks would need to take into further consideration should this option be considered further, and these include:

- This option impacts all properties immediately downstream of the Kidman Way, by increasing the flood depths as a result of greater conveyance under the road. Any adverse impacts on existing properties would have to be carefully considered in conjunction with the positive benefit the option provides.
- The land upstream and downstream of the Kidman Way in this location is covered with Terrestrial Biodiversity constraints, as indicated on Murrumbidgee LEP 2103. Any works in the area must consider the impact on these biodiversity constraints.
- There are significant costs associated with the implementation of this option, primarily associated with the number of concrete culverts. There is opportunity to replace these concrete culverts with a prefabricated low level bridge, as included with Option 4. Such a structure has a greater up-front cost, however, has reduced requirements for earthwork and foundation establishments, which would provide cost savings.

Overall, the introduction of a formalised high level flowpath under the Kidman Way appears to provide a decrease in flood levels for a significant length of the Murrumbidgee River downstream, however these reductions are considered minor.

5.6 Evaluation of FM Option 5

Table H.10 - Evaluation outcomes on improving the flow conveyance under or over the Kidman way south of Darlington Point

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-1	Minor decreases in flood level in the Murrumbidgee River and around north Darlington Point. Increases in flood levels downstream of The Kidman Way for all design flood events up to and including the extreme flood event.
Inundated Buildings	0	3 properties would have increased flood depths in the 5% AEP design flood event however 123 properties would have a reduction on over floor flooding in the 1% AEP design flood event.
Emergency Response	+1	Improvements in the trafficability of The Kidman Way during all design events up to and including the 0.5% AEP design flood event if culverts are introduced.
Technical Feasibility	+2	Considered reasonably straight forward to construct. Could be constructed by Council.
Environmental Impacts	0	Terrestrial biodiversity constraints up and downstream. Changes to the hydrological cycles as a result of these works introducing more frequent floodwaters into the area downstream would have to ensure no adverse impact on these terrestrial biodiversity constraints. Minimal environmental impacts anticipated once construction complete.
Economic Feasibility	-2	Low BCR with a significant capital cost.
Community Acceptance	-2	Over 70% of the community indicated support to upgrade roads so they are less susceptible to flooding. Introducing a causeway at this location has the opposite effect. Including culverts under the Kidman Way increases flood levels immediately downstream where there is existing development.
SCORE	**-2**	

5.7 Summary of FM Option 5 Assessment

Neither FM Option 5A nor 5B are recommended for further investigation as part of this study.

6 FM Option 6 – Widening Murrumbidgee River Channel

6.1 Concept Design of FM Option 6

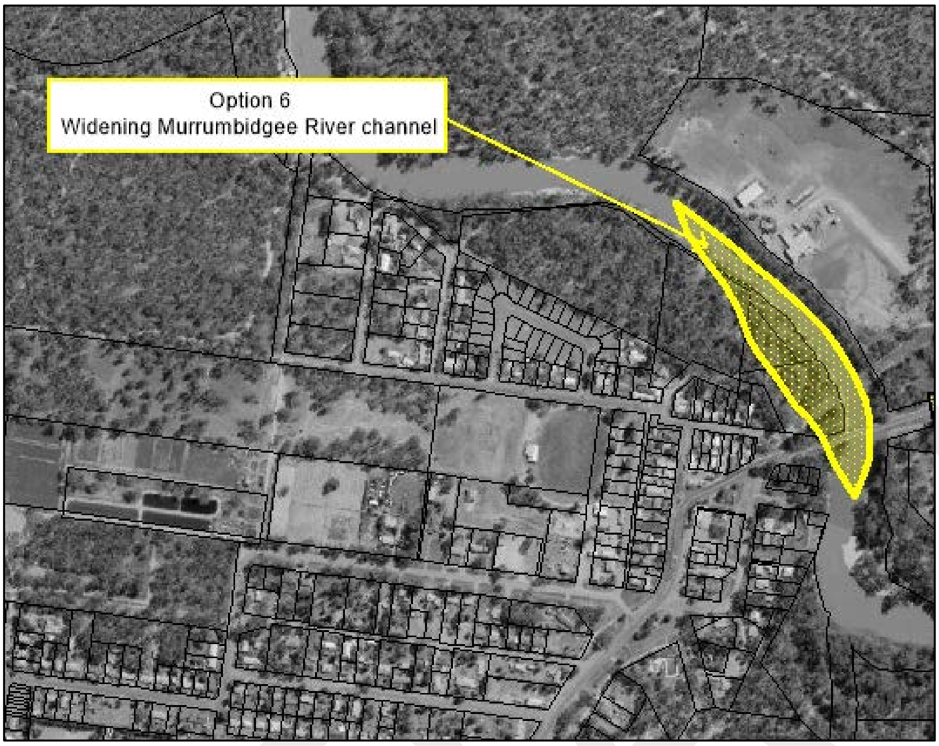


Plate H.30 - FM Option 6 – Location of works

As discussed in **Section 4** of the floodplain risk management study, significant flood depths anticipated on the overbank areas of the floodplain upstream, downstream, and adjacent to the levee around Darlington Point. Several responses received during the community consultation phase undertaken during stage 1 of this project noted concern over the perceived insufficient capacity of the main Murrumbidgee River channel at the location of the two bridge crossings and the impacts it had on flooding at north Darlington Point. Therefore, the opportunity to increase this channel capacity was assessed.

Essentially, this option involved removing the natural earthen embankment that is currently located between the two bridges over the Murrumbidgee River to assess what influence this area has on the flooding characteristics at north Darlington Point.

6.2 Cost Estimate of FM Option 6

The potential location of the embankment sections to be removed is shown in **Plate H.30.** A cost estimate was prepared for the works to widen the Murrumbidgee channel and is included in **Appendix G**. This determined that these works would cost approximately $1.54 million to undertake.

6.3 Hydraulic Impact of FM Option 6

The hydraulic benefits of increasing the conveyance area of the channel were quantified by including the works in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the culverts in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the embankment sections removed. The difference mapping is presented in **Plate H.31**, **Plate H.32** and **Plate H.33** for the 5% AEP and 1% AEP and 0.2% AEP events respectively.

The flood level difference mapping shows that these works will reduce flood levels upstream for a distance of approximately 7 kilometres by up to 0.02 metres during the 5% AEP design flood event. Reductions of between 0.02 metres and 0.06 metres are estimated to occur in the high level flowpath under the Kidman Way south of Darlington Point during the 1% AEP design flood event. Reductions up to 0.15 metres are anticipated to be experienced in north Darlington Point during the 1% AEP design flood event. Flood levels are expected to increase downstream of the bridges in the Murrumbidgee River with increased flood levels anticipated to continue for over 10 kilometres during the 1% AEP design flood event.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as:

Table H. 11 - Hydraulic Impact of FM Option 6

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	0
2% AEP	-4	0
1% AEP	0	-1
1% AEP	-3	-2
0.2% AEP	-4	+3
Extreme flood event	-5	+4

6.4 Reduction in Flood Damages

The potential financial benefit associated with implementation of this work was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the section of channel embankment removed. The outcomes of the revised damages assessment estimates that these earthworks would reduce flood damage costs by $157,000 over the 50-year design life estimate. This yielded a preliminary benefit-cost ratio of 0.1. Accordingly, the costs of construction of these works outweigh the financial benefits anticipated as a result of the works.

However any works that have the opportunity to reduce the mainstream flood levels of the Murrumbidgee River adjacent to the existing levee have the potential to increase the level of protection of the levee, say from a 1% AEP design flood level to a 0.5 % AEP design flood level (plus a freeboard).

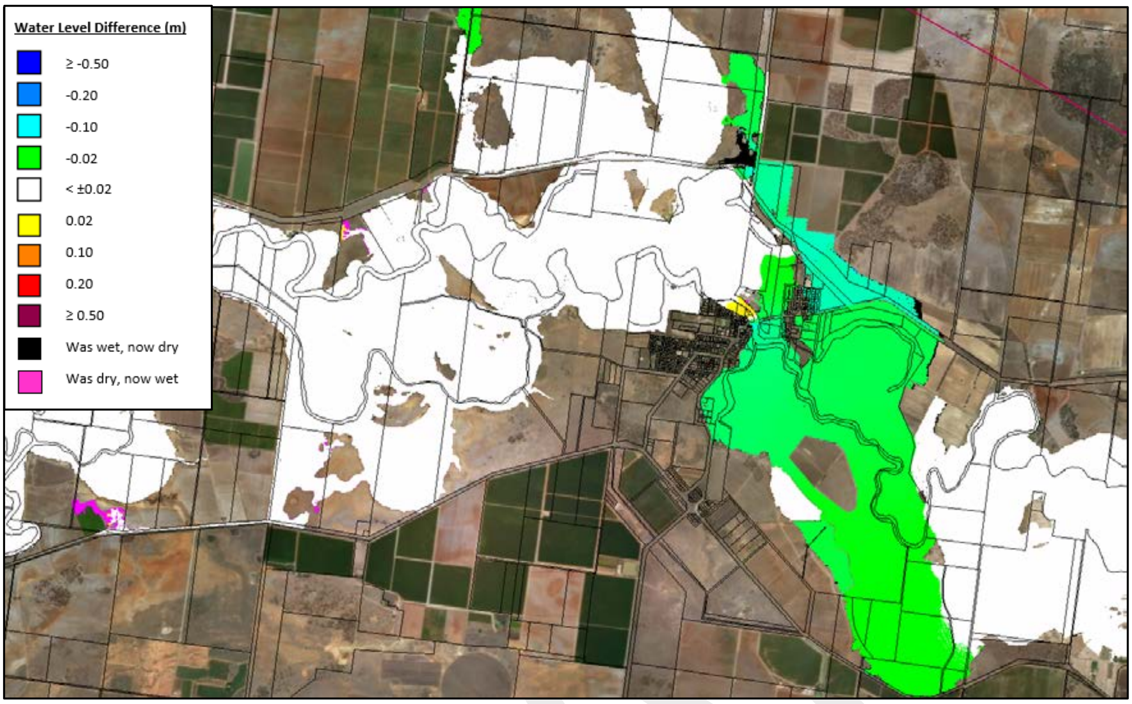


Plate H.31 – FM Option 6 floodwater level differences for the 5% AEP

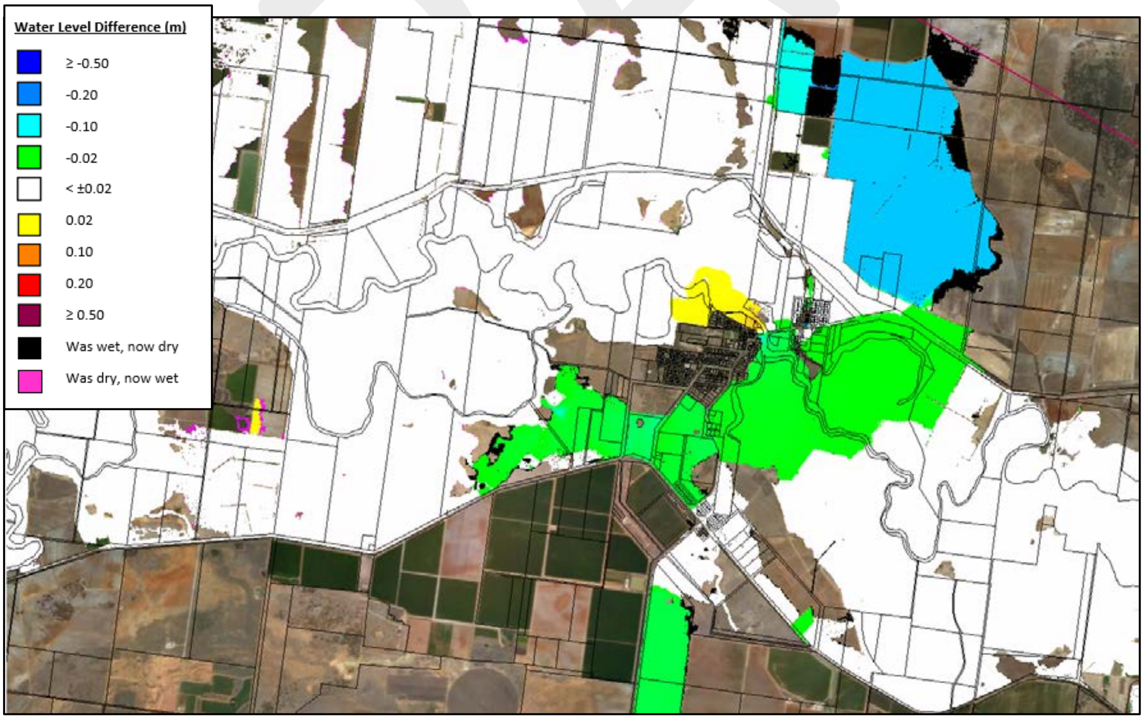


Plate H.32 – FM Option 6 floodwater level differences for the 1% AEP

Plate H.33 – FM Option 6 floodwater level differences for the 0.2% AEP

6.5 Comment on FM Option 6

This option was generally supported by the community with comments provided during initial community consultation drop-in sessions and at the floodplain committee meetings.

There are a number of constraints involved with the removal of the channel embankment that would need to be taken into consideration should this option be considered further, and these include:

- Terrestrial and biodiversity constraints, and Wetlands, are mapped in the Murrumbidgee LEP 2013 along the main river channel and floodplain areas where this work would be undertaken. As such, if these works are supported for further investigation, the detail design would have to consider the constraints as per the Environmental Planning and Assessment Act 1979 and the Murrumbidgee LEP 2013.
- This option would have to consider a number of state government regulations and requirements, including the *Fisheries Management Act 1994,* the *Water Management Act 2000, Biodiversity Conservation Act 2016* due to the location of the works in and adjacent to the river banks.
- This option would have to potentially consider the *NSW National Parks and Wildlife Act 1974* if additional items of Aboriginal heritage are discovered in the area proposed for works.
- This option would be incredibly difficult to construct, as it requires the embankment sections within the Murrumbidgee channel to be removed. this would require significant

in-stream erosion and sediment controls measures to be in place during and after construction to ensure sediment is not transported into the Murrumbidgee River.

- The road and bridges across the Murrumbidgee River are RMS assets, and so approval would have to be sought from the RMS for any works close to or on their assets.

Overall, despite the extent over which these works would reduce flood levels along the length of the Murrumbidgee River, these impacts are considered minor when the cost and associated environmental impacts during construction are taken into consideration.

6.6 Evaluation of FM Option 6

Table H.12 - Evaluation outcomes of widening the Murrumbidgee River channel at the existing bridge crossings

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**+1**	Minor decreases in flood level in the Murrumbidgee River and around north Darlington Point and across the Kidman Way south of Darlington Point. Increases in flood levels downstream of The Kidman Way for all design flood events generally within existing floodplain areas.
Inundated Buildings	**+1**	Small reduction in the number of buildings inundated above floor for almost all design flood events.
Emergency Response	**0**	No quantifiable improvements to the inundation of roads around Darlington Point or emergency response outcomes.
Technical Feasibility	**-2**	Difficult to construct. Would require numerous approvals under different legislation.
Environmental Impacts	**-2**	Terrestrial biodiversity constraints up and downstream. Immediate impacts on water quality due to construction in channel. Minimal environmental impacts anticipated once construction complete.
Economic Feasibility	**-2**	Low BCR with a significant capital cost.
Community Acceptance	**+1**	General discussions with the community during initial community consultation phase revealed some support for this option.
SCORE	**-3**	

6.7 Summary of FM Option 6 Assessment

Option 6 is not recommended for further investigation.

7 FM Option 7 – Increased Flow Conveyance Under the Kidman Way Adjacent to the Caravan Park

7.1 Concept Design of FM Option 7

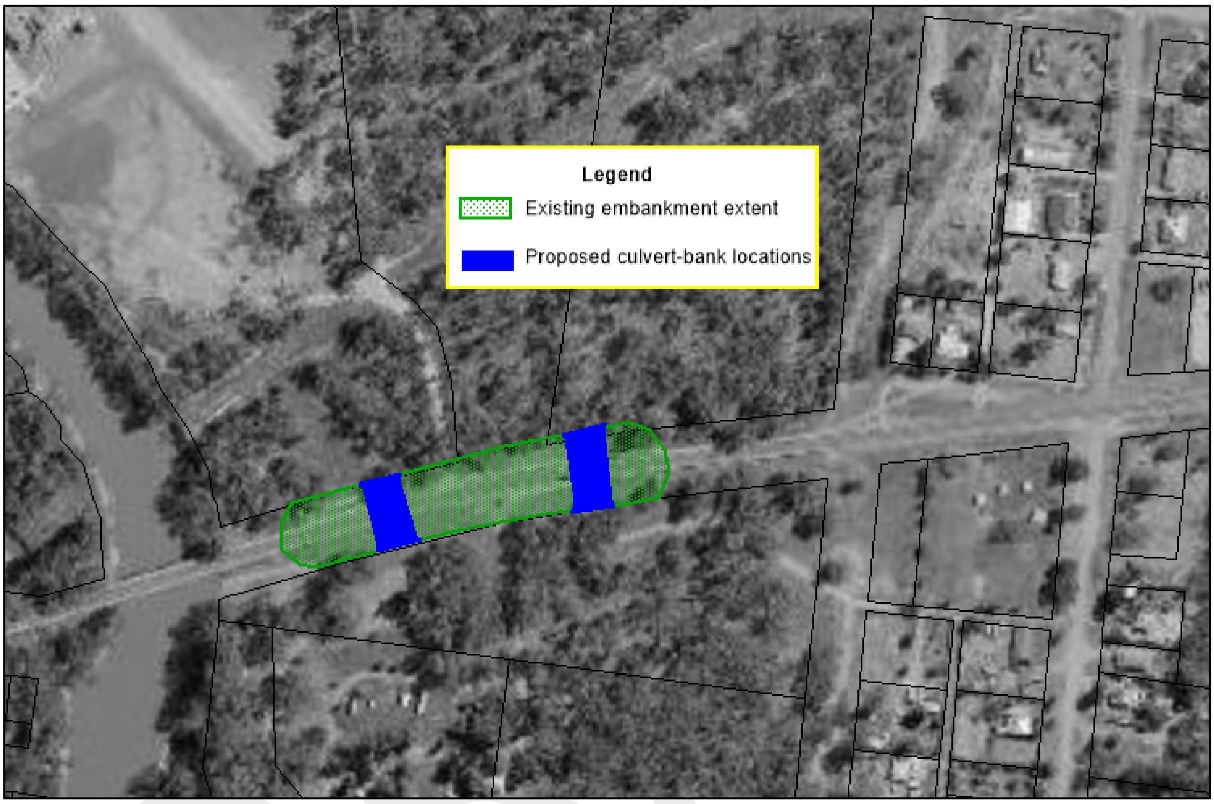


Plate H.34 – FM Option 7 concept design

As discussed in **Section 4** of the floodplain risk management study, there are considerable flood depths anticipated on the overbank areas of the floodplain immediately around the Darlington Point levee. Option 6 assessed the feasibility of increasing the conveyance area available in the Murrumbidgee channel by removing some of the embankment between the two existing bridges. Option 7 assesses the feasibility of providing additional conveyance capacity under the Kidman Way immediately adjacent to the Darlington Point Caravan Park.

This would involve removing some of the earth embankment of the Kidman Way and replacing it with a series of concrete culverts. These culverts would include 20 reinforced concrete box culverts of 1800mm high x 1200mm high. Additional earthworks would be required on the northern side of the Kidman Way to provide a continuous downward grade from the culverts for approximately 100 metres. These culverts would be located on both the eastern and western side of the roadway access to Darlington Point Caravan Park.

The potential location of the embankment sections to be removed is shown **Plate H.34.**

7.2 Cost estimate of FM Option 7

A cost estimate was prepared for the works and is included in **Appendix G**. This determined that these works would cost approximately $2.39 million to undertake.

7.3 Hydraulic Impact of FM Option 7

The hydraulic benefits of increasing the conveyance capacity under the Kidman Way in this area were quantified by including the works in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the culverts in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the embankment sections removed. The difference mapping is presented in **Plate H.35, Plate H.36 and Plate H.37** for the 5% AEP and 1% AEP and 0.2% AEP events respectively.

The flood level difference mapping shows that these works will have a more significant impact immediately downstream of the Kidman Way with flood levels predicted to decrease by up to 0.10 metres in the 5% AEP design flood event. However, these impacts result in flood levels increasing further downstream in the floodplain areas by up to 0.02 metres. Flood levels upstream of the Kidman Way are predicted to decrease by up to 0.02 metres across a larger area of the floodplain, stretching from Waddi Creek in the south-west to Darlington Lagoon in the north-east during the 5% AEP design flood event. As the flood event increases in magnitude, the impacts of these works decrease. Flood levels increase by up to 0.02 metres downstream of the works in the 1% AEP design flood event, however flood levels are also shown to decrease in the rural areas east of north Darlington Point by up to 0.02 metres. The only discernible impacts in the 0.2% AEP design flood event are estimated to be immediately downstream of the works, where flood levels are predicted to increase by up to 0.02 metres.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as follows:

Table H. 13 - Hydraulic Impact of FM Option 7

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	0
2% AEP	-1	+1
1% AEP	0	0
0.2% AEP	-2	-1
0.5% AEP	-1	+1
Extreme flood event	-1	+1

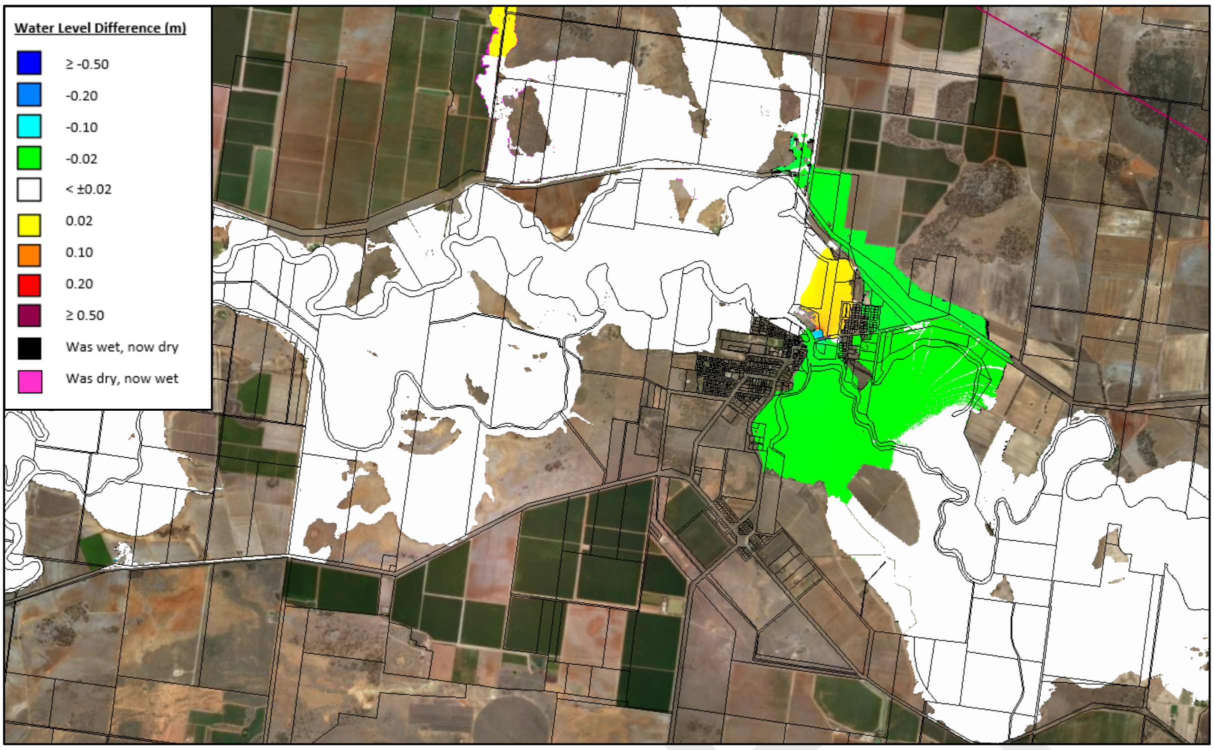


Plate H.35 - FM Option 7 floodwater level differences for the 5% AEP

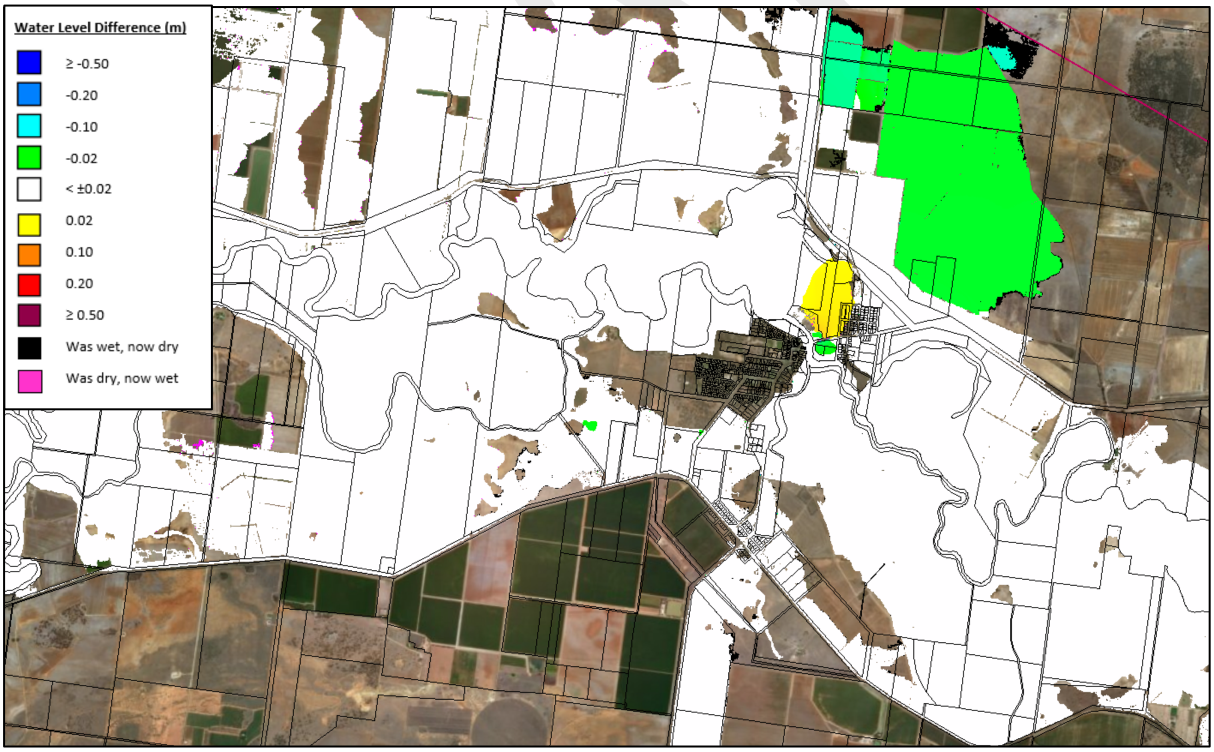


Plate H.36 – FM Option 7 floodwater level differences for the 1% AEP

Plate H.37 – FM Option 7 floodwater level differences for the 0.2% AEP

7.4 Reduction in flood damages

The potential financial benefit associated with implementation of this work was quantified by preparing revised flood damage calculations based upon the hydraulic modelling results with the section of channel embankment removed. The outcomes of the revised damages assessment estimates that these earthworks would reduce flood damage costs by $53,000 over the 50-year design life estimate. This yielded a preliminary benefit-cost ratio of less than 0.1. Accordingly, the costs of construction of these works outweigh the financial benefits anticipated as a result of the works.

7.5 Comment on FM Option 7

This option had been suggested by a community member during initial community consultation drop-in sessions as an alternate flood mitigation works to option 6. Therefore, it could be argued that there is some small community support for this option.

There are a number of constraints involved with the removal of the road embankment that would need to be taken into consideration should this option proceed, and these include:

- Terrestrial and biodiversity constraints, and Wetlands, are mapped in the Murrumbidgee LEP 2013 in this section of the floodplain. As such, the Environmental Planning and Assessment Act 1979 and the Murrumbidgee LEP 2013 would have to be taken into account.
- This option would have to consider a number of state government regulations and requirements, including the *Fisheries Management Act 1994,* the *Water Management Act*

2000, Biodiversity Conservation Act 2016 due to the location of the works in and adjacent to the river banks.

- There are numerous Aboriginal heritage items in the vicinity of these works that have already been recorded during the levee upgrade works, however there may be more that have not been recorded yet. Due to the abundance of currently recorded Aboriginal heritage items in the area, it is anticipated that more may be discovered as part of the works in this option. If so, this option would have to potentially consider the *NSW National Parks and Wildlife Act 1974.*
- The Kidman Way is an RMS assets and so approval would have to be sought from the RMS for these works.
- This option would be incredibly difficult to construct, as it would require the closure of the Kidman Way for a period of time.

Overall, despite the extent over which flood levels decrease as a result of implementation of this option, they are only minor decreases in flood levels during all design flood events in the Murrumbidgee river and north Darlington Point. In addition, these reductions in flood levels do not reduce the number of properties impacted by over floor flooding in the study area.

7.6 Evaluation of FM Option 7

Table H.14 - Evaluation outcomes of increasing flow conveyance under The Kidman Way adjacent to caravan park

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**+1**	Minor decreases in flood level in the Murrumbidgee River and at north Darlington Point primarily in channel and overbank areas. More substantial decreases in flood level are localised and maintained to the area immediately downstream of the works.
Inundated Buildings	**0**	No change to the number of buildings inundated above floor.
Emergency Response	**0**	No changes to the trafficability of roads either side of this section of road for emergency management purposes during flood events.
Technical Feasibility	**-2**	Would be difficult to construct as would require closure of the Kidman Way for a period.
Environmental Impacts	**-1**	Terrestrial biodiversity and wetland constraints in the general area of proposed works.
Economic Feasibility	**-2**	Low BCR with a significant capital cost.
Community Acceptance	**+1**	Minimal community support for this option.
SCORE	**-3**	

7.7 Summary of FM Option 7 Assessment

Option 7 is not considered to be financially viable at this time as part of this floodplain risk management study and plan, however, could be undertaken as part of future asset management works or road upgrades by the RMS and/or Council.

8 FM Option 8 – Smoothing Out of Vegetation Through Channel Through National Park Adjacent to North Darlington Point

8.1 Concept Design of FM Option 8

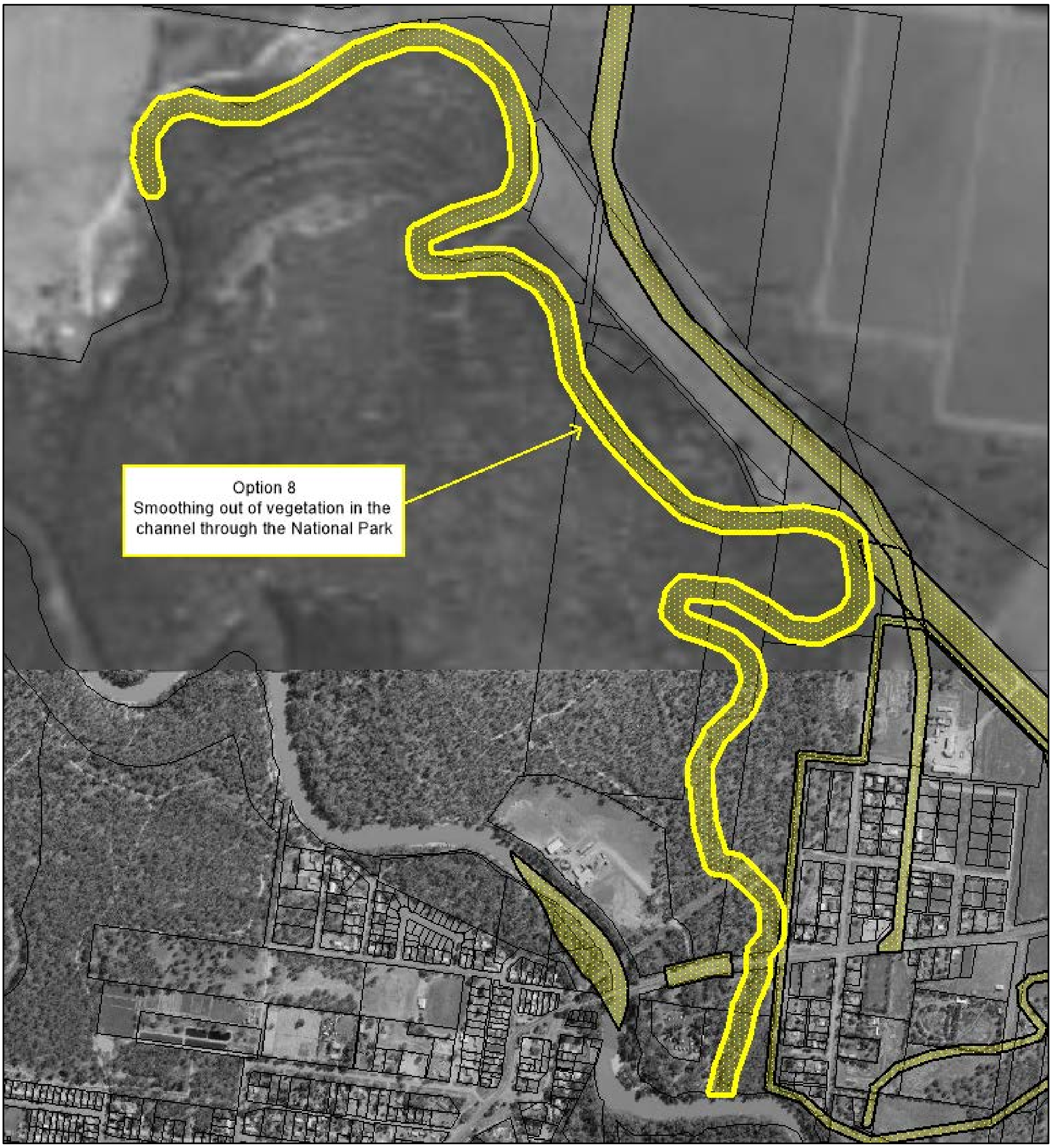


Plate H.38 - Location of FM Option 8

During floodplain management committee meetings, as well as during the community consultation undertaken during stage one of this study, several residents noted that some of the channels through the National Park north of north Darlington Point were littered with vegetation and large fallen trees. There was concern from the community members that the vegetation in these areas was restricting the flow of water, thereby elevating water levels elsewhere, particularly north Darlington Point. There was also concern that parts of the vegetation (e.g., branches) may also be mobilised during floods leading to blockages downstream. Therefore, the potential benefits associated with removing this larger debris from the major channels through the National Park north of north Darlington Point was investigated.

Plate H.39 provides an example of fallen tree debris in these channels.

Plate H.39 - Fallen debris through channels in the National Park

The area proposed for clearing is completely covered by Riparian Lands and Watercourses and Terrestrial Biodiversity layers included in the Murrumbidgee LEP 2013 mapping. Therefore, complete clearing of all vegetation along the channel is unlikely to be supported however was investigated as part of this study to gain an understanding the impact this vegetation and debris has on flood behaviour in the study area.

The extent of the area where vegetation removal was investigated as part of the study is shown in **Plate H.38.**

8.2 Cost Estimate of FM Option 8

It is difficult to determine an accurate costing for this option. The estimates costs of these works assumed that the owners of the land (NSW Government) undertook the works themselves and removed some of the vegetation off site. A cost of $1.07 million was estimated for this work to be carried out.

8.3 Hydraulic Impact of FM Option 8

The hydraulic impacts associated with the vegetation removal were quantified by including it within the TUFLOW model. This involved reducing the Manning's "n" roughness across the areas identified in **Plate H.38** to 0.08 (down from 0.1).

The 20% AEP, 10% AEP, 5% AEP, 2%,1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event were re-simulated with these changes in place. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the removal of this vegetation and debris. The difference mapping is presented in **Plate H.40, Plate H.41 and Plate H.42** for the 5% AEP and 1% AEP and 0.2% AEP events respectively.

The flood level difference mapping indicates that the removal of the vegetation could reduce flood levels by up to 0.02 metres almost 6 kilometres upstream of the works during the 5% AEP design flood event, with reductions up to 0.10 metres estimated to occur in the eastern sections of north Darlington Point. The reduction in flood level decrease as the design flood event increases. The reduction in flood levels during the 1% AEP design flood event are estimated to remain at 0.02 metres for approximately 2.5 kilometres upstream of Darlington Point. However, during the 1% AEP design flood event, flood level reductions are estimated to occur along the high-level flow path that crosses the Kidman Way south of Darlington Point and into the downstream rural areas. Reductions of up to 0.20 metres are predicted to occur across the rural areas east of north Darlington Point, with reductions of only 0.02 metres estimated to occur through the north Darlington Point area. During the 0.2% AEP design flood event, the reduction in flood levels is estimated to occur primarily along the high-level flow path that crosses the Kidman Way south of Darlington Point, with reductions in flood levels estimated between 0.02 metres and 0.10 metres across the rural lands.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as follows:

Table H. 15 - Hydraulic Impact of FM Option 8

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	-1
2% AEP	-4	-1
1% AEP	0	-3
0.5% AEP	-31	+12
0.2% AEP	-5	+2
Extreme flood event	-5	+4

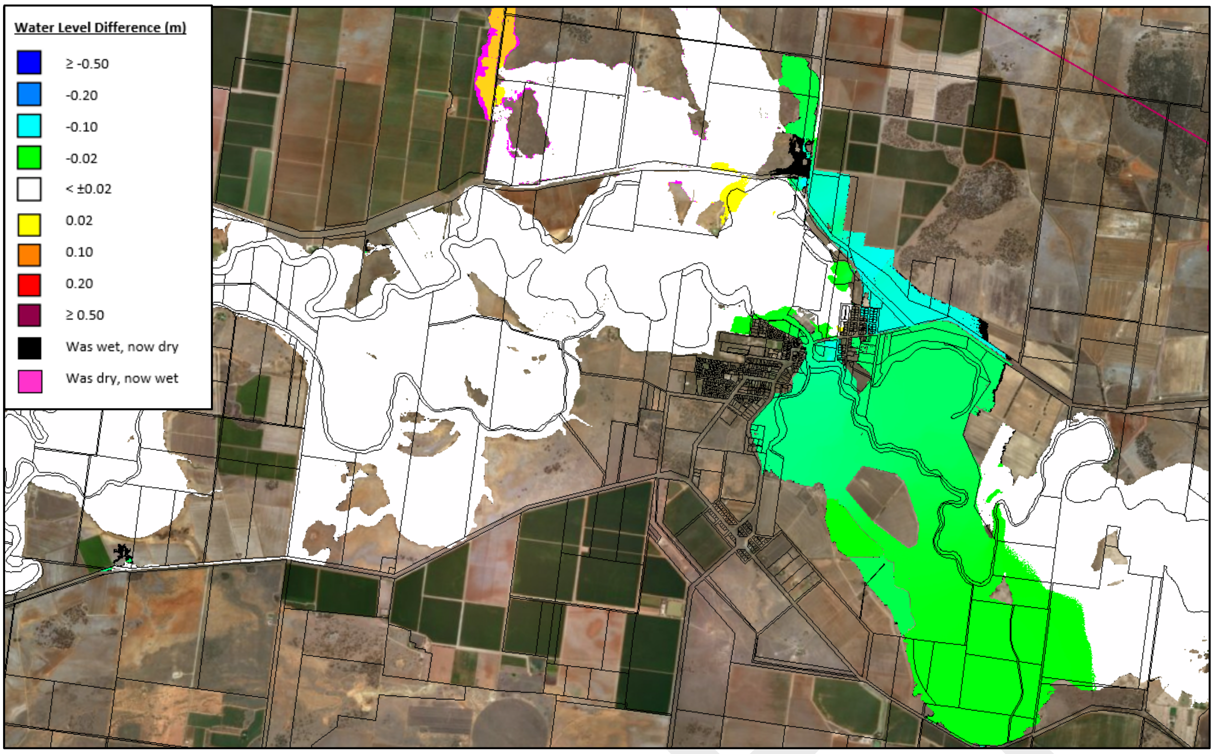


Plate H.40 - FM Option 8 floodwater level differences for the 5% AEP

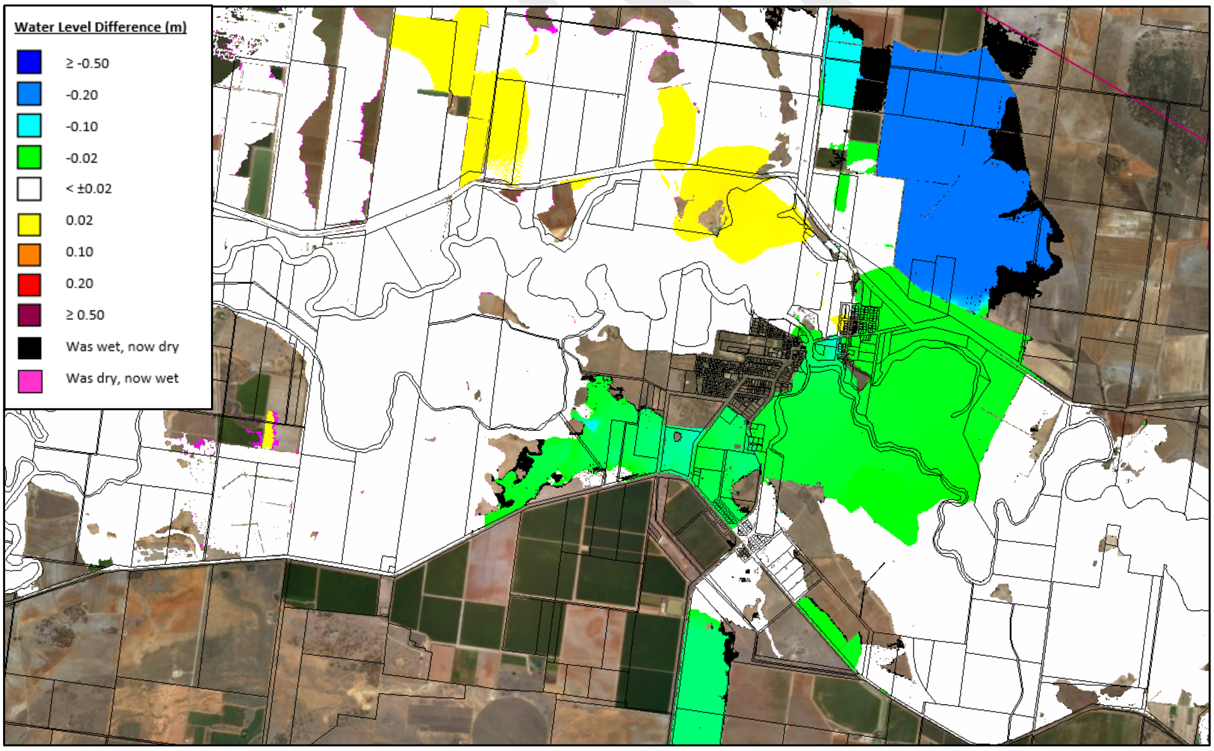


Plate H.41 – FM Option 8 floodwater level differences for the 1% AEP

Plate H.42 - FM Option 8 floodwater level differences for the 0.2% AEP

8.4 Reduction in flood damages

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the vegetation clearing. This determined that vegetation clearing would reduce flood damage costs by $260,000 over 50 years. This provides a BCR of 0.30. Therefore, the financial benefits associated with vegetation clearing are significantly lower than the costs to implement and maintain this option.

8.5 Comment on FM Option 8

The primary drawback associated with this option is the proposed location of works within a National Park and within areas mapped as Riparian Lands and Watercourses and Terrestrial Biodiversity layer on Murrumbidgee LEP 2103. It would be extremely difficult to gain approval for these works, particularly as there are negligible changes to the flood levels expected in the study area. There would also be ongoing costs associated with the continual upkeep of the channel to ensure vegetation or other debris do not remain in the channel and allow it to revegetate again.

Overall, the high capital and ongoing costs and very low financial benefits mean that vegetation clearing through the National Park is not supported for implementation as part of this floodplain risk management plan.

8.6 Evaluation of FM Option 8

Table H.16 - Evaluation outcomes on the vegetation removal through the National Park channels

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	**+1**	Minor decreases in flood level upstream of the works, extending to the outer areas of the floodplain.
Inundated Buildings	**0**	No change to the number of buildings inundated above floor.
Emergency Response	**0**	No changes to the trafficability of roads in the study area for emergency management purposes during flood events or impact on emergency management procedures.
Technical Feasibility	**-1**	Could be difficult to access and move some of the larger debris due to location within the National Park.
Environmental Impacts	**-1**	Terrestrial biodiversity and wetland constraints up and downstream. Would be difficult to determine what vegetation or debris could actually be removed in accordance with legislation without detailed investigation, which may restrict how much and the location of what can be removed.
Economic Feasibility	**-2**	Low BCR with a significant capital cost.
Community Acceptance	**+1**	General minimal community acceptance of this option.
SCORE	**-2**	

8.7 Summary of FM Option 8 assessment

Option 8 is not recommended for further investigation.

9 FM Option 9 – Causeway along Hay Road

9.1 Concept Design of FM Option 9

During the upgrade works of the levee around Darlington Point, concerns were raised by members of the community on the potential adverse impacts on properties to the south along Hay Road as a result of the levee works. The potential to offset these impacts with a causeway along Hay Road was suggested by residents.

The option of reducing the road crest levels by 0.50 metres along an approximate length of 430 metres was assessed. The location of this causeway was consistent with the general location of the high level flow path assessed as part of FM option 5.

Plate H.39 provides an outline of the location and length of this proposed causeway.

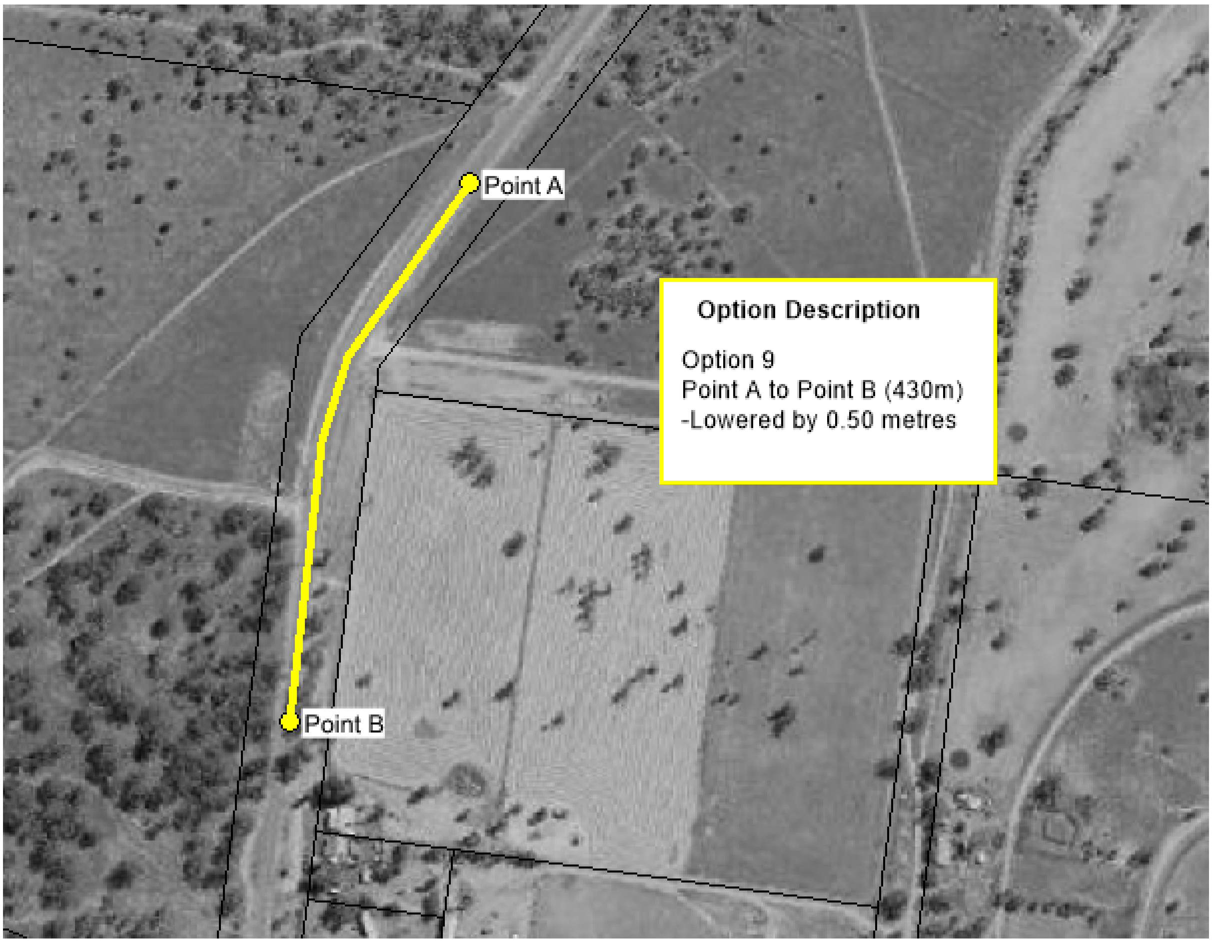


Plate H.43 – Concept design of FM Option 9

9.2 Cost Estimate of FM Option 9

A cost estimate was prepared for the works and is included in **Appendix G**. This determined that these works would cost approximately $803, 500 to undertake.

9.3 Hydraulic Impact of FM Option 9

The hydraulic impacts associated with the construction of this causeway were quantified by including it within the TUFLOW model. This involved reducing the road levels along the length of Hay Road as identified in **Plate H.44**.

The 20% AEP, 10% AEP, 5% AEP, 2%,1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event were re-simulated with these changes in place. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the removal of this reduction in road crest levels along Hay Road. The difference mapping is presented in **Plate H.45** and **Plate H.46** for the 1% AEP and 0.2% AEP events respectively.

Flood level impacts of this option only occur during flood events of magnitudes equal to or greater than the 1% AEP design flood event. During the 1% AEP design flood event, flood level reductions up to 0.02 metres extend approximately upstream to The Kidman way in the south-east (Approximately 900 metres) and to the boundary of the levee 700 metres north.

In the immediate area upstream of the causeway, flood level reductions between 0.1 and 0.2 meters are estimated to occur during the 1% AEP design flood event, although these impacts are estimated to occur over a distance less than 150 metres.

During the 0.2 % AEP design flood event, the reduction in flood levels occur over a very small areas upstream of Hay Road up to 0.02 metres.

A review of the results of all design flood simulations indicate the number of properties subject to changes in property inundation or above floor inundation are predicted as follows:

Table H. 17 - Hydraulic Impact of FM Option 9

Design Flood Event	Change in number of properties impacted by over floor flooding	Change in number of properties impacted by flood waters (in addition to above floor flooding)
5% AEP	0	0
2% AEP	0	0
1% AEP	0	-2
0.5% AEP	0	0
0.2% AEP	0	0
Extreme flood event	0	0

Plate H.44 – FM Option 9 floodwater level differences for the 1% AEP

Plate H.45 – FM Option 9 floodwater level differences for the 0.2% AEP

9.4 Reduction in flood damages

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the construction of the causeway. This determined that construction of the causeway reduce flood damage costs by less than $4,000 over 50 years. This provides a BCR less than 0.01. Therefore, the financial benefits associated with the construction of a causeway along Hay Road are significantly lower than the costs to implement and maintain this option.

9.5 Comment on FM Option 9

The high capital costs and low financial benefit of this option, whereby only 2 residential properties are positively impacted, means that the construction of a causeway along Hay Road is not supported for implementation as part of this floodplain risk management plan.

9.6 Evaluation of FM Option 9

Table H.18 - Evaluation outcomes of the construction of a causeway along Hay Road

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	+1	Minor decreases in flood level upstream of the works, extending to the north approximately 700 meters and the south-west 900 metres during the 1% AP design flood event.
Inundated Buildings	+1	2 buildings no longer inundated by above floor flooding.
Emergency Response	-2	Decrease in the trafficability of Hay Road for emergency management purposes during flood events should the Kidman Way become untrafficable.
Technical Feasibility	+2	Considered reasonably straight forward to construct. Could be constructed by Council.
Environmental Impacts	0	Minimal environmental impacts expected as a result of the construction of the causeway.
Economic Feasibility	-2	Low BCR with a significant capital cost.
Community Acceptance	0	Unknown community acceptance of this option.
SCORE	**0**	

9.7 Summary of FM Option 9 assessment

Option 9 is not recommended for further investigation.

10 FM Option 10 – General Upgrade of Existing Stormwater Culverts around Darlington Point

10.1 Concept Design of FM Option 10

Plate H.46 - Locations of culverts upgraded as part of Option 10

There are a number of stormwater drainage pipes and culverts around Darlington Point that were assessed for potential upgrade. These culverts are located outside of the area bounded by the levee and are primarily under local road crossings. These culverts primarily provide connectivity between open channels in the study area.

The hydraulic impacts associated with upgrading the culverts to double their current size were quantified by including them in the TUFLOW model. The 20% AEP and 1% AEP design flood event were re-simulated with these changes in place.

10.2 Comment on FM Option 10

In general, the culvert upgrades were found to provide only benefits in the more frequent flood events. During the larger flood events these upgrade works did not to provide a significant hydraulic benefit. Any reduction in flood levels were very localised and did not extend out very far beyond the culvert itself during the 20% AEP design flood event. There was no change to the number of floor levels impacted by these upgrades to the stormwater drainage infrastructure. As such, it was difficult to quantify the benefits of upgrading the culverts and a benefit cost ration was not determined.

10.3 Summary of FM Option 10 Assessment

Not recommended for implementation.

Plate H.47 – FM Option 10 floodwater level differences for the 20% AEP

Plate H.48 – FM Option 10 floodwater level differences for the 1% AEP

11 SUMMARY OF ASSESSMENT OF FLOOD MODIFICATION OPTIONS

Table H. 19 - Economic Assessment of Flood Modification Options

Flood Modification Option	Present Value Estimates ($ millions)				BCR
	Cost Estimate	Total Damage for Existing Conditions	Total Damage with Option in Place	Reduction in Damage with Option in Place	
FM1 – North Darlington Point levee	$7.68	2.280	1.811	0.47	0.06
FM2 - North Darlington Point levee – temporary levee	$2.49	2.280	2.254	0.03	0.01
FM3 – Spillway analysis	$0.20	Not determined			
FM4 – Travelling Stock Route flowpath	$6.14	2.280	2.284	0.00	0.00
FM5A - Improving flow conveyance under the Kidman Way south of Darlington Point with a causeway	$1.42	2.280	1.233	1.05	0.74
FM5B - Improving flow conveyance under the Kidman Way south of Darlington Point with low level bridge	$3.08	2.280	2.059		
FM6 - Widening Murrumbidgee River channel	$1.54	2.280	2.123	0.16	0.10
FM7 - Increased flow conveyance under The Kidman Way adjacent to the caravan park	$2.39	2.280	2.227	0.05	0.02
FM8 - Vegetation Removal through National Park flowpaths	$1.07	2.280	2.020	0.26	0.24
FM9 – Causeway along Hay Road	$0.80	2.280	2.276	0.004	0.01
FM9 - General upgrade of culverts throughout the Darlington Point area	N/A	N/A	N/A	N/A	N/A

Table H. 20 - Change in Number of Properties Impacted by Above Floor Flooding due to Flood Modification Options

Flood Modification Option	Change in Number of Properties Impacted by Above Floor Flooding		
	5% AEP Design Flood Event	1% AEP Design Flood Event	Extreme Flood Design Flood Event
FM1 – North Darlington Point levee	-3	-24	-42
FM2 - North Darlington Point levee – temporary levee	-1	-7	1
FM3 – Spillway analysis	Not determined		
FM4 – Travelling Stock Route flowpath	0	0	2
FM5A - Improving flow conveyance under the Kidman Way south of Darlington Point with a causeway	3	-4	-31
FM5B - Improving flow conveyance under the Kidman Way south of Darlington Point with low level bridge	3	-4	-31
FM6 - Widening Murrumbidgee River channel	0	-1	-1
FM7 - Increased flow conveyance under The Kidman Way adjacent to the caravan park	0	0	0
FM8 - Vegetation Removal through National Park flowpaths	-1	-3	-1
FM9 – Causeway along Hay Road	0	-2	0
FM9 - General upgrade of culverts throughout the Darlington Point area	0	0	0

12 RM Option 7 – Raising the Kidman Way to the North

12.1 Concept Design of Response Modification Option 7

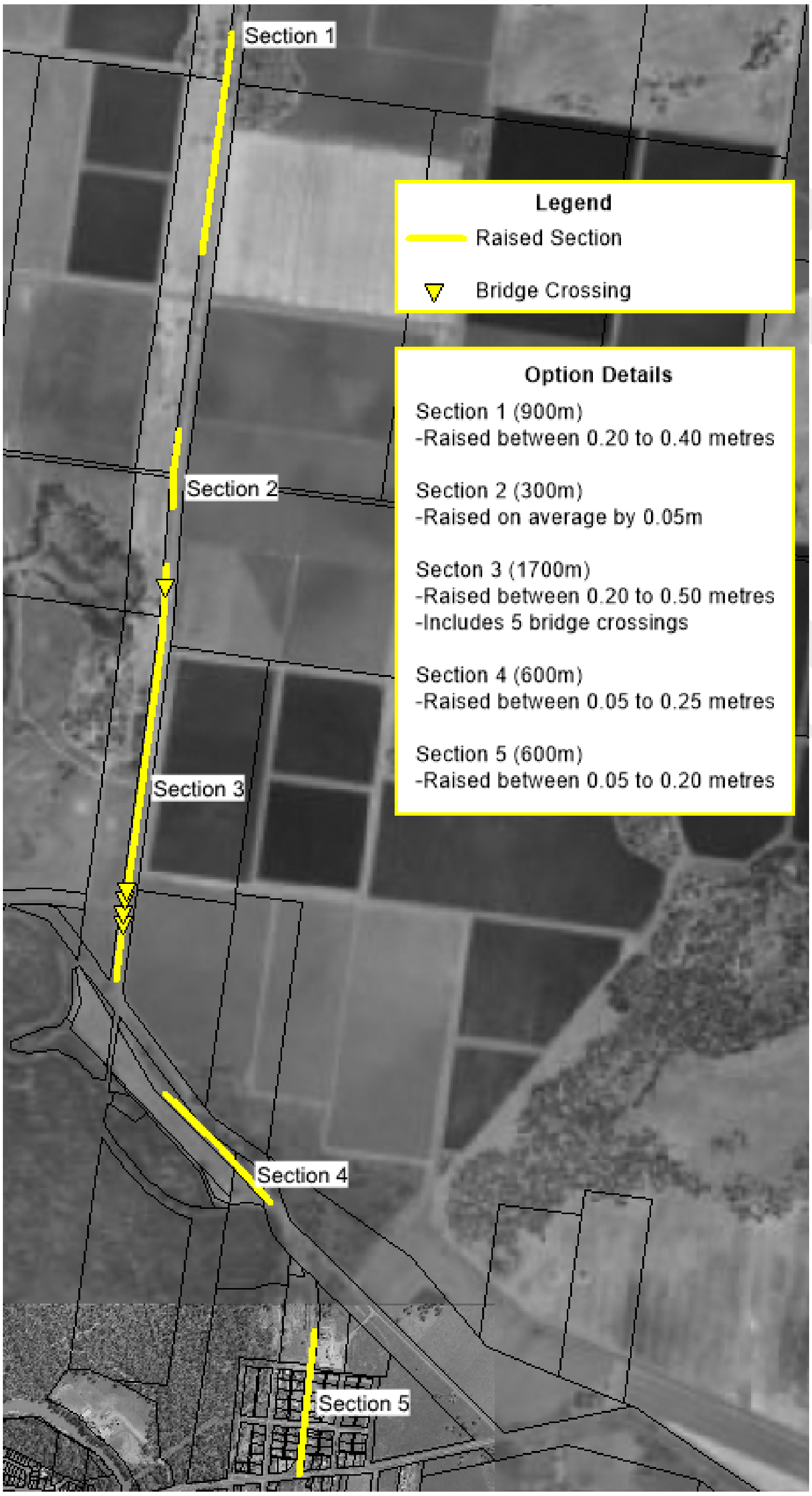


Plate H.49 – RM Option 7 concept design

The Kidman Road north of Darlington Point is currently estimated to be inundated at flood levels that just exceed the 1% AEP design flood event. This is an RMS road and any road works needs to be approved by the RMS. This road is the only road north out of Darlington Point, and is a very important thoroughfare for traffic travelling to Griffith. Opportunities to raise this section of the road were examined so that the road would provide flood immunity for the 1% AEP design flood level with a 200mm freeboard. It would also afford additional evacuation time during larger floods north to Griffith from the area to the south, including the area behind the levee.

The concept design for the road raising incorporates:

- Increase in road crest levels to the 1% AEP design flood level plus 200mm along a length of 4.1 kilometres. This results in a maximum depth of fill of approximately one (1) metre.
- Low level bridge of 80 metres length to cater for the cross flows under various sections of this roadway.

The potential location of the upgrades to the road levels are shown in **Plate H.49.** Road raising is along a length of 4,100 metres was included in the hydraulic model, with two sets of cross drainage structures to facilitate the flow of flows from east to west under this upgraded road.

12.2 Cost estimate of Option RM7

A cost estimate was prepared for the road raising and hydraulic drainage structures and is included in **Appendix G**. This determined that the road raising would cost approximately $8.35 million to construct. The maintenance requirements of the upgraded road would be no different to the current maintenance arrangements of the existing road, so no additional allowance has been made for future asset management requirements of the upgraded road as this is considered to be part of Councils existing asset management program.

12.3 Hydraulic Impact of Option RM7

The hydraulic benefits of the upgraded road were quantified by including the works in the TUFLOW model and re-simulating each of the design floods. Predicted floodwater depths, levels and velocities with the culverts in place were determined for the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP, 0.2% AEP and the extreme flood event. Flood level difference mapping was also prepared to quantify the location and magnitude of changes in flood levels and extents associated with the embankment sections removed. The difference mapping is presented in **Plate H.50**, **Plate H.51** and **Plate H.52** for the 5% AEP, 1% AEP and 0.2% AEP design flood events respectively.

Plate H.50 – RM Option 7 floodwater level differences for the 5% AEP

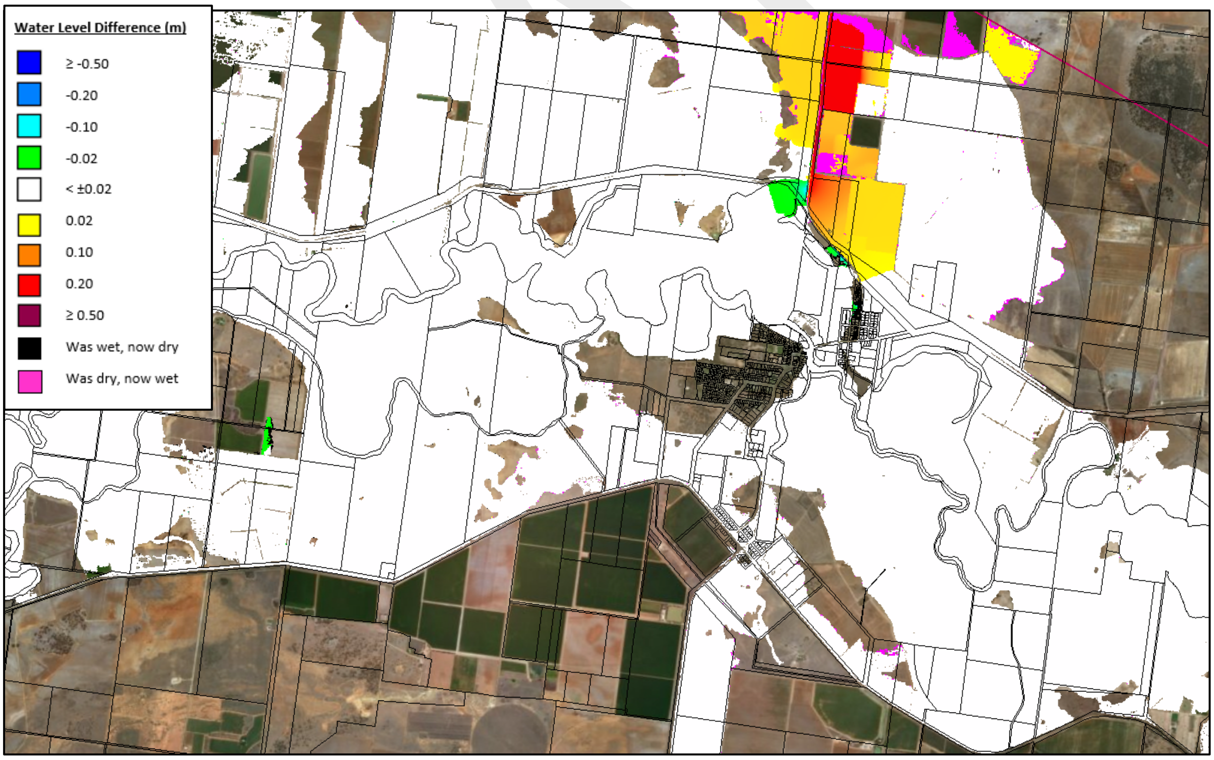


Plate H.51 – RM Option 7 floodwater level differences for the 1% AEP

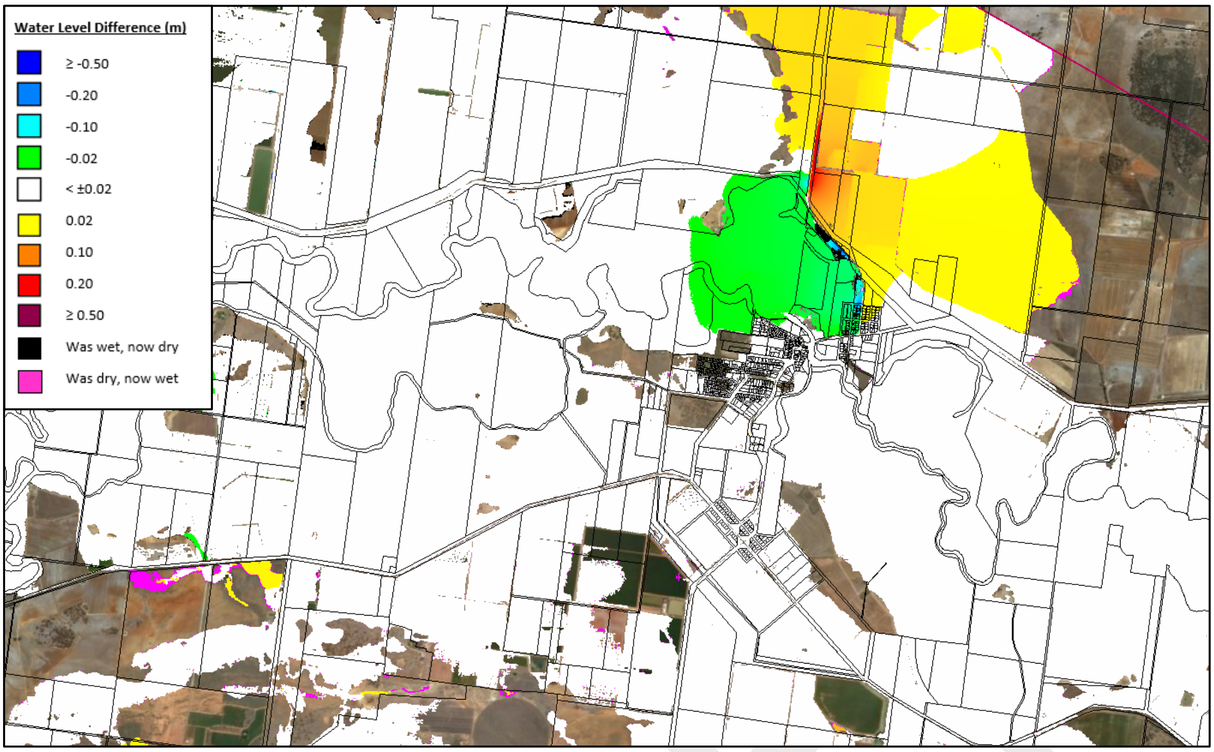


Plate H.52 – RM Option 7 floodwater level differences for the 0.2% AEP

12.4 Reduction in Flood Damages

Revised flood damage calculations were also prepared to quantify the financial impacts associated with the raising of the Kidman Way to the north. This determined that the works would reduce flood damage costs by $12,000 over 50 years. This provides a BCR of less than 0.1. Therefore, the financial benefits associated with raising of the road are significantly lower than the costs to implement and maintain this option.

It must be noted that this option was assessed for its impact on improving emergency management in the study area, and so the results in changes in flood damages should also be assessed with the improvements to the trafficability of The Kidman way during larger flood events.

12.5 Comment on Option RM7

This option looks to reinforce the level of flood immunity provided by The Kidman Way between north Darlington Point and Griffith during the 1% AEP design flood event and greater floods. This would also provide the additional benefit of having a trafficable road during the 0.5% AEP design flood event.

The upgraded levee provides a level of protection to the 1% AEP design flood event with a freeboard of 0.750 metres. Therefore, it is anticipated should a flood greater than the 1% AEP design flood event be predicted, evacuation of Darlington Point would be undertaken. This evacuation may be north to Griffith or south to the Sturt Highway. As such, it would be anticipated that this section of the Kidman Way adjacent to north Darlington Point would only be traversed by emergency management vehicles during floods equal to or greater than the 1% AEP design flood event. Therefore, the cost of this option seems quite cost prohibitive to Council at this time relative to the level of flood risk management it will provide when considering benefit cost ratio only.

However, this road is an RMS asset and a very important component of the Kidman Way particularly for emergency management during flood times. This option is not recommended for further investigation as part of the Floodplain Risk Management Plan but could be undertaken as part of future asset management works or road upgrades by the RMS and/or Council..

12.6 Evaluation of Option RM7

Table H.21 - Evaluation outcomes on the raising of the Kidman Way north of Darlington Point

Evaluation Criteria	Rating	Comments
Hydraulic Impacts	-1	Minor decreases in flood level in the Murrumbidgee River and at north Darlington Point. Increases in flood levels downstream of The Kidman Way for all design flood events.
Inundated Buildings	0	No change to the number of buildings inundated above floor.
Emergency Response	+2	Improvements in the trafficability of The Kidman Way during all design events up to and including the 0.5% AEP design flood event.
Technical Feasibility	+2	Considered straight forward to construct. Could be constructed by Council
Environmental Impacts	-1	Terrestrial biodiversity constraints up and downstream. Changes to the hydrological cycles as a result of these works would have to ensure not adverse impact on these Terrestrial biodiversity constraints. Minimal environmental impacts anticipated as a result of construction.
Economic Feasibility	-2	Low BCR with a significant capital cost.
Community Acceptance	+1	Over 70% of the community indicated support to upgrade roads so they are less susceptible to flooding.
SCORE	**1**	

12.7 Summary of Option RM7 Assessment

Option 7 is not considered to be financially viable at this time as part of this floodplain risk management study and plan, however, could be undertaken as part of future asset management works or road upgrades by the RMS and/or Council.

APPENDIX I

UPDATES TO DEVELOPMENT CONTROLS

I1 INFORMATION FOR UPDATES TO PLANNING AND DEVELOPMENT CONTROLS

1 OVERVIEW

Section 6.3 of the Darlington Point Floodplain Risk Management Study reviews the current flood related development controls currently available in use by Murrumbidgee Shire Council. Potential updates or changes to these controls have also been discussed.

This floodplain risk management study has identified the range of current and potential future floods risk for the various areas in and around Darlington Point. It is up to Council to determine the most appropriate method to manage these risks through their planning and development guidelines. Discussions with Councils planner (K. Tyson, (9/3/20) reveal that Murrumbidgee LEP and DCP are currently under review, therefore this is an opportune time to include flood related development controls in a manner consistent with other natural hazard controls that are being included in the DCP.

The information contained within this appendix is a summary of what has been included in the floodplain risk management study report and should be considered as part of Councils' update to the flood related development controls. The draft Flood Policy provides the basis for the formation of a Flood Policy for Development on Floodprone Lands in the Murrumbidgee LGA and can be used as is or amended and updated as Council sees fit. It has been based on existing flood policies in other LGAs and the flood hazards in the Darlington Point area.

This draft Flood Policy includes consideration of the full range of design flood events, including the extreme flood. To include the area between the flood planning level and the extreme flood into those areas where flood related development controls, the draft Darlington Point Floodplain Risk Management Study and Plan recommends the introduction of a "Floodplain Risk Management" clause into the Murrumbidgee LEP 2013. As part of the inclusion of this additional LEP clause, there is opportunity to include a map for were these flood related development controls apply. There is also opportunity to include this information on a Section 10.7(5) certificate. The extent of this mapping of the area applicable to the "Floodplain Risk Management" clause would be equivalent to the "*low flood risk precinct*" indicated on **Figure I.1**, attached to this draft Flood Policy.

2 Draft Flood Policy

2.1.1 Objectives

The objectives of this flood policy are:

a) To reduce the risk to human life and damage to property caused by flooding through controlling development on land affected by floods in accordance with the flood hazard.
a) To ensure new development is consistent with the flood response strategies adopted by the NSW State Emergency Service (**NSW SES**) and does not impose any additional burdens on, or risk to its personnel during flood emergencies.
b) To provide clear and concise flood related development controls for all land affected by flooding, up to and including the land impacted by the extreme food event.
c) To inform the community of the flood hazards and flood risks in the floodplain, and provide the tools for resilient building design and occupation of the floodplain.

2.1.2 Where this Policy applies

The flood policy apples to land below the flood planning level and land located within the flood planning area, as defined in the draft Darlington Point Floodplain Risk Management Plan.

The (recommended updated version of) the FPL is:

Flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5 metres freeboard, or other flood planning level as determined by an adopted floodplain risk management plan.'

The Darlington Point Floodplain Risk Management Plan recommends the flood planning level as the level of the 1% AEP design flood event plus a 0.30 metres land use, for all development types, in that study area. The Darlington Point flood plain includes both mainstream flooding from the Murrumbidgee River and local overland flooding for the area behind the levee. The flood planning area is shown on Figure 35 of the Darlington Point Floodplain Risk Management Study and Plan.

2.1.3 How to use this policy

a) Determine the land use category
b) Determine the flood risk precinct that applies to that site
c) Apply relevant development controls

3 Land Use type Category

Development types and land uses have been divided into six (6) land use categories for use with flood related development controls

i. Ancillary or concessional development
ii. Commercial and Industrial development
iii. Critical infrastructure or facilities (public utilities, evacuation centres, water treatment plants)
iv. Recreation
v. Residential development
vi. Subdivision
vii. Tourist Related development (with a permanent residence on site)
viii. Tourist Related development (with no permanent residence on site)
ix. Vulnerable development (education establishments, hospitals, residential care facilities, child care centre)

4 DETERMINE THE FLOOD RISK PRECINCT THAT APPLIES TO THE SITE

Flood hazards have been determined for each study area in a completed floodplain risk management plan.

At the time of writing, the Jerilderie Floodplain Risk Management Plan has been adopted by Council, and the draft Darlington Point Floodplain Risk Management Plan was under preparation. **Figure I.1** outlines the flood hazard categories applicable to the Darlington Point area.

Flood hazards for development controls have been divided into three categories:

i. High Flood Risk Precinct
ii. Medium Flood Risk Precinct
iii. Low Flood Risk Precinct

Flood hazards have been defined based on Australian Institute for Disaster Resilience's (AIDR) *'Technical Flood Risk Management Guideline: Flood Hazard'* (2014).

NOTE:
Where more than one (1) flood hazard applies to a site, then the flood hazards that apply at the location of the proposed dwelling or building should be used for planning and development purposes. In addition, the flood hazard of the access to the site, (including both internal access around the site and access to external roads and along the local road network) should be noted.

High flood Risk Precinct – Those areas of the land prone to flooding in the 1% AEP design flood event subject to high hydraulic hazards or where there are significant evacuation difficulties. Flood hazards of H4, H5 and H6 in the 1% AEP design flood event.

Medium Flood Risk Precinct – The area identified as flood planning area (based on the 1% AEP design flood event) not subject to high hydraulic hazards and where there are not significant evacuation difficulties. Flood hazards of H1, H2 and H3 in the 1% AEP design flood event.

Low Flood Risk Precinct - The area of the floodplain between the extent of the flood planning area and the extent of the extreme flood or probable maximum flood.

5 Apply relevant development controls

Development Type	Development Controls														
	Low Flood Risk Precinct					Medium Flood Risk Precinct					High Flood Risk Precinct				
	Building Floor levels	Structural soundness and Building components	Flood Impacts including filling	Carparks and Vehicular accessway	Evacuation and flood emergency management planning	Building Floor levels	Structural soundness and Building components	Flood Impacts including filling	Carparks and Vehicular accessway	Evacuation and flood emergency management planning	Building Floor levels	Structural soundness and Building components	Flood Impacts including filling	Carparks and Vehicular accessway	Evacuation and flood emergency management planning
Ancillary or concessional development	No flood related development controls apply					1	1	2	1	n/a	Not supported				
Commercial and Industrial	No flood related development controls apply					1	1	2	1	1	Not supported				
Critical Infrastructure	2	2	2	2	1	Not supported					Not supported				
Recreation	No flood related development controls apply					1	1	2	1	1	1	1	1	1	1
Residential development	No flood related development controls apply					1	1	2	1	1	Not supported				
Subdivision	1	1	1,2	2	1	Not supported					Not supported				
Tourist related development (with permanent residence)	No flood related development controls apply					1	1	2	1	1	Not supported				
Tourist related development (with no permanent residence)	No flood related development controls apply					1	1	2	1	1	1	1	1	1	1
Vulnerable development	Not supported					Not supported					Not supported				

5.1 Development controls

Flood related development controls should include considerations of:

5.1.1 Building floor level (habitable and non-habitable structures)

1 = All building floor levels have a minimum flood planning level of the 1% AEP design flood event and a 0.30 metres freeboard.

For non-habitable floor developments where this is not possible, floor levels should be as high as practicable but no less than the 1% AEP design flood level.

The floor level for alterations and additions should be at the 1% AEP design flood event and a 0.30 metres freeboard or as high as possible, but no lower than the existing floor level. This will occur once only for each property.

2 = All building floor levels have a minimum flood planning level of the extreme flood or probable maximum flood.

5.1.2 Structural soundness of the building and Building components below the flood planning level

1 = All structures to have flood compatible building components below the flood planning level (1% AEP design flood level plus 0.30 metres freeboard). Any building components built below the flood planning level must be designed and constructed to withstand flood forces for the 1% AEP design flood event. All electrical connections to be located above the flood planning level.

2 = All structures to have flood compatible materials up to the level of the extreme flood event or probable maximum flood. Any building components built below the flood planning level must be designed and constructed to withstand flood forces for the extreme flood event. This includes locating all electrical connections above the extreme flood level.

5.1.3 Flood Impacts including filling

Any development in a floodplain should not adversely impact the flood characteristics at any other property.

1 = An Engineer's report may be required to certify that the development will not increase flood effects elsewhere, having regard to: (i) loss of flood storage; (ii) changes in flood levels and velocities caused by alterations to the flood conveyance; and (iii) the cumulative impacts of multiple developments in the floodplain.

2 = Filling will only be permissible for the building footprint, open car parking and on site sewer management system areas only.

5.1.4 Carparks and Vehicular accessway

1 = The minimum surface level of open and closed car parking spaces or carports shall be as high as practical, but no lower than the 5% AEP design flood level.

The driveway providing access between the road and parking space shall be as high as possible, but no lower than the 5% AEP design flood level and generally rising in the egress direction.

2 = The level of the driveway providing access between the road and parking space shall be no lower than 0.3 metres below the 1% AEP deign flood level or such that the depth of inundation during a 1% AEP deign flood level is not greater than either the depth at the road or the depth at the location of the development or proposed building footprint.

5.1.5 Evacuation and flood emergency management planning

1 = The development application for any site in the floodplain should include the development of a flood emergency response plan. This flood emergency response plan should consider the flood vulnerability for the development site itself, the vulnerability of the internal road accesses and external access along the local road network and existing emergency management protocols in the area. The flood emergency response plans should be reviewed annually by the resident to ensure the information remains up to dat.

6 GLOSSARY OF TERMS

Ancillary or Concessional development – Single dwelling house addition up to 40m^2 of habitable floor area at or above the same level as the existing adjoining approved floor level for habitable floor area. The allowance for additions shall be made no more than once for any given development and be supported with appropriate information at the development application stage that the proposed development can meet the requirements of the Building Code of Australia.

Annual Exceedance Probability (AEP) - The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, for a flood magnitude having five per cent (5%) AEP, there is a five per cent probability that there would be floods of greater magnitude each year.

Australian Height Datum (AHD) - A common national surface level datum corresponding approximately to mean sea level.

Extreme Flood Event - The largest flood that could conceivably occur at a particular location. Also referred to as the Probable Maximum Flood. Generally, it is not physically or economically possible to provide complete protection against this event. The extreme flood event is used for flood emergency management planning. Purposes.

Flood Fringe – the remaining area of flood prone land after floodway and flood storage have been defined.

Flood Planning Area (FPA) – The area of land subject to flood related development controls. Based on the level of the design flood event and with the additional of a freeboard. The area of land that is shown to be in the Flood Planning Area on the *Flood Planning Map.*

Flood Planning Map - The *Flood Planning Map* refers to the map attached to this Flood Policy that indicates the Flood Planning Area as developed and adopted in the floodplain risk management plan.

Flood Planning Level (FPL) - In areas of Darlington Point subject to local overland flooding, the FPL is the level of the 1% AEP flood event minus 0.1 metres, with a 0.30 metre freeboard. For areas outside the Darlington Point levee, the FPL is the level of the 1% AEP flood event plus 0.30 metre freeboard.

Flood Prone/Flood Liable – Land susceptible to flooding by the extreme or probable maximum flood event.

Floodway Those areas of the floodplain where a significant discharge of water occurs during floods. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

Flood Storage Area Those parts of the floodplain that may be important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.

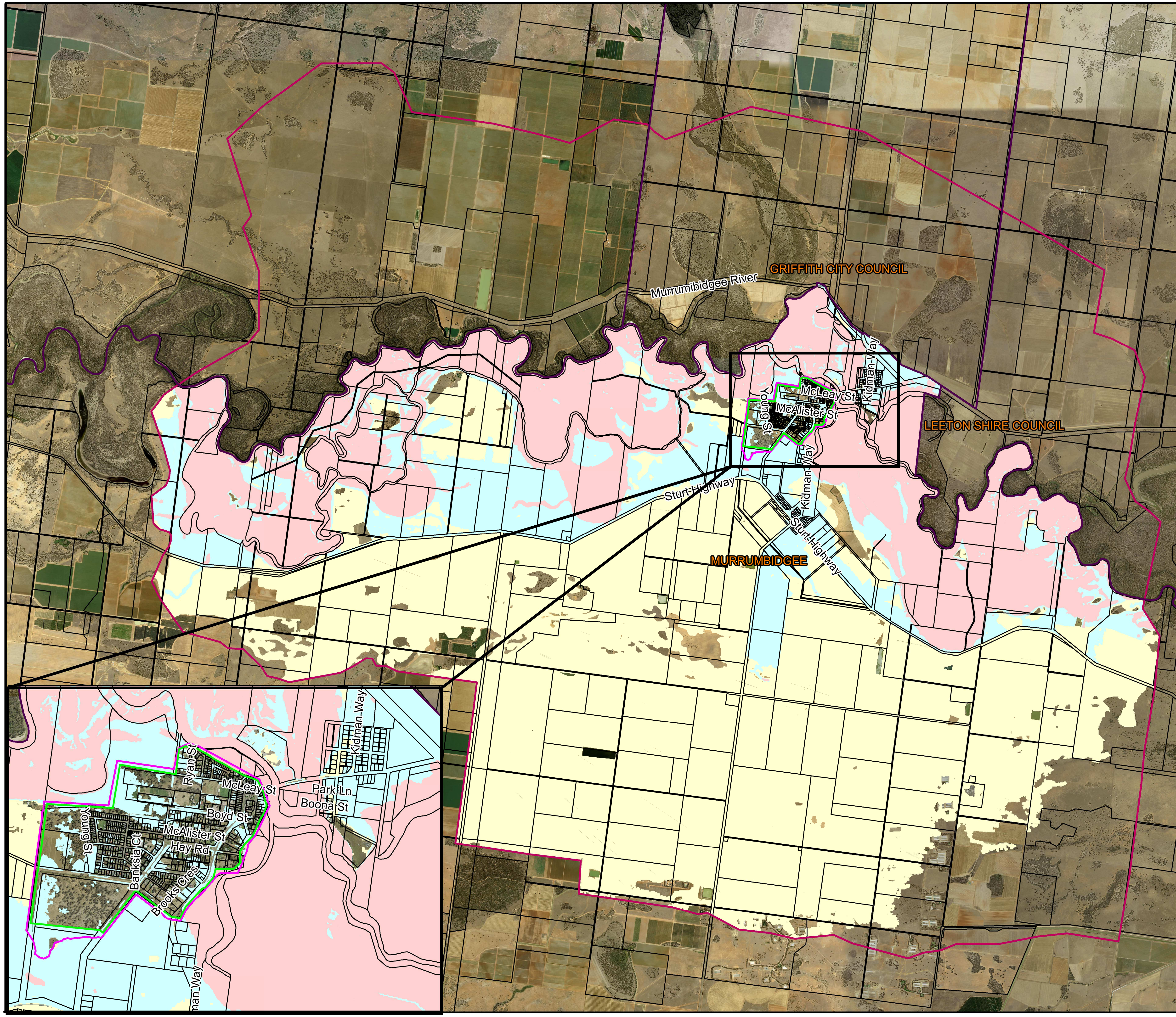
Freeboard - Provides reasonable certainty that the risk exposure selected in deciding a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, and the design of flood mitigation measures such as levee crests. levee crest levels, etc.

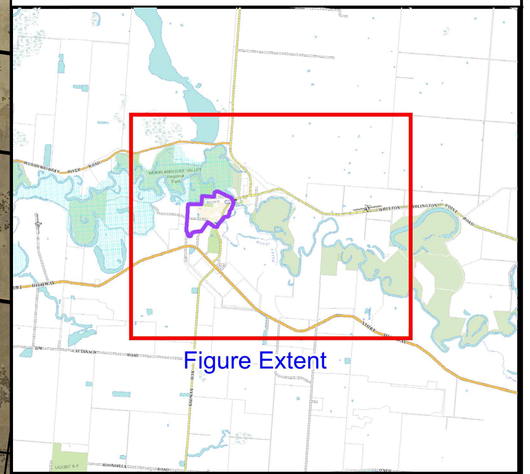
Habitable Room - In a residential development a living or working area, such as a lounge room, dining room, kitchen, bedroom or workroom. In an industrial or commercial developments an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.

Local Overland Flooding - Where the depth of overland flooding during the 1% AEP storm event is greater than 100 mm.

Probable Maximum Flood - The largest flood that could conceivably be expected to occur at a particular location, usually estimated from probable maximum precipitation. Also referred to as the Extreme Flood Event.

Structure – The term structure applies to all constructed buildings as well as temporary structures such as relocatable buildings, shipping containers and any other large constructed object that may float during a flood event and cause blockage issues downstream (e.g. vehicles).





LEGEND

- Local Catchment Model Extent
- Location of Final Alignment of Upgraded Levee

Flood Planning Area

- High Flood Risk Precinct
- Medium Flood Risk Precinct
- Low Flood Risk Precinct

Notes:

N
W E
S

Scale 1:36,000 (at A3)

0 1.0 2.0 Km

Figure I1:
(Draft) Flood Planning Area Precincts

Prepared By:

Catchment Simulation Solutions
Suite 10.01, 70 Phillip St
Sydney, NSW 2000

File Name:Figure I1 Draft Flood Planning Area Precincts

APPENDIX J

INFORMATION FOR SES

J1 Information for updates to SES Flood Plan

This appendix incudes a summary of information presented throughout various sections of the report. Where possible, these report sections and figures have been referenced.

1.1 Review of Local Flood Plan

The *Murrumbidgee Local Flood Plan* (NSW SES, 1994) (LFP) sets out procedures to follow before, during and after a flood including who is responsible for each of these activities within the *Murrumbidgee* local government area. A summary of pertinent components of the LFP for the Murrumbidgee River at Darlington Point are provided in **Table J.1.**

The whole of the Murrumbidgee Local Flood Plan requires an update to align with the structure and contents of the new SES Local Flood Plan template and to include more up to date flood information, from both actual events (2010, 2012, 2016 in particular) and floodplain risk management studies and plans.

Part 1 of the local flood plan details the area the plan covers and organisational responsibilities for managing flooding hazards. Almost all of the information in this section requires updating. It currently refers to government agencies and departments that are now defunct or renamed. As this local flood plan was prepared prior to the amalgamation of Murrumbidgee Shire and Jerilderie Shire, the areas referred to in this plan do not include those from the former Jerilderie Shire.

Part 2 of the local flood plan describes preparedness. This section is in need of an update, both to align the structure and contents with the new NSW SES local flood plan template, and to incorporate flood intelligence from more recent flood studies, floodplain risk management studies, and actual floods. In particular, it currently refers to the Murrumbidgee Local Controller, however there is no local Darlington Point SES Unit and no local Darlington Point controller. As such, there needs to be clear guidance on roles for SES personnel that come from other areas, until such time as a local SES Unit is re-established. The local flood plan also says very little about flooding risks from local overland flow, which can be included based on the information provided in this floodplain risk management study.

Part 3 of the local flood plan describes response arrangements. This section also needs significant update, to align the structure and contents with the new NSW SES local flood plan template, and to incorporate up to date information. This section references the Murrumbidgee Local Controller and the Murrumbidgee SES Division Headquarters, neither of which currently exist. The information produced in this floodplain risk management study, and the updated flood protection provided by the upgraded levee, should also be included in this section. The section is also relatively vague with respect to when warnings and evacuation orders should be issued. Therefore, this section should be updated using information from this floodplain risk management study. The volume includes a list of gauges to be monitored prior to and during flooding. Information provided in this table should be verified to ensure it is the most up to date information for those gauges (Annex C). The list of media outlets should be reviewed (Annex E). Additionally, Annex F should be updated based on the upgrades that have been completed to the levee around Darlington Point. All flooding maps should also be updated to include the information produced in this floodplain risk management study. Finally, considerable effort is needed to provide the detail consistent with the new SES LFP template.

Part 4 details the recovery arrangements. Again, considerable effort will be needed to provide the detail consistent with the new SES LFP template. This section references Murrumbidgee Local Controller and will require updating and clear instructions on those SES Units coming into Darlington Point from elsewhere during an event, until such time that a local SES unit is established.

There is a rage of information that can be included in the each of the Annexes, with a summary of this information outlined in **Table J.1** below.

Table J.1 - Comments on Current Murrumbidgee Local Flood Plan 1994 – Volume 2

Section	Description	Comment
Volume 2 Hazard and Risk in Murrumbidgee LGA		
Annex A	Characteristics of flooding	Peak design flood levels determined in this FRMS should be included. This includes floods rarer than the 1% AEP event for the Murrumbidgee River at Darlington Point.
Annex A	Flood History	Should be updated to include reference to more recent floods (e.g. 2010, 2012, 2016)
Annex A	Flood Mitigation Systems	Information on the upgraded levee and the level of protection should be included, including a figure of its location with crest heights.
Annex B	Effects of Flooding on the Community	Information in this FRMS should be used to describe the effects of flooding on the community, including: • Information on the location and type of buildings with over-floor flooding at the various design flood levels. • Flood impacts to critical facilities and vulnerable developments. • Location where roads get cut by floodwaters
Volume 3 SES Response Arrangements		
Annex D	Dissemination of SES Flood Bulletins	The list of media outlets for flood bulletins needs to be updated.
Annex E	Dissemination of Flood Warnings and other Flood information.	The list of media outlets for flood warning dissemination needs to be updated.
Annex F	Vulnerable Facilities	Should be updated based upon the information contained in **Section** Error! Reference source not found. of this report. This includes Darlington Point Caravan Park and the Altina Wildlife Park, north Darlington Point and the area behind the levee.

Section	Description	Comment
Annex G	Roads Subject to Flooding	The list of roads should be updated based on information contained in **Section 1.2** of this report. Also, the Sturt Highway outside of the study area has the potential to be cut by floodwaters and should also be included.
Maps	Maps	The maps should be updated to include a map dedicated to Darlington Point and surrounds.
Missing Information		Volume 3 is also missing a number of key components, particularly: • A breakdown of the local SES response arrangements (e.g. sectors) and response strategies whilst there is no local SES Unit. • Resupply arrangements for isolated properties.

1.2 Darlington Point Gauge Level vs Design Flood Heights

Table J. 2 - Design flood levels vs gauge level at Darlington Point bridge gauge 410021

Gauge level (metres)	Reduced level (mAHD)	Approximate design Flood Event
6.44	124.30	20% AEP
7.01	124.87	10% AEP
7.33	125.19	5% AEP
7.64	125.51	2% AEP
7.78	125.64	1% AEP
7.86	125.73	0.5% AEP
7.94	125.81	0.2% AEP
8.25	126.11	Extreme flood event

1.3 Flood emergency response classifications

The flood emergency response classification for each lot has been estimated and mapped, with **Figure 36** indicating flood emergency response classification for the **5% AEP** design flood event, **Figure 37** for the 1% AEP design flood event and **Figure 38** for the extreme flood event.

1.4 Impacts on Transportation Links

An assessment of the location where roadways are first predicted to be overtopped was completed as part of the Flood Emergency Response Precinct classifications discussed in **Section 5.1.2** of the floodplain risk management study. **Plate J.1** below identifies the roadway over topping locations considered in this study.

Table J.3 - Gauge and Flood levels at which road segments would be cut

Flood level (mAHD)	Height at Murrumbidgee Gauge 410021 (m)	Consequences
125.25	7.39	Access cut at Location 9
125.42	7.55	Access cut at Locations 1 and 9
125.77	7.91	Access cut at Locations 1, 3, 5, 9 and 10
125.94	8.08	Access cut at Locations 1, 3, 5, 6, 7, 9 and 10
126.10	8.24	Access cut at Locations 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10

Plate J.1 - Road Over topping locations identified in this study

1.5 Frequency of above floor flooding for existing developments

Figure 39 outlines the estimated frequency of flooding of the floor levels in and round Darlington Point and north Darlington Point. **Table J.4** outlines the number of properties subject to above floor inundation as a result of local flooding behind the levee only. **Table J.5** outlines the estimated number of properties subject to above floor inundation as a result of mainstream flooding from the Murrumbidgee River only. The information presented on **Figure 39** summarises the information from both **Table J.4** and **Table J.5.**

Table J.4 - Number of Properties Subject to Above Floor Inundation and Property Damage as a result of local flooding behind the levee only.

Flood Event	Number of Properties Impacted by flooding			
	Residential		Commercial/ Industrial	Total
	External Damage only	Above floor Flooding		
20% AEP	16	0	1*	**17**
10% AEP	18	0	1*	**19**
5% AEP	21	0	1*	**22**
2% AEP	25	0	1*	**26**
1% AEP	30	2	2	**34**
0.5% AEP	32	3	2	**37**
0.2% AEP	39	4	2	**45**
Extreme Flood	97	158	24	**279**

*This property is one of the community open space areas in Darlington Point behind the levee that only consists of open space with no buildings.

Table J.5 - Number of Properties Subject to Above Floor Inundation and Property Damage as a result of mainstream flooding from the Murrumbidgee River only

Flood Event	Number of Properties Impacted by flooding			
	Residential		Commercial/ Industrial	Total
	External Damage only	Above floor Flooding		
20% AEP	0	0	0	**0**
10% AEP	0	0	1**	**1**
5% AEP	2	1	1**	**4**
2% AEP	11	8	5	**24**
1% AEP	17	15	5	**37**
0.5% AEP	86	146	28	**261**
0.2% AEP	98	179	33	**310**
Extreme Flood	106	306	33	**452**

**Darlington Point Caravan Park

1.6 Vulnerable and Critical Infrastructure

A summary of vulnerable and critical facilities located within the study area was provided in **Section 2.4.3** of the floodplain risk management study, and the location of each facility is shown on **Figure 8**. All but 2 of these of vulnerable and critical facilities are located within the areas protected by the levee. The Darlington Point Caravan Park and the electricity sub-station along the northern sections of The Kidman Way to the north of north Darlington Point are located outside of the levee and are both vulnerable to flooding.

Table J.6 outlines the depth of flooding estimated to occur at each facility.

The information presented in **Table J.6** highlights the vulnerability of the Darlington Point caravan park to flooding. It is subject to at least partial inundation during events as frequent as the 10% AEP design flood event. The depth and velocity of floodwater is unlikely to pose a hazard to people during the 5% AEP design flood event and is currently estimated as H3 flood hazard. This flood hazard at the caravan park dramatically increases to H4 and H5 during the 1% AEP design flood event, which is not safe for people or vehicles. Less robust buildings are vulnerable to failure during the hazards of H5 or greater.

The electricity sub-station to the north of north Darlington Point is first impacted by floodwaters during the 1% AEP design flood event, however the Kidman Way (Location number 10 on **Plate J.1**) is more vulnerable to flooding and is impacted by floodwaters during more frequent events.

Table J.6 -Critical and Vulnerable Facilities outside the levee vulnerable to flooding.

Design flood event	Depth of flooding estimated across property	
	Darlington Point Caravan Park (metres)	Electricity sub station (metres)
10% AEP	0.15	N/A
5% AEP	0.53	N/A
2% AEP	0.90	N/A
1% AEP	1.05	0.04
0.5%AEP	1.15	0.09
0.2% AEP	1.24	0.12
Extreme flood event	1.59	0.37