WERRI BEACH HOLIDAY FLOOD MITIGATION INVESTIGATION

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
ARR	Australian Rainfall and Runoff
FPA	Flood Planning Area
FPL	Flood Planning Level
IFD	Intensity Frequency Duration
LiDAR	Light Detection and Ranging
KMC	Kiama Municipal Council
WMS	Water Modelling Solutions

1 INTRODUCTION

Kiama Municipal Council (KMC) engaged Water Modelling Solutions to undertake a flood mitigation investigation for flooding at the Werri Beach Holiday Park. Werri Beach is located in the town of Gerringong approximately 10 km south of Kiama on the New South Wales south coast. A redevelopment of the northern area of the Holiday Park is underway and a flood assessment is required to inform the Council of construction constraints and mitigation options that may be implemented to reduce flood risk. This information will be used to progress design of the redevelopment and satisfy the requirements for DA lodgement.

1.1 SCOPE OF WORK

The project scope of works is briefly outlined as follows:

1.) Preliminary Option Identification
   - a. Project initiation
   - b. Desktop data review
   - c. Site visit
   - d. ARR2019 Hydrology model update
   - e. Initial option identification workshop
2.) Targeted issues investigation
   - a. Survey Brief
   - b. Hydraulic Modelling with reduced cell size
   - c. Emergency response, environmental, social and political issues
3.) Options impact assessment
   - a. Flood impact assessment
   - b. Emergency response and planning considerations
4.) Concept design and cost estimation
   - a. Concept design drawings
   - b. Concept cost estimates
5.) Recommendations and reporting
   - a. Draft Report
   - b. Final Report

1.2 PURPOSE OF THIS REPORT

The objective of this Flood Mitigation Investigation Report is to provide an understanding of the processes undertaken as part of the investigation and the impact of mitigation measures on the flooding of the Werri Beach Holiday Park.

This report will follow the structure of the Scope of Work as listed above.

2 STUDY AREA

Werri Beach Holiday Park is located at 1A Bridges Road, Gerringong, on the NSW South Coast. The site is zoned RE1: Public Recreation, which applies to public open space areas and land used for recreational activities. The intention of the zone is to provide a range of recreational settings and compatible land uses while protecting and enhancing the natural environment for recreational purposes. The topography shown in Figure 2-1 in the vicinity of the site is developed using 1 m resolution 2011 LiDAR data. As shown, the Holiday Park is located at the base of a relatively steep hill, with limited upstream catchment area. The local watercourse is a tributary of Werri Gully which flows into Werri Lagoon to the north. The site itself is relatively flat, with the watercourse running along the western boundary. This proximity to the watercourse, limited gradient across the site and the hydraulic control of Werri Lagoon means that the site is subject to flood risk during storms and may take hours if not days to drain to the north.

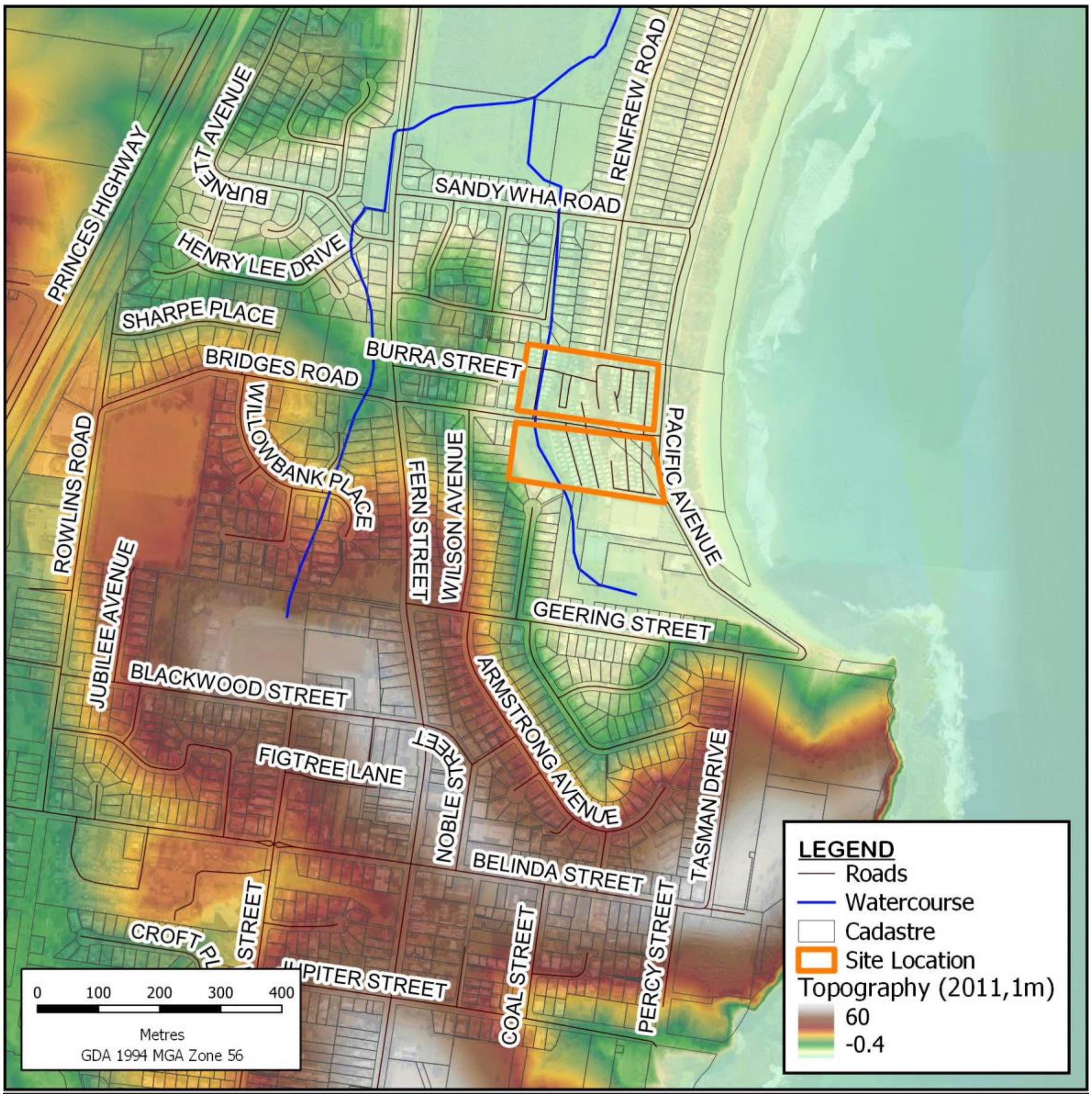


Figure 2-1 Subject Study Area

3 AVAILABLE DATA

3.1 PREVIOUS INVESTIGATIONS

3.1.1 Ooaree Creek and Werri Lagoon Catchment Flood Study, SMEC, 2019

The Ooaree Creek and Werri Lagoon Catchment Flood Study was completed by SMEC for KMC in 2019. The study area included the local Werri Gully catchment as well as the wider Ooaree Creek catchment and Werri Lagoon Catchment that flows into Werri Lagoon from the west. The total study area encompasses approximately 17 km². The flood study defined flood behaviour under historic and existing conditions to produce design flood levels, velocities, flows, hydraulic categories, provisional hazard categories and flood damages. It also assessed flood behaviour under several lagoon outlet condition scenarios due to the changing outlet bathymetry. A WBNM hydrology model and TUFLOW hydraulic model was adopted and updated from the Princes Highway Gerringong Upgrade project for development of the flood study. Modelling adopted the use of Australian Rainfall and Runoff (ARR) 1987 rainfall. There was found to be insufficient data for a comprehensive model calibration, but verification to the February 2017 event was carried out through assessment of the rainfall and lagoon water level. The modelling from this Ooree Creek and Werri Lagoon Catchment Flood Study forms the basis of the Werri Beach Holiday Park Investigation. Section 4.1 of the Ooree Creek and Werri Lagoon Catchment Flood Study outlines additional investigations that have been utilised in the study area.

3.1.2 Gerringong & Jamberoo Flooding Investigation, Catchment Simulation Solutions, 2020

In response to flooding in August 2020, KMC commissioned Catchment Simulation Solutions to investigate known flooding hotspots in three catchments. These catchments include Bridges Road, Wyalla Road and Jamberoo Town Centre. The investigations will allow Council to confirm the location and extent of flooding problems and identify where flood mitigation measures may be of most benefit.

3.2 HYDROLOGICAL DATA

Water Modelling Solutions received the Ooaree Creek and Werri Lagoon Catchment Flood study WBNM hydrology model from KMC. The model was simulated for design events using Australian Rainfall and Runoff (ARR) 1987 Guidelines and Intensity Frequency Duration (IFD) Data. The WBNM hydrologic model was used to simulate the 20%, 10%, 5% and 1% Annual Exceedance Probability (AEP) design events and the Probable Maximum Flood (PMF) event.

ARR2019 has since superseded ARR1987 Guidelines that were used in the 2019 Flood Study. As such, the Werri Beach Holiday Park investigation provides an opportunity to update the hydrology to be consistent with ARR2019. Some re-delineation of local catchments and updates to land use parameters will also be carried out to improve the representation of local catchment features. No GIS catchment or stream files used in the WBNM model build have been provided.

The WBNM model was tested and found to run successfully for the 1% AEP event.

3.2.1 Historical flood records

Flood events are known to have occurred in February 2017 and August 2020. Council has sent some photos of flooding in the area of interest during the August 2020 event. No further direct records of historical flooding have been provided but some historic flood information and community consultation responses are available in the Ooree Creek and Werri Lagoon Catchment Flood Study. Review of this information has confirmed that numerous flood related complaints have been received from local residents in recent years. The Werri Beach area is therefore verified to flood in frequent events, although the severity of flooding remains unclear.

3.2.2 Hydraulic Data

The Ooaree Creek and Werri Lagoon Catchment Flood Study TUFLOW model was received from KMC and successfully simulated for the 1% AEP event, thereby confirming that the model is in working order. A number of lagoon outlet breach scenarios and sensitivities tests were present in the model control files. GIS files for these runs were not supplied but it is understood no testing of these past scenarios will be required as part of the Werri Beach Holiday Park Investigation.

3.2.3 Topographical and Physical Survey

3.2.3.1 Model DEM Data

The following Digital Elevation Model (DEM) surfaces were supplied by KMC as part of the hydraulic model handover :

- kiama_dem2m.asc – LiDAR of the model area from 2011
- 1m_WerriLagoon.dem – Bathymetric surface of the Werri Lagoon and beach outlet.
- TD00_NOBRIDGE_2m.dem –Design surface of the Princes Highway
- FernSt_Raised_1m.dem – Fern Street.
- FernSt_Basin_1m.dem – Fern Street Basin levels at the corner of Fern Street and Sandy Wha Road
- Werri_Lagoon_Survey_DEM_003.asc – Survey of ground areas around Werri Lagoon.

The 2011 2 m Kiama model LiDAR was compared to 1m LiDAR sourced from Geosciences Australia. The LiDAR from Geoscience Australia was also from 2011. Review of the two surfaces indicated that they were near identical and likely derived from the same raw data. The 1 m LiDAR will be used for the modelling as this provides a finer resolution surface for model refinement.

High definition 2011 aerial imagery was provided by KMC. Review of this aerial against the more recent NSW SIX MAPS imagery indicates that the Holiday Park and watercourse of interest have changed very little in the 10 years from 2011. This would suggest that despite the age of the LiDAR data (also from 2011) it is likely to provide a sufficient representation of the study area, and is appropriate for use in the model.

Recent topographic survey has been provided in the form of a .dwg file, “2377-Detail Survey April 2021.dwg”. WMS has imported this file to 12d, and appropriate layers were exported as a surface .dem file. The survey covered the Holiday Park and surrounding areas up to Geering Street. Some survey layers were found to be inappropriate for export due to missing z values or large distances between survey strings that would have interpolated levels over large distances, thereby reducing accuracy. The exported survey surface was compared to the 1 m LiDAR and found to appropriately represent ground levels. Comparison cross sections are shown in figures Figure 3-1, Figure 3-2 and Figure 3-3. The cross-section locations and survey extent are shown in Figure 3-4. The survey was found to be slightly lower (approximately 100 mm) than the LiDAR. This is not unusual; LiDAR typically has an accuracy of +/-150 mm in the vertical plane. Cross Section 3 is over the shallow concrete channel north of Bridge Road, the LiDAR appears to be overestimating the channel depth through this reach and is to be superseded by the later survey. The survey data will supersede the 2011 1 m LiDAR where the data is available.

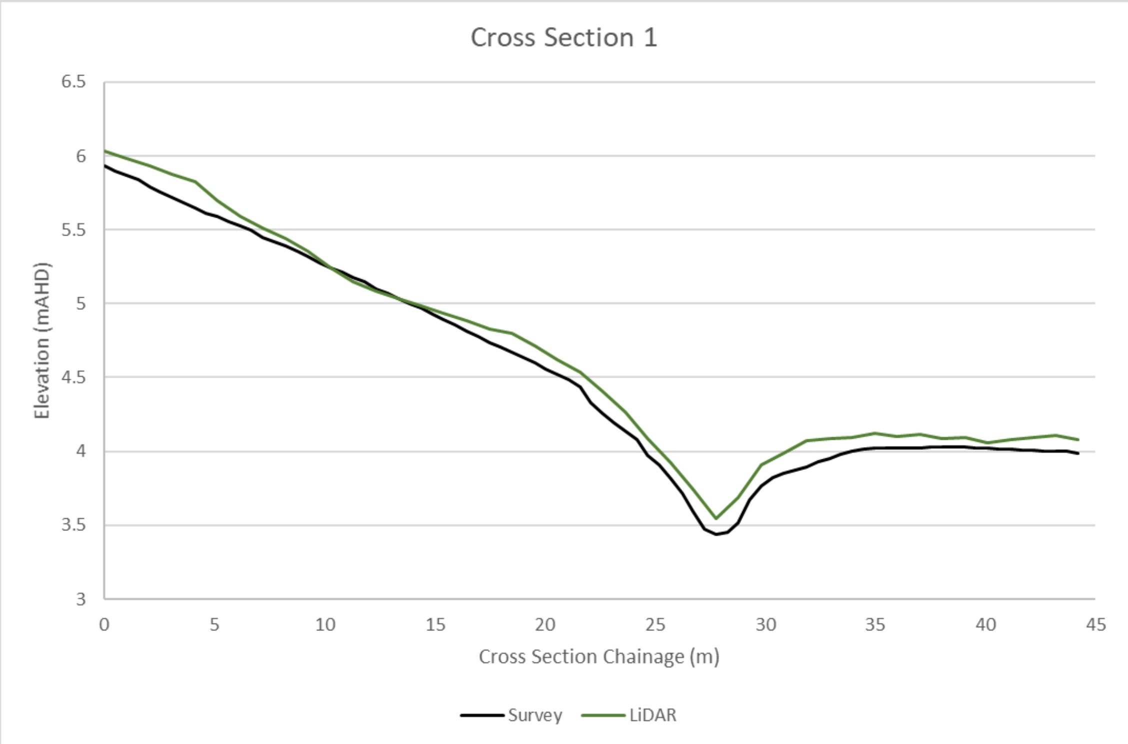


Figure 3-1 Cross Section 1 Survey compared with LiDAR

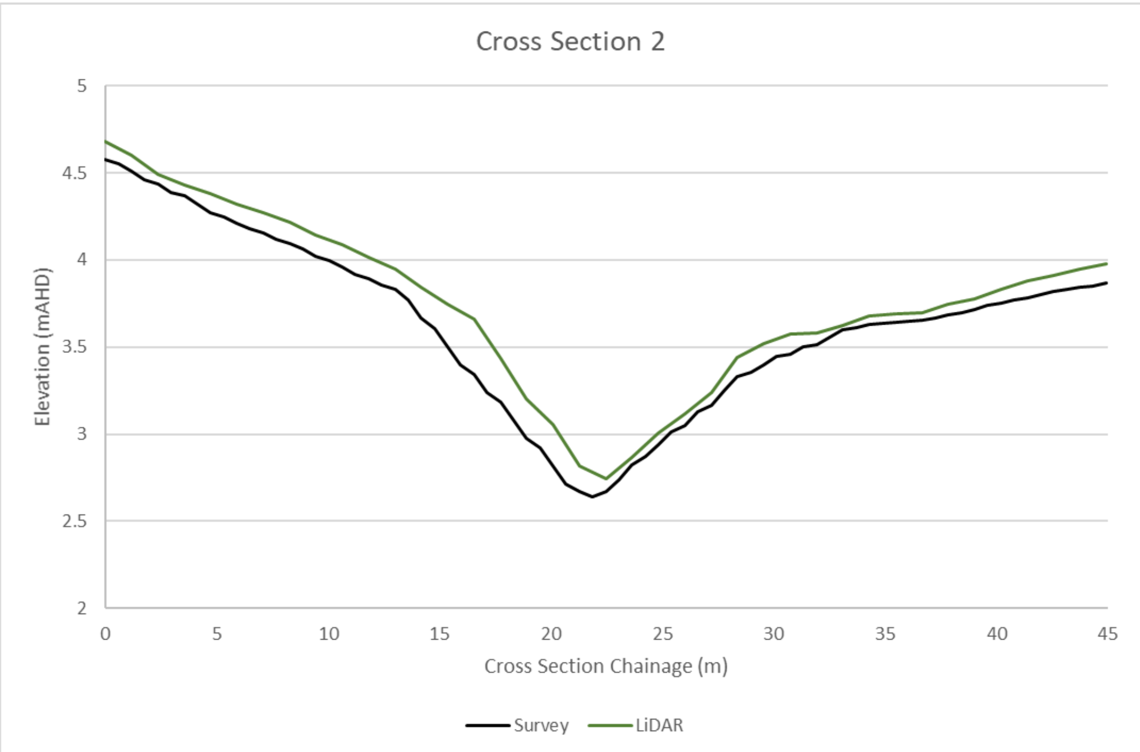


Figure 3-2 Cross Section 2 Survey compared with LiDAR

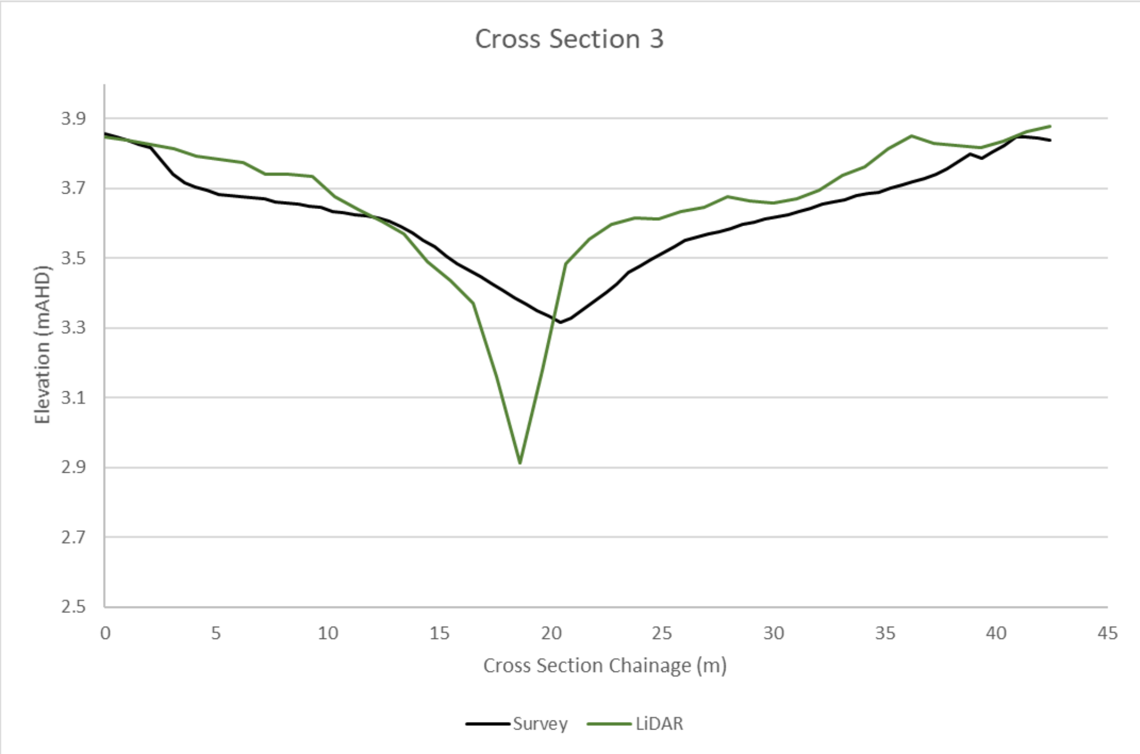


Figure 3-3 Cross Section 3 Survey compared with LiDAR

Figure 3-4 2021 Survey Extent

Geosciences Australia also has LAS file format surface data available from 2018. This is raw LiDAR data and cannot be used in hydraulic modelling but additional efforts to post process and convert this newer data may improve model outcomes. It was concluded the existing 2011 LiDAR in combination with the detailed surveys provided were adequate for this investigation and the 2018 LAS data was not used.

3.2.3.2 Bathymetric Survey

Bathymetric survey has been provided for Werri Lagoon. However, inspection of the LiDAR suggests that the tributary watercourse was dry or near dry at the time of LiDAR capture and provides a better representation. As such, tributary watercourse bathymetry is not required as its topography is well represented in the LiDAR.

3.2.4 Hydraulic Structures

No bridge structures are present in the local Werri Gully catchment, but the main watercourse includes transverse culvert structures, an open concrete drain and underground drain. The hydraulic structure configuration is depicted in Figure 4-5. Immediately upstream of the Holiday Park the watercourse is an open channel, with a concrete lined low flow, Figure 3-5. On the upstream side of Bridges Road, the watercourse is split in two, Figure 3-6. An underground rectangular stormwater line conveys part of the flow more than 400 m downstream where the system daylights north of Sandy Wha Road and flows into Werri Lagoon via open channel. Upstream of Bridges Road once the underground stormwater line reaches capacity flow enters culverts under Bridges Road. The culverts discharge into a shallow concrete drain on the downstream side of Bridges Road. The concrete drain passes through some access road culverts in the Holiday Park before discharging into an underground pipe immediately downstream of the Holiday Park. This pipe also discharges downstream of the Sandy Wha Road in the open channel. The culverts, pipes and drains are all modelled in 1D in the Ooree Creek and Werri Lagoon TUFLOW model.

Figure 3-5 Open channel with concrete lined low flow

Figure 3-6 Underground rectangular stormwater line (Left) and Concrete drain (Right

These key drainage structures are listed in Table 3-1. The details are compiled from inspection of the model files and drain cross sections provided in file 2377-Alignment1-Flood Analysis.pdf. The received survey has also been inspected to confirm the details although some inconsistencies are present. The underground drain dimensions are unclear from the survey but appear inconsistent with the dimensions modelled (2400mm x 900mm RCBC). The survey suggests that the drain is an irregular v-cut underground channel.

Table 3-1 Key Drainage Structures as per MBRC Pit and Pipe Network Data

Key Crossing	Model ID	Dimensions	Upstream Invert	Downstream Invert (m AHD)	Length (m)
Underground drain	C-SUR-6	2400mm x 900mm RCBC	2.34	1.03	430
Bridge Road Culverts	C-SUR-1	3000mm x 300mm RCBC	3.02	2.88	11
Open Concrete drain (Chainage 5.03)	NA	2100mm x 400mm (Approx.) Open Channel	NA	NA	7
Open Concrete drain (Chainage 50)	CH-SUR-2	2100mm x 600mm (Approx.) Open Channel	2.88	2.65	68
Open Concrete drain (Chainage 103.26)	CH-SUR-1	2800mm x 600mm (Approx.) Open Channel	2.64	2.51	33
Access road culverts	C-SUR-4	2000 x 600mm RCBC	2.65	2.64	4
Underground Pipes (upstream reach)	C-SUR-7	1200 mm RCP	2.51	1.93	125
Underground Pipes (downstream reach)	C-SUR-8	2/ 750 mm RCP	1.93	1.03	156

3.3 SITE VISIT

WMS staff visited the Werri Beach Holiday Park Site and the surrounding catchment area to undertake a site visit on the 25th January 2022. The objective of the site visit was to inspect the topography, land use, and hydraulic features of the study area to validate the inputs used for the TUFLOW model, as well as consider potential mitigation options.

The location and size of several stormwater pits and pipes within the study area were confirmed, and the topography on site reflected the DEM developed using the available LiDAR data and detailed survey.

A full catalogue of images and notes from the site visit are available in Appendix C.

The main features noted on site were as follows:

- Stormwater pits are located on the beachfront road and appear to discharge onto beach at location of proposed mitigation (see Figure C-7 and Figure C-8 in Appendix C);
- Stormwater running down Werri Gully travels past the Tennis Courts before excess water is sent backwards to a storage area in the park south of the surf club (see Figure C-4 in Appendix C); and
- Noticeable grade differences between Werri Gully, the park to the south of the surf club and the beach, potential flow path to between Werri Gully and the beach is along the back fence of the houses and to the south of the carpark (see Figure C-4 and Figure C-5 in Appendix C).

3.4 ADDITIONAL GUIDANCE

This flood mitigation investigation has been undertaken in accordance with current industry guidance and best practice, referring to neighbouring LGAs for guidance where appropriate. In particular, guidance has been sought in relation to blockage factors and flood planning controls specifically for caravan parks. These have been listed in Table 3-2.

Table 3-2 Legislation and Guidelines

Document	Relevant Aspect	Report Section
Australian Rainfall and Runoff: A Guide to Flood Estimation (Ball et al., 2016)	ARR2019 Modelling Methodology	Section 4.1.2 Section 4.2.2 Section 5.2
Australian Rainfall and Runoff: A Guide to Flood Estimation (Ball et al., 2016)	Blockage Factors	Appendix A Section A.3
Wollongong Development Control Plan (Wollongong City Council, 2009)	Blockage Factors	Appendix A Section A.3
Elliot Lake - Little Lake Flood Study (Cardno Lawson Treloar, 2006)	Blockage Factors	Appendix A Section A.3
Shoalhaven Development Control Plan (Shoalhaven, 2014)	Caravan Parks in Flood Prone Areas Controls	Section 6

3.5 DATA SUMMARY

Table 3-3 Data Gap Analysis and Recommendations

No.	Gap	Purpose	Way forward if unavailable	Status
1	There have been no GIS files provided for the WBNM model sub-catchment delineation or stream lines.	To update the WBNM model, the files used to develop the original model are needed.	The hydraulic model's source area inflow file appears to include the sub-catchment delineations and can be used to recreate the catchment files. This will be more time consuming and may be less	Not Required The hydraulic model's source area inflow file was used to recreate the

No.	Gap	Purpose	Way forward if unavailable	Status
			accurate particularly if the sa file delineation has been edited for use in the hydraulic model. The sub-catchment delineations will be refined by WMS in line with the smaller study area.	sub-catchment delineation.
2	Further details of historic flooding such as complaints register extract or emergency response records. In particular, events that have occurred since the completion of the Ooaree Creek and Werri Lagoon Catchment Flood Study in February 2019, are of interest.	This will establish impacts of frequent flood events and help verify what is justifiable mitigation.	The investigation can proceed in the absence of this data but there is a higher risk of developing mitigation options that are less suited to the true flood issue.	Not available, WMS will proceed with design flood information as per the Brief.
3	Confirmation if Council would like to invest further in LAS data investigation and conversion.	To represent the wider floodplain area more accurately.	If unavailable, the 2011 LiDAR and site survey will provide sufficient surface data to progress the study. Due to the 1 m grid resolution of the available LiDAR data and comparative nature of the assessment, WMS do not deem the LAS data investigation to be necessary at this stage. The additional data should be investigated prior to detailed design.	Not Required Adopted 2011 LiDAR and site survey are considered fit for purpose and have been used to create DEM.
4	Any further or more up to date bathymetric data for the Lagoon and surrounds.	To represent existing bathymetric conditions more accurately.	2017 lagoon bathymetry data is already available and can be used in combination with other available dem surfaces to progress the modelling.	Not Required
5	Further confirmation of the drainage details through supply of structure drawings or GIS drainage details, in particular the underground drain between bridge street and Sandy Wha Road.	To ensure hydraulic structures in the area of interest are represented appropriately in the hydraulic model.	Verification of structures has already been undertaken with 2021 ground survey of the study area. The modelling can be progressed with reasonable confidence in the representation of hydraulic structures. Where details remain uncertain educated estimates of structure details can be made. Further verification will also take place on site, where access is possible.	Not available, hydraulic structures verified during site visit.
6	Current detailed aerial imagery.	To assist in model parametrisation, revise material land use layers and present mapping.	In the absence of up to date detailed aerial imagery the online NSW Six Map dataset will be used. Site features will also be verified during the site visit.	Not required. NSW Six Map aerial used and verified through site visit
7	Housing floor levels.	Floor levels will allow assessment of building immunity to a higher level of accuracy.	Floor level assumptions can be made in the absence of surveyed floor level data, but any calculated property impacts are likely to be less accurate and may over or	Not required for the purposes of this assessment.

No.	Gap	Purpose	Way forward if unavailable	Status
			underestimate the effectiveness of mitigation.	
8	Major Infrastructure Works Plans (if applicable).	Infrastructure works may have an influence on watercourse hydraulics or hydrology and may need to be modelled.	If major works are planned in the study catchment and details are not provided, receiving flows or tailwater levels at the study area may be slightly altered. If works interact or re-route waterways the impacts may be more significant.	No works planned.

4 FLOOD MODEL UPDATES AND VALIDATION

4.1 HYDROLOGIC MODEL

4.1.1 Existing WBNM Model

The WBNM Model built as part of the Ooaree Creek Werri Lagoon Catchment Flood Study (SMEC, 2019), herein referred to as the 2019 Flood Study, extends over the entire Ooaree Creek and Werri Lagoon 17 km^2 catchment, from the ridge line at the top of the catchment down to the outlet where the Werri Lagoon meets the South Pacific Ocean. The model is made up of 49 catchments ranging in size from 1.71 ha to 129 ha and was completed using the ARR1987 modelling methodology.

This flood mitigation investigation provided an opportunity to refine the 2019 Flood Study WBNM model, which was adopted as a base and updated to be suitable for this investigation. The model extent was redefined to only incorporate the Werri Gully catchment, and the sub catchments surrounding the site were reconfigured. The modelling methodology was also updated to ARR2019, incorporating the necessary design rainfall intensities and loss parameters.

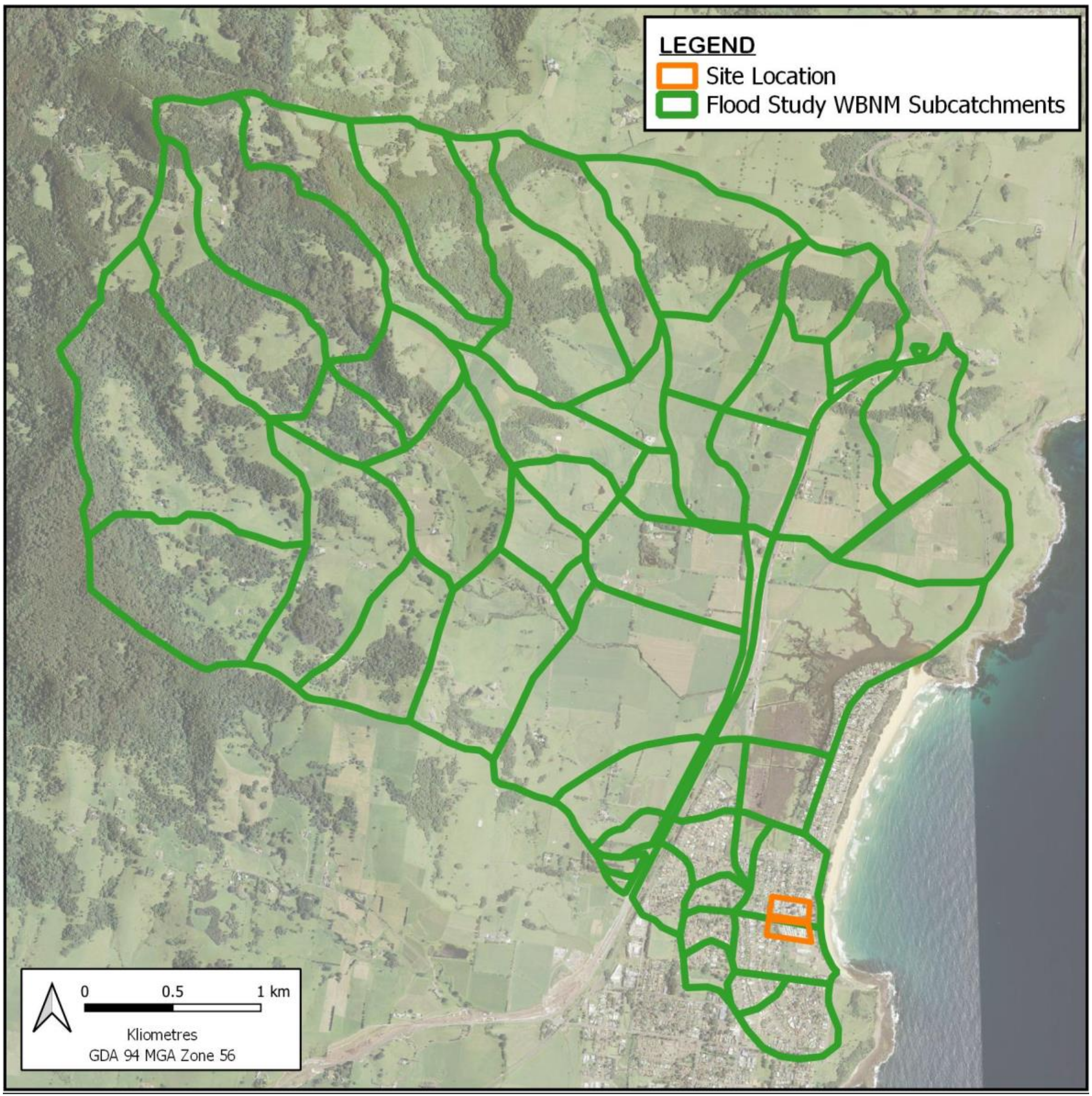


Figure 4-1 2019 Flood Study WBNM model extent

4.1.2 Updates to WBNM Model

4.1.2.1 Sub Catchment Delineation

The sub catchments surrounding and upstream of the site were refined to improve the representation of points of concentration, and better translate inflows to the hydraulic modelling. The sub catchments were redefined based on the topography, hydraulic features, and site location. Consideration was also given to the future assessment of potential mitigation options, to ensure that the sub catchments would be suitable without further adjustment later in the study. A total of 5 sub catchments were adjusted, these are outlined in Table 4-1 below, along with relevant properties, and are depicted in Figure 4-2.

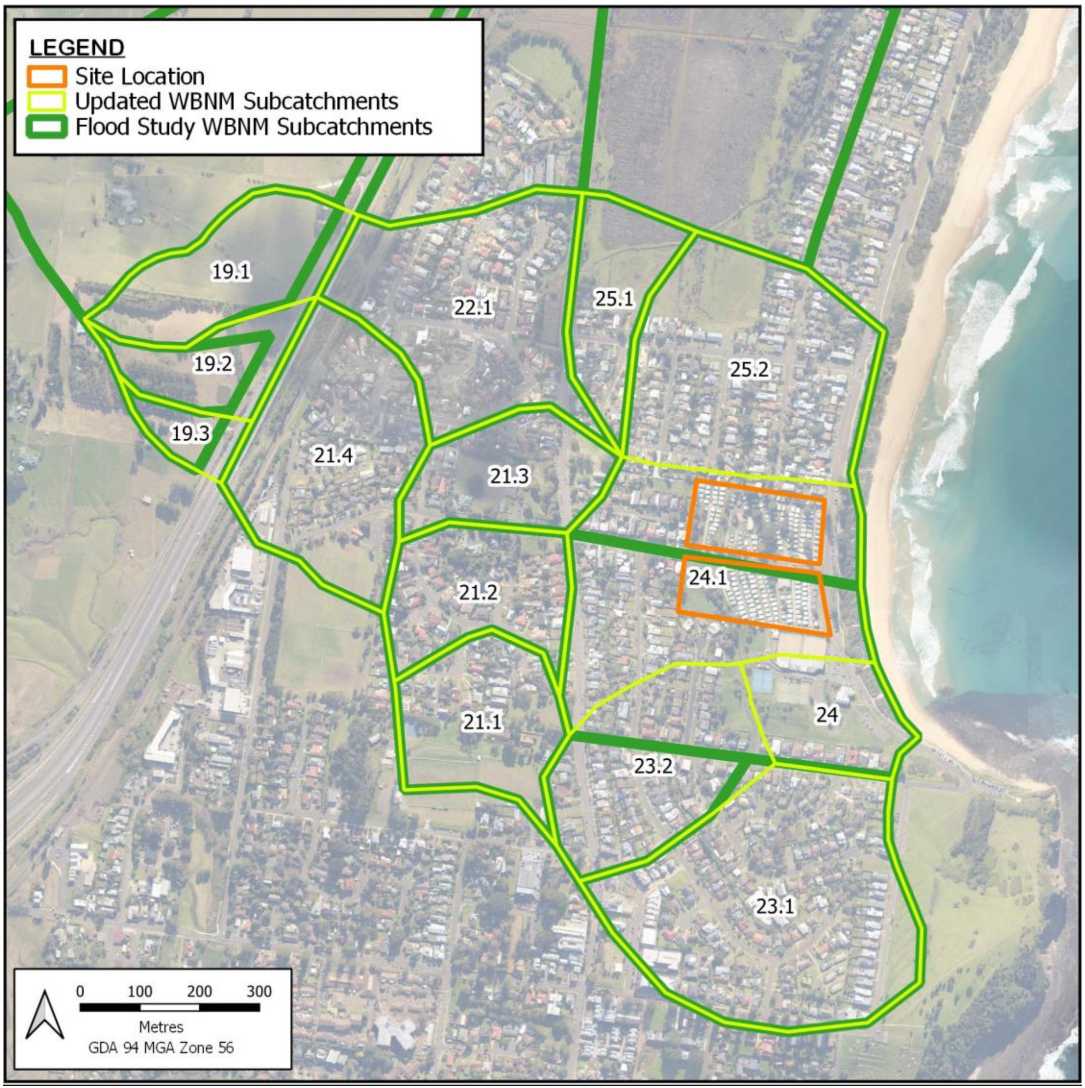


Figure 4-2 Updated WBNM model extent

4.1.2.2 Model Extents

This investigation has a focus on the Werri Beach Holiday Park and has been refined to only model the Werri Gully Catchment. The Holiday Park sits in the lower reach of the Werri Gully Catchment and the upstream end of the Werri Lagoon to the north has been incorporated to ensure the hydraulic model represents an appropriate water level downstream of the site.

4.1.2.3 Fraction Impervious

The fraction impervious values for the updated sub catchments were calculated using the 2011 Kiama Local Environment Plan (LEP) land zoning layers. Several sub catchments which remained unchanged were validated and found to be consistent with the 2019 Flood Study WBNM model and the fraction impervious methodology adopted for this study was deemed appropriate.

Table 4-1 Updated WBNM Sub Catchments

Sub Catchment ID	Area (ha)	Fraction Impervious (%)	Downstream Sub Catchment ID
23.1	17.02	70	24
23.2	9.04	60	24.1
24	4.39	15	24.1
24.1	16.12	35	25.2
25.2	13.68	60	25

4.1.3 Conversion to ARR2019 Modelling Methodology

4.1.3.1 IFD table

The Bureau of Meteorology's (BOM) Design Rainfall Data System (2016) was used to extract the Intensity Frequency Duration (IFD) data for the catchment. The data was sourced on the 19th of January 2022 and is available in Appendix A.

4.1.3.2 Losses

The losses adopted for the modelling are taken from the ARR2019 Data Hub (Sourced: January 2022) and as the catchment is within New South Wales (NSW) the Continuing Loss has been factored by a value of 0.4. The losses are as follows in Table 4-2.

Table 4-2 Updated WBNM Loss Values

Initial Loss (mm)	Continuing Loss (mm/hr)
47	1.56 (3.9 * 0.4)

4.1.3.3 Critical Duration Shortlist

The hydrology model was run for durations and temporal patterns from 10 minutes through to 1440 minutes (24 hours) for the 1% and 5% AEP events as required by ARR2019. The duration that produced the highest peak flows at the site location (sub catchment 24.1), plus three durations either side (seven in total) were shortlisted for running in the hydraulic model (see Table 4-3). For the purposes of this assessment it was considered appropriate to base selection of the critical duration on peak flood level rather than flow, using the hydraulic model rather than relying on outputs from the hydrology model only. The results are discussed in Section 4.2.3

Table 4-3 Updated WBNM Critical Durations

Event (AEP)	Durations (mins)
1%	15, 20, 30, 45, 60, 90, 180
5%	15, 20, 30, 45, 60, 90, 180

Further explanation into the selection of critical duration and temporal patterns is available in Appendix A.

4.2 HYDRAULIC MODEL

4.2.1 Existing TUFLOW Model

The TUFLOW Model built as part of the 2019 Flood Study has a modelled extent of 10 km^2. The extent covers the lower areas of the Werri Gully catchment, including the farmland to the west of the highway, and Werri Lagoon. The model has a 5 m grid cell size and discharges to the ocean via a Head versus Time (HT) boundary connection. The inflows to the model are defined as sub catchment wide source-area (SA) inflow boundaries and all the stormwater networks and open channels are represented in the 1D network.

This flood mitigation investigation provided an opportunity to refine the 2019 Flood Study TUFLOW model. The model extent was redefined to only incorporate the lower lying areas of the Werri Gully catchment and the upstream end of the Werri Lagoon. The inflows, 1D network, grid cell size and model boundaries were all refined to ensure the most accurate depiction of the Werri Beach Holiday Park could be modelled.

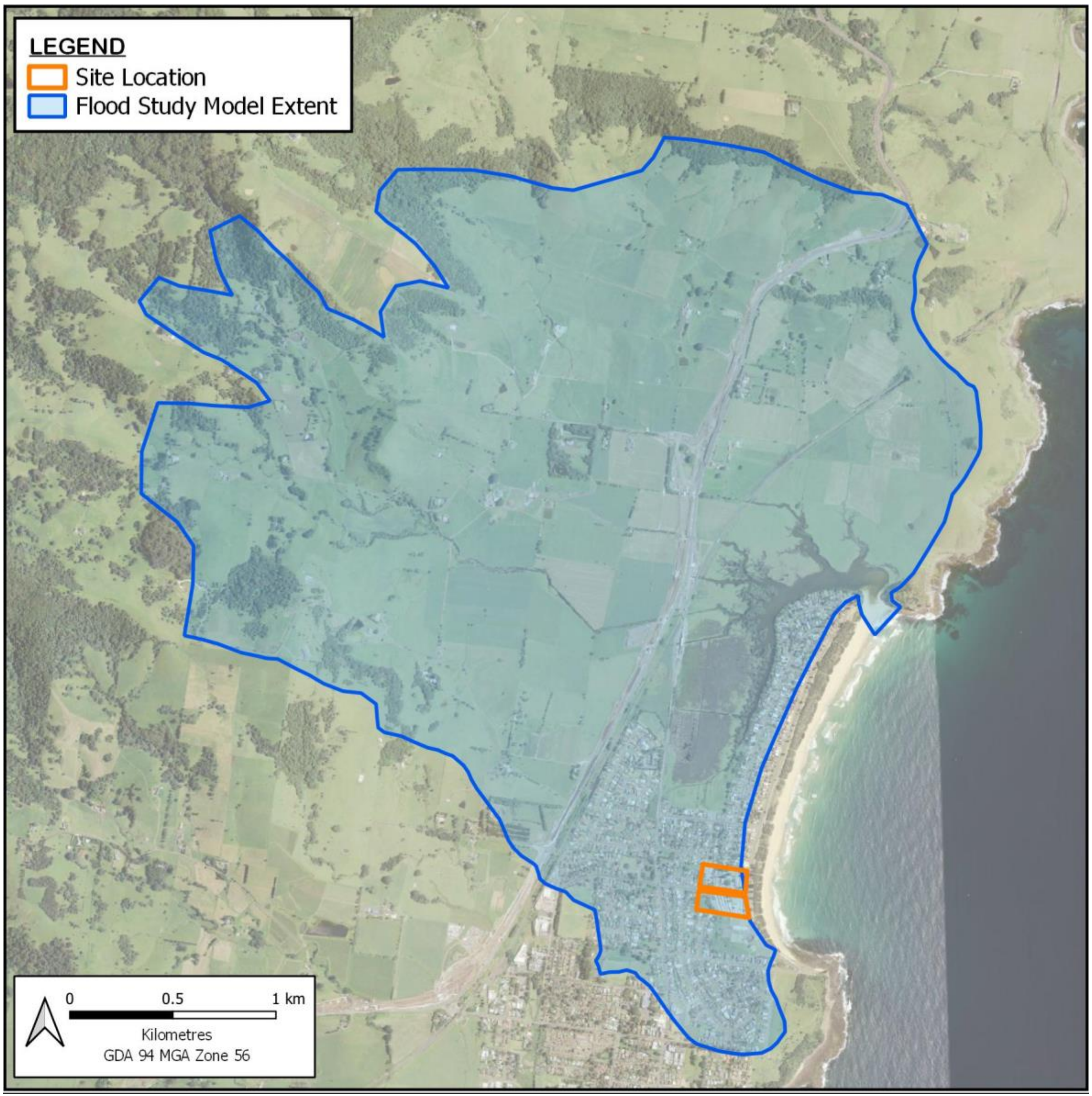


Figure 4-3 Existing TUFLOW Extent

4.2.2 Updates to TUFLOW Model

4.2.2.1 Grid Cell Size

This model has adopted a 1 m grid cell size, this has been adjusted from the 2019 Flood Study 5 m grid as the smaller grid size allows for improved representation of current catchment conditions. In addition, the finer grid cell resolution improves the model's ability to simulate a range of mitigation measures and the impacts to be assessed for the Holiday Park.

4.2.2.2 Boundaries

The refined model has an extent of 74 ha, with a downstream boundary at the southern end of the Werri Lagoon. The downstream boundary is represented as a HT, and the appropriate water levels for each AEP event from the results of the 2019 Flood Study have been adopted. The appropriateness of adopting the 2019 Flood Study Water levels as the HT downstream boundary value was investigated further using a sensitivity test, this sensitivity test is outlined in Section 5.1.1. The initial water level has been set as the downstream boundary water level. The SA inflows have been adjusted from the 2019 Flood Study based on the redefined sub catchments and reduced in size to only cover a small portion of the sub catchment.

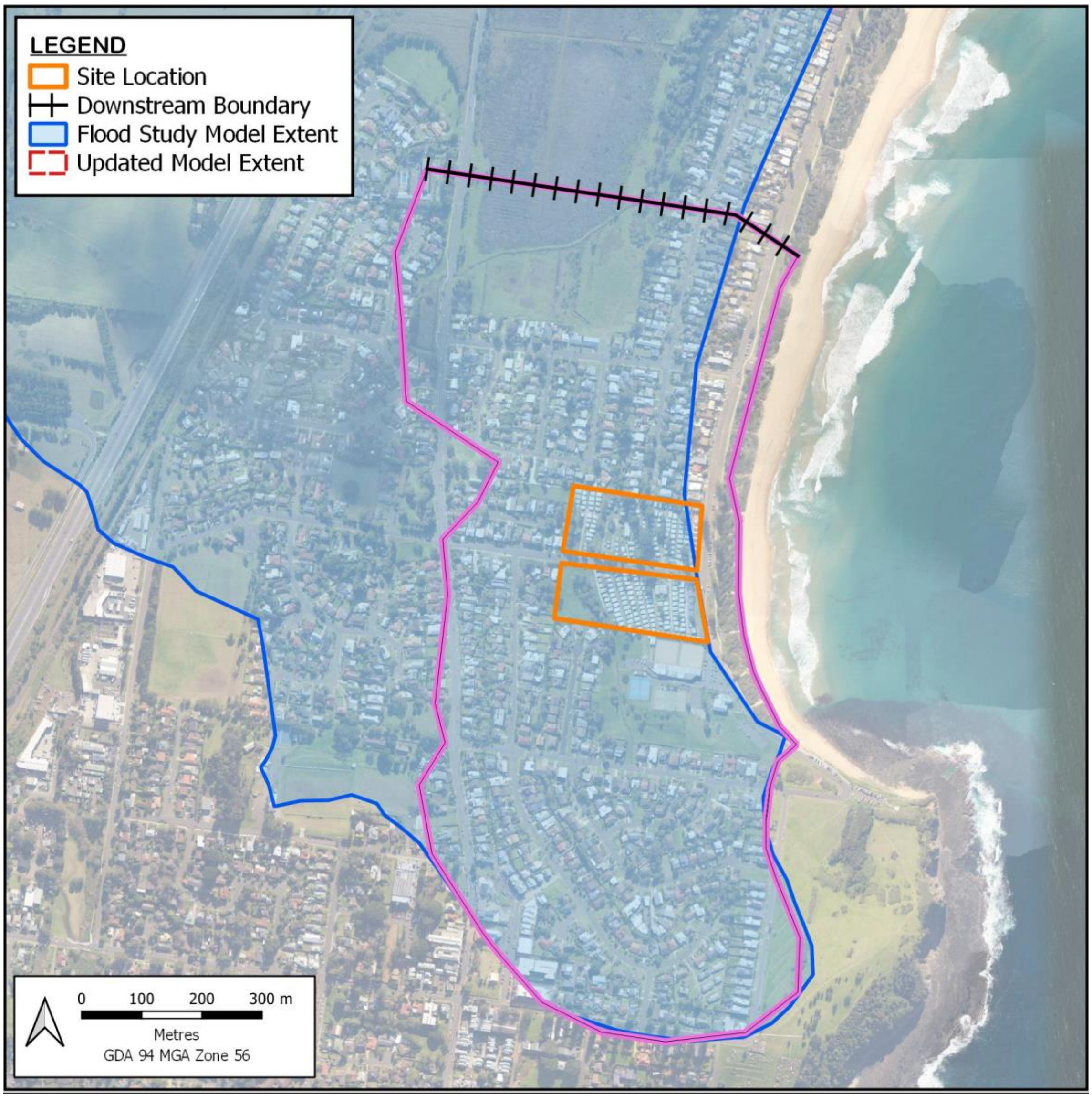


Figure 4-4 Updated TUFLOW Extent

4.2.2.3 Hydraulic Structures

The drainage network within the study was represented in the model as a 1D network and adopted from the 2019 Flood Study model. Pipe sizes and properties were confirmed and cross-checked with the data received from council, see section 3.3.2, and the site visit.

The representation of the pipe network has been adjusted slightly from the 2019 Flood Study and where necessary the 1D-2D connections have been updated to ensure an adequate number of cells are connected. The 2019 Flood Study also had the open channel represented within the 1D domain, to avoid model instabilities and due to the refined 1m grid cell size, it was concluded the open channels would be more accurately represented in the 2D domain for this investigation. The changes to the pipe network are listed below:

- Updated configuration under Bridges Road; and
- Conversion of open channels into the 2D domain.

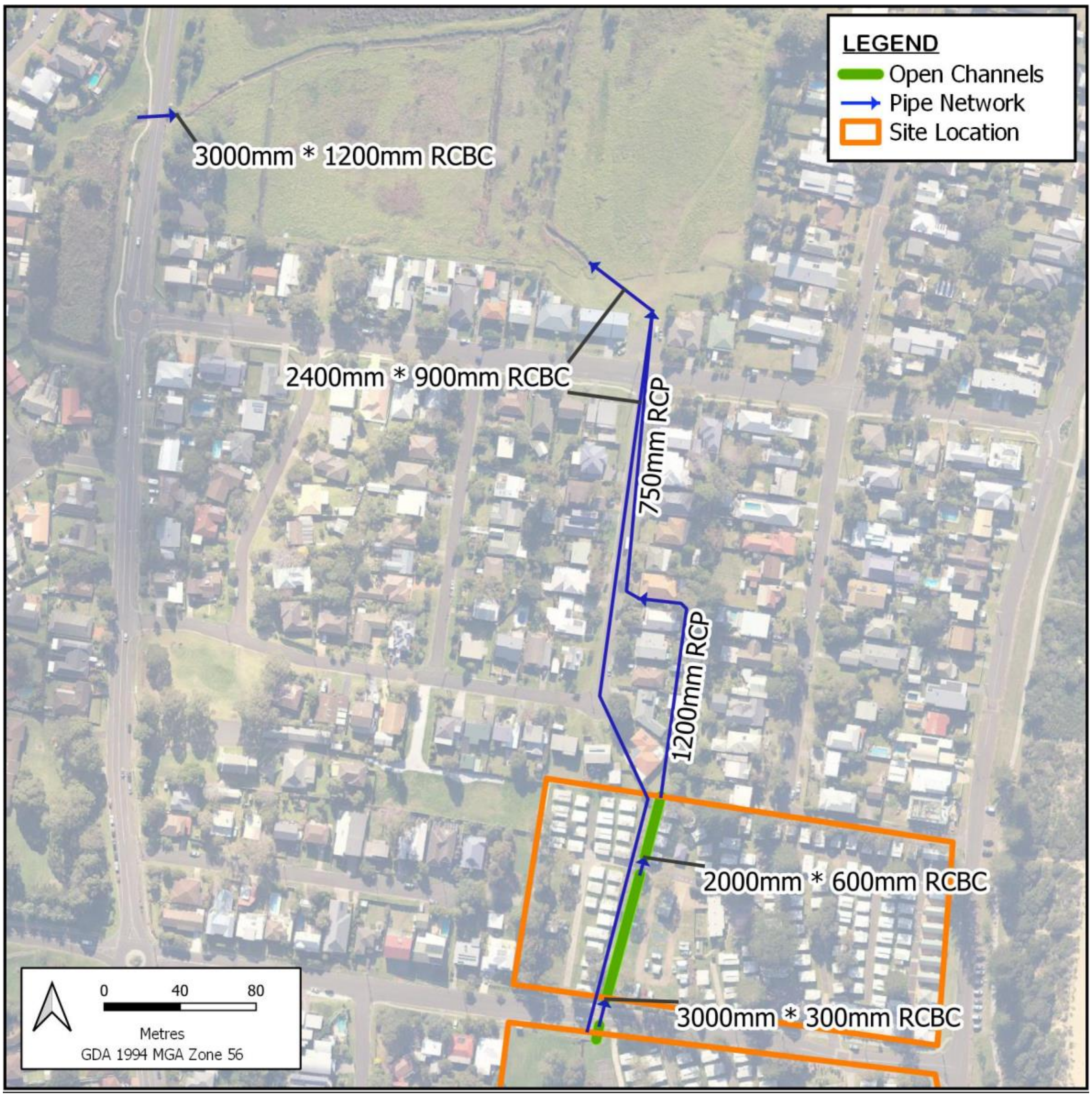


Figure 4-5 Drainage Network

4.2.2.4 Blockage Factors

Blockage factors adopted in the 2019 Flood Study are derived from Project 11 'Blockage of Hydraulic Structures' of Australian Rainfall and Runoff ARR, which was the latest industry guidance at the time of the 2019 Flood Study. An investigation was undertaken to understand the appropriateness of these blockage factors and values to be adopted for this study, this is explained further in Section A.3 in Appendix A.

A 100% blockage factor has been adopted for this investigation, for both AEP events, on each pipe network as depicted above in Figure 4-5. The blockage factors were investigated further using a sensitivity test to ensure the appropriateness of this value, this sensitivity test is outlined in Section 5.1.2.

4.2.2.5 Topography

The 2019 Flood Study used the most up to date 2011 LiDAR dataset supplied by KMC as well as additional survey information, to create the digital terrain model (DEM) for the investigation. The additional data used in the 2019 Flood Study is listed below:

- detailed survey of the Fern Street Upgrade;

- detailed bathymetric survey of Werri lagoon and near shore ocean bathymetry from the NSW office of Environment and Heritage compiled in 2003; and
- SMEC detailed design of Princes Highway Gerringong Upgrade.

The DEM for this investigation was refined to remove the bathymetric data from 2003, as this is superseded by the 2011 LiDAR and found to be the most accurate representation of the area after review against aerial imagery, and ground-truthing during the site visit.

4.2.2.6 Hydraulic Roughness and buildings

The hydraulic roughness (Manning's 'n') values used in the 2019 Flood Model were validated and in line with the ranges outlined in Book 6 of the ARR2019. The spatial distribution of roughness values were validated based on inspection of aerial imagery, Google Street view and site visit observations, and land use data. Areas of additional hydraulic roughness definition were required where the model extend was expanded, the values adopted in these areas were in line with the values used in the 2019 Flood Study. The hydraulic roughness values are explained tabulated in Section A.2.1 and depicted in Figure A-1.

4.2.3 Critical Durations

For the purposes of this study, the critical duration is defined as the length of storm that produces the highest peak flood level in our area of interest (i.e. the Werri Beach Holiday Park).

The refined ensemble of durations and temporal patterns, as discussed in Section 4.1.3.3, were run in the existing hydrology model. Following these runs the selection of the critical duration at the site location were selected and adopted for all sensitivity runs and mitigation design scenarios. The durations listed in Table 4-4 were selected as the critical durations at the site.

Table 4-4 Updated TUFLOW Critical Durations

Event (AEP)	Durations (mins)
1%	90
5%	270

5 FLOOD MODELLING RESULTS

5.1 EXISTING CONDITIONS

The results of the flood modelling depict partial inundation of the Holiday Park site in both the 1% and 5% AEP event. The downstream of the model depicts water pooling in Werri Lagoon and provides insight into the hydraulic characteristics at the site. The full results for the 1% and 5% AEP events for the water surface level, flood depths, hazard and velocity are available in Appendix B and key observations made from the results are listed below:

- The terrain to the north of the site is very flat, falling only 0.4 m over 250 m from upstream to downstream. As such, water backing up in the lagoon (ie the downstream boundary) controls flood behaviour in the vicinity of the site;
- The Water Surface Level in Werri Lagoon is 2.8 mAHD in the 5% AEP event and 3.1 mAHD in the 1% AEP event;
- The capacity of the open drain upstream of the site is exceeded in both the 1% AEP and 5% AEP events;
- Overland flow travels north along Willawa Avenue towards Werri Lagoon and inundates the properties on the east of the road. The flow along this road reaches velocities of up to 1.8 m/s in the 5% AEP event and 2 m/s in the 1% AEP event, and resultant hazard (depth * velocity) values of 0.5 m^2/s and 0.75 m^2/s for the 5% and 1% AEP events respectively;
- Overland flow is depicted to travel along the drainage lines and makes its way north through the Holiday Park towards Werri Lagoon, through the properties to the north of the Holiday Park and on the eastern side of Willawa Avenue;
- The Water Surface Level at the downstream and upstream ends of the site are 4.2 mAHD and 4.25 mAHD, respectively, in the 5% AEP event and 4.34 mAHD and 4.42 mAHD, respectively, in the 1% AEP event;
- The Holiday Park is inundated in both the 1% and 5% AEP events, with flows appearing to breakout form the open drain to the west of the southern part of the site and the open channel through the northern end of site;
- The open drain to the west of the southern part of the site breakouts and in the 1% AEP event extends 65 m into the Holiday Park and 55m in the 5% AEP event.
- The open channel in the northern part of the holiday park breakouts and extends 50m to the west and 35m to the east in the 1% AEP event and 40m to the west and 30m to the east in the 5% AEP event.
- The velocity through the site predominantly remains below 0.25 m/s in both the 1% and 5% AEP events with isolated areas reaching up to 0.65 m/s within the open channel running through the northern end of the site during the 5% AEP event and up to 0.75 m/s in the same area during the 1% AEP event. The 1% AEP event has higher velocities within the open channel running through the northern end of the site with velocity values on average of 0.3 m/s.
- The 1% AEP event sees the flood extent breakout of the open drain upstream of the site on average 8 m to the west of the open drain and to the east inundates the western set of tennis courts and fills the depression in the park. The depression in the park is filled via a natural channel which leaves the open drain just before it passes the tennis courts and flows backwards to create a natural detention system. The 5% AEP event covers a similar flood extent and follow the same hydraulic characteristics as with the 1% AEP event.
- Velocities in the open drain have an average value of 0.6 m/s in the 5% AEP event and 0.8 m/s in the 1% AEP event, these high velocity values are restricted to the open drain and its immediate surrounds and the adjacent park area has velocities predominantly less than 0.3 m/s in both events; and
- The hazard in the park area remains below 0.4 m^2/s and high hazard values are only in the upstream end of the open drain in the 5% AEP event and both the upstream and downstream ends of the open drain in the 1% AEP event.

5.1.1 Downstream Tailwater Conditions Sensitivity Testing

Flood behaviour in the vicinity of the site is largely controlled by the level in Werri Lagoon. Sensitivity testing on downstream conditions was conducted to investigate the influence selection of tailwater has on design levels in our area of interest.

The peak flood level at the downstream boundary for the 1% and 5% AEP event from the 2019 Flood Study were extracted and set as the HT level at the downstream boundary. A sensitivity was then run adopting water levels from the 1% AEP High High Water Spring (HHWS) event to understand the implications of varying downstream boundary levels at the site. The scenarios outlined in Table 5-1 were run as sensitivity tests.

Table 5-1 Updated TUFLOW Downstream Boundary Sensitivity Test

Scenario	AEP (%)	HT (mAHD)
S01	1%	3.1
S02	1%	3.24 (1% AEP HHWS)
S01	5%	2.8
S02	5%	3.24 (1% AEP HHWS)

The outcomes of the sensitivity test concluded that the varying downstream boundary water levels have a significant impact on the water level in the downstream extent of the model, as depicted in Figure 5-1and Figure 5-3, and a minor impact on the water level just upstream of the Holiday Park site, see Figure 5-2 and Figure 5-4.

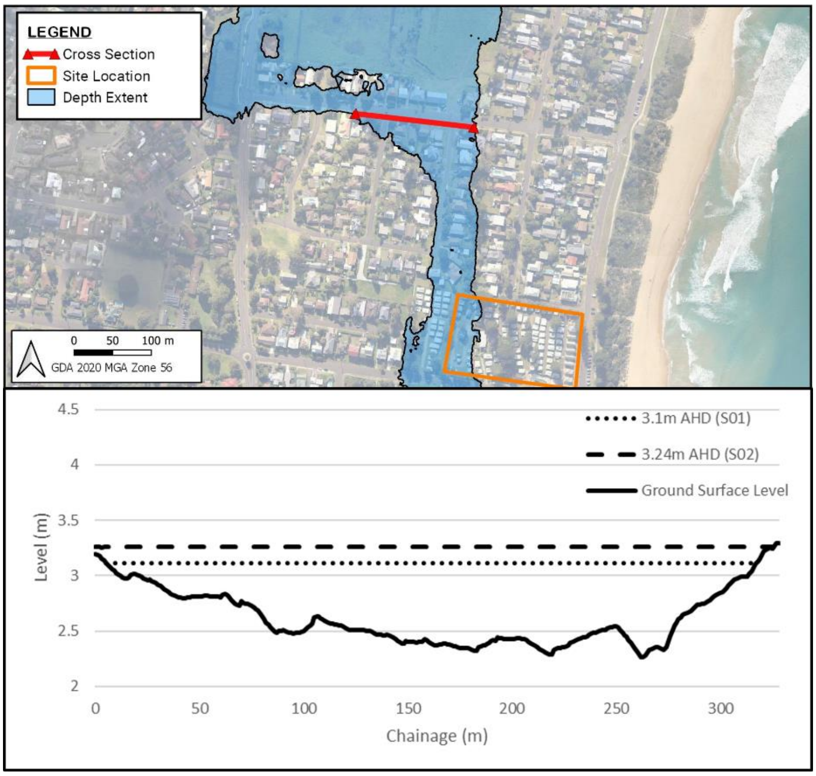


Figure 5-1 1% AEP Downstream of the site

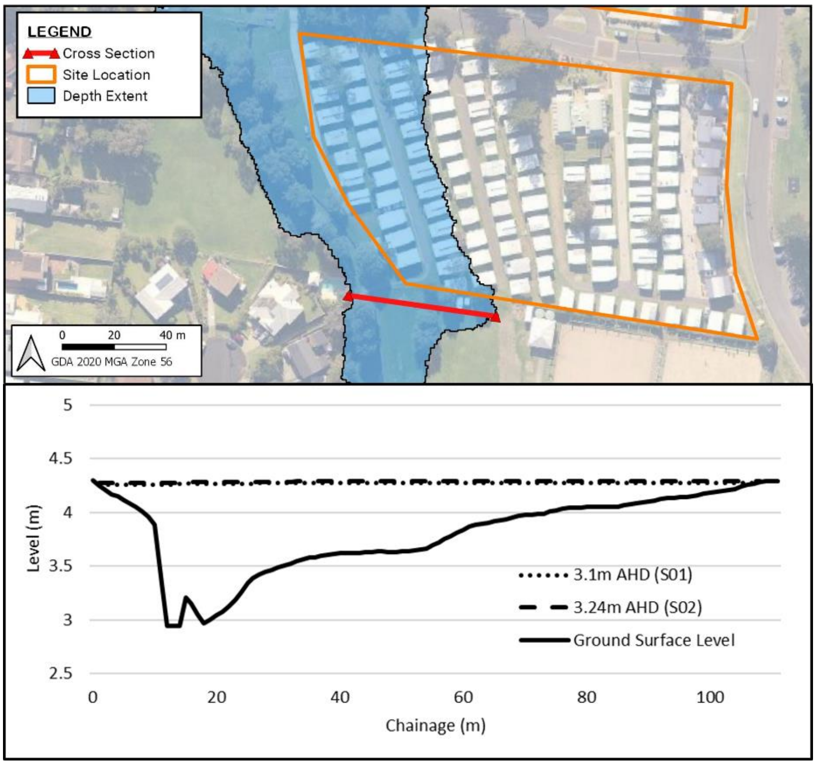


Figure 5-2 1% AEP Upstream of the site

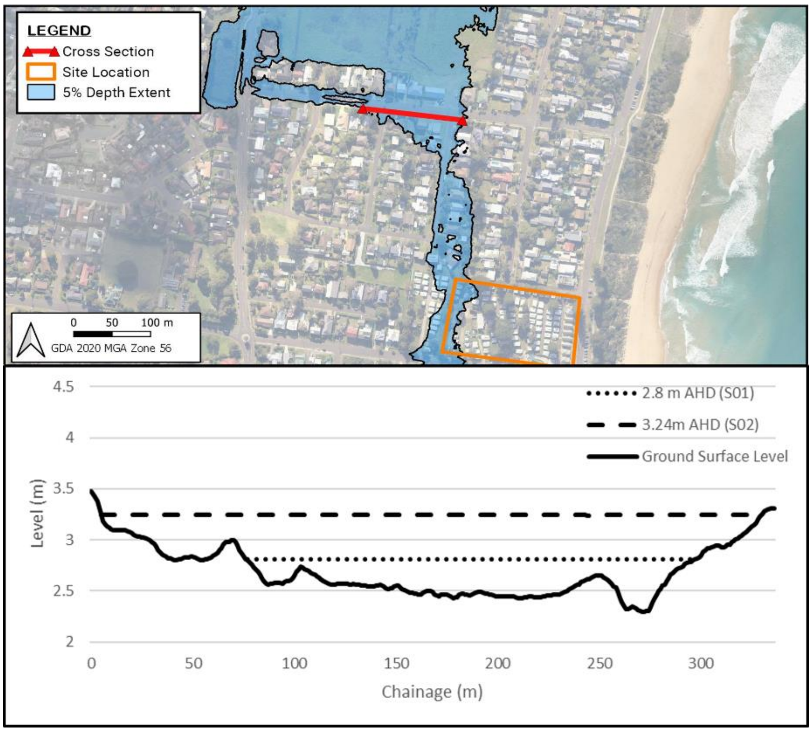


Figure 5-3 *5% AEP Downstream of the site*

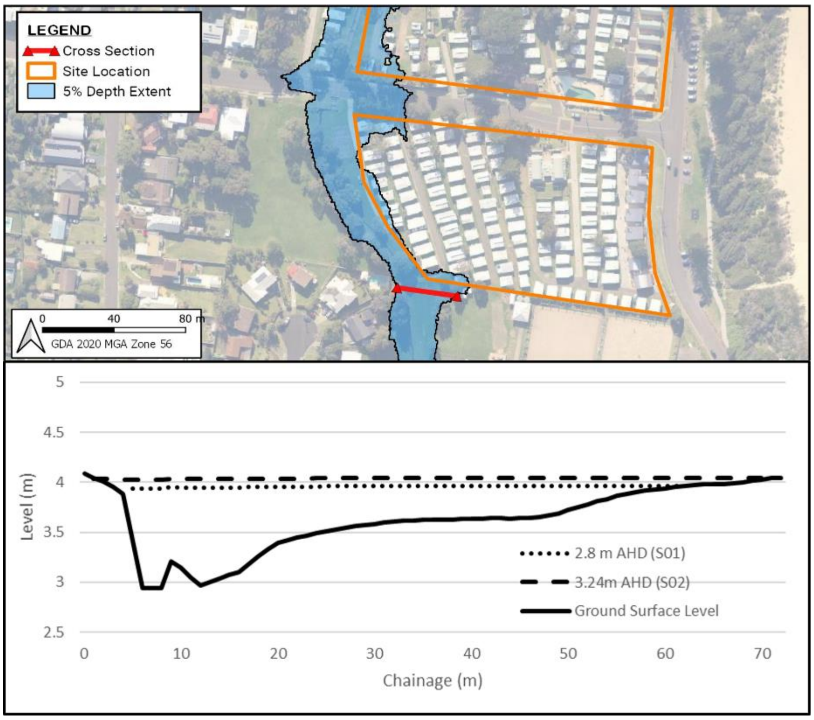


Figure 5-4 *5% AEP Upstream of the site*

5.1.1.1 Tailwater Boundary Condition Recommendation

It was concluded that the tailwater levels adopted in Scenario S01 for both the 1% and 5% AEP events, the lower tailwater levels, would be adopted for the model as it will help to better asses the effectiveness of any mitigation options and these levels are in line with the 2019 Flood Study. Following the running of several design options as part of the mitigation scenarios the preferred design will be assessed under a high tailwater condition as a sensitivity to ensure hydraulic characteristic outcomes are appropriate.

5.1.2 Blockage Factors Sensitivity Test

The drainage network running beneath the site has a large culvert opening at the upstream end and several open channels throughout the network, see Figure 5-5. The culvert receives stormwater from the upstream residential catchment and some areas of the Werri Beach Holiday Park and the open channels run through the Holiday Park and are protected by wire fencing of an approximate height of 1.3 meters. There is the potential for these channels and culverts to be blocked by items in the surrounding Holiday Park such as camping equipment, children's toys, sports equipment such as balls and frisbees or other water sports equipment such as surfboards, boogie boards or kayaks. Advice was sought from Shoalhaven City Council, Shellharbour Council and Wollongong City Council to understand the range of approaches used in similar areas. More discussion on the findings is provided in Appendix B.

Figure 5-5 Underground rectangular stormwater line (Left) and Concrete drain (Right

In the interest of public safety considerations into the blockage factors used in the modelling to accurately represent the potential for the network to be blocked during design storms have been made based on the guidance provided by both surrounding local councils, ARR2019 and local knowledge. Several blockage factors sensitivity tests were run as part of this study, these are outlined in Table 5-2 below and S03 in Figure 5-6 and S04 in Figure 5-7. Further commentary on the blockage factors adopted and the two scenarios is provided in Appendix B.

Table 5-2 Updated TUFLOW Blockage Factors Sensitivity Test

Scenario	AEP (%)	Hydraulic Structures Blocked	Blockage Factor
S03	1%	All Culverts and Pipes	100%
S04	1%	Underground Culverts	100%
S03	5%	All Culverts and Pipes	100%
S04	5%	Underground Culverts	100%

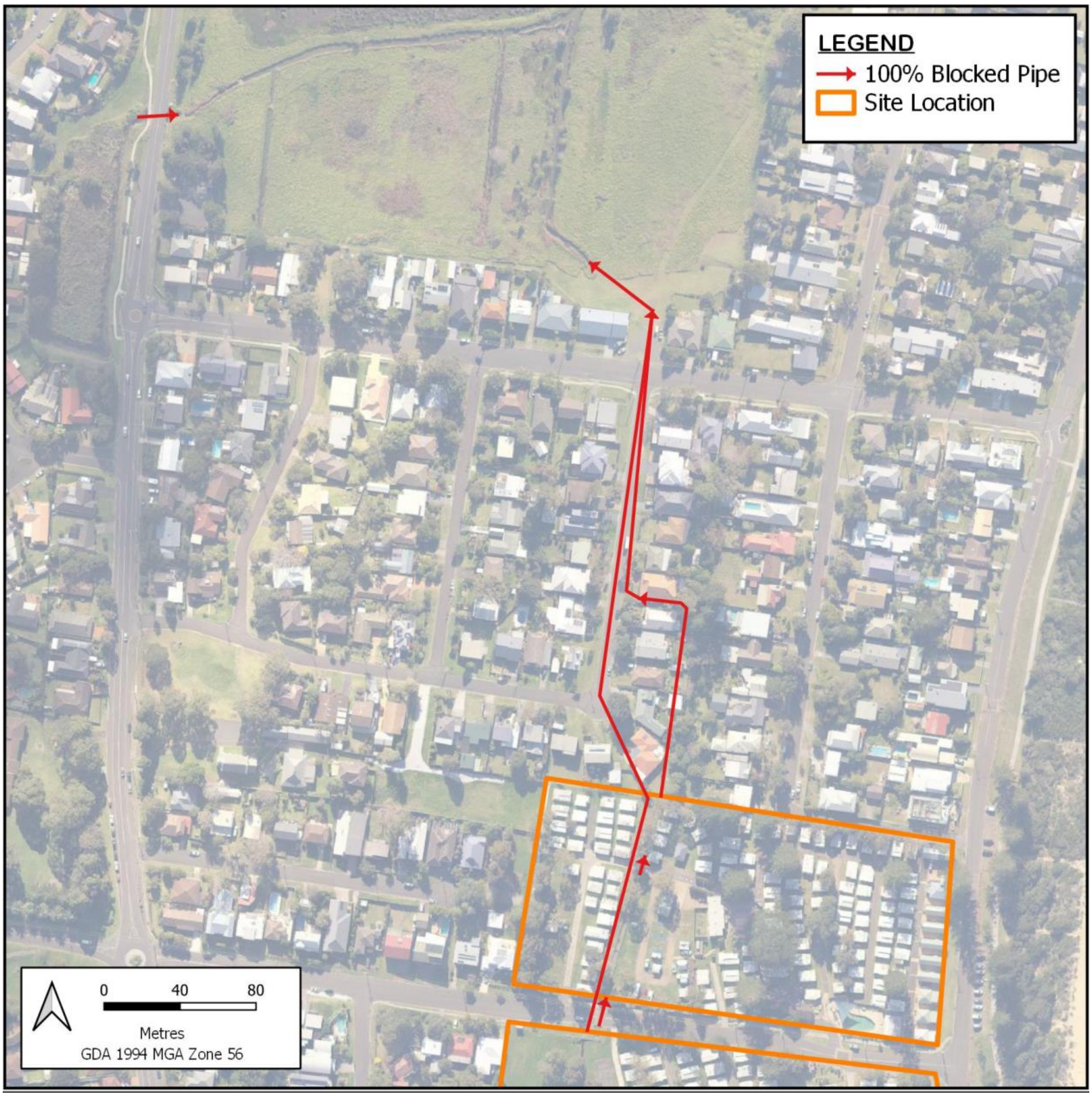


Figure 5-6 S03 - All culverts and pipes blocked

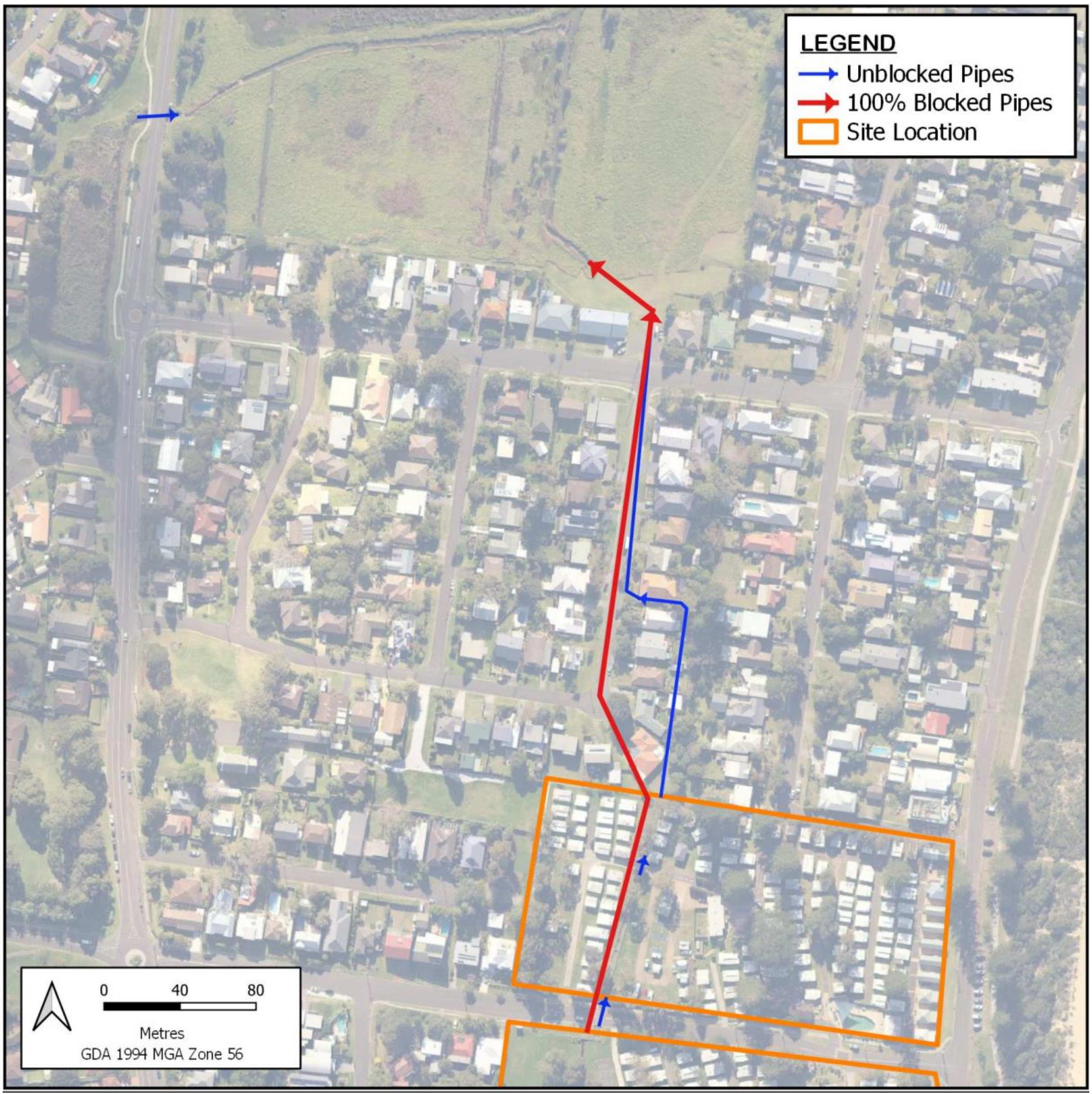


Figure 5-7 S04 - Only underground pipes blocked

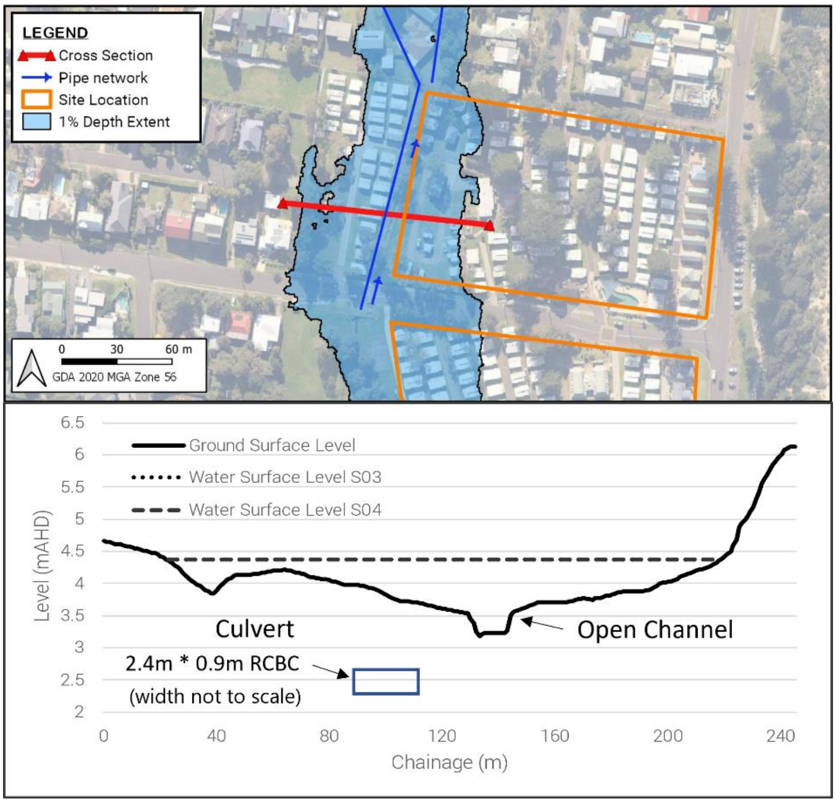


Figure 5-8 1% AEP blockage comparison between S03 and S04

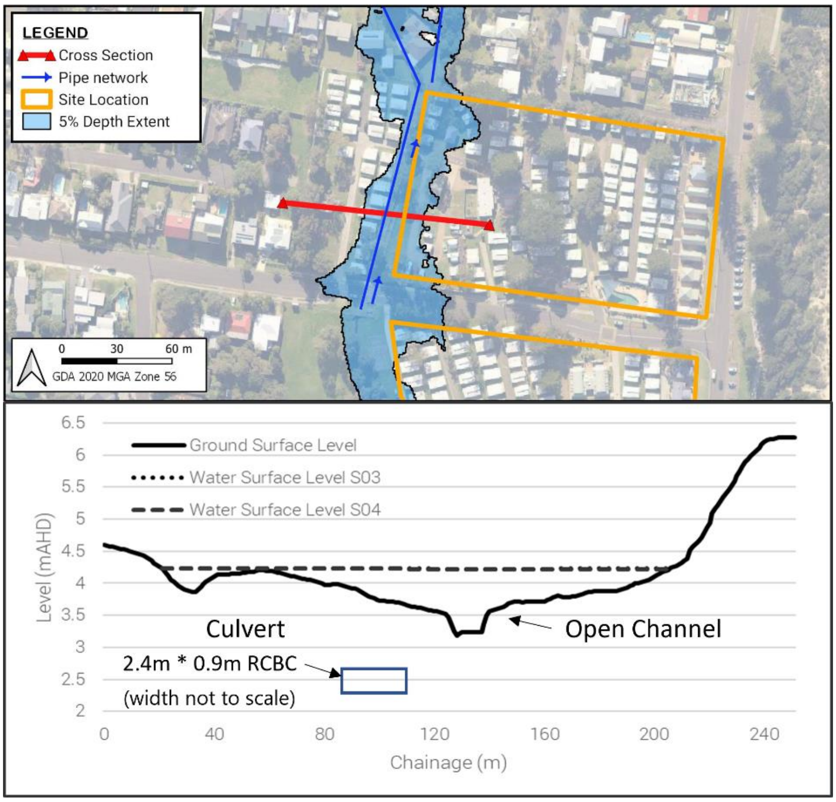


Figure 5-9 5% AEP blockage comparison between S03 and S04

The blocking of all the pipes and culverts (S03) and the blocking of only the underground culvert (S04) resulted in similar water surface levels and flood extents for both the 1% and 5% AEP events. The cross sections above in Figure 5-8 and Figure 5-9 depicts the open channel and culvert both being fully submerged. Therefore due to the large amount of water sitting above the two hydraulic features the impacts of the blockage factors in scenarios S03 and S04 are being mitigated as the flood waters and characteristics appear to be governed by the overland flow.

It was concluded that the blockage factors adopted in Scenario S03 for both the 1% and 5% AEP events, all culvert and pipes blocked, would be adopted for the model as it would be a more conservative approach and ensure the safety of the community residing in the Holiday Park at the time of any storm events is considered and planned for.

5.2 COMPARISON TO 2019 FLOOD STUDY

5.2.1 ARR1987 Update to ARR2019 Hydrological Comparison

A comparison was conducted between peak outflows at several sub catchments between the 2019 Flood Study WBNM model and the updated WBNM model for this investigation for the 1% AEP events. The sub catchments were chosen based on sub catchments whose areas and characteristics remained unchanged between the two models, therefore the comparison will depict the differences in peak flows between the ARR1987 and ARR2019 modelling methodologies.

The peak flow hydrographs show the ARR1987 modelling having higher peak flows overall, longer critical durations and an overall larger volume of flows. These larger volumes and peak flows can be contributed to the initial loss with ARR1987 being 10mm whereas it is 47mm for ARR2019 and in general the intensities adopted in ARR1987 are higher at the catchment location. Figure 5-10 depicts the peak outflow hydrographs for the critical durations from the two modelling methodologies for sub catchment 21.4.

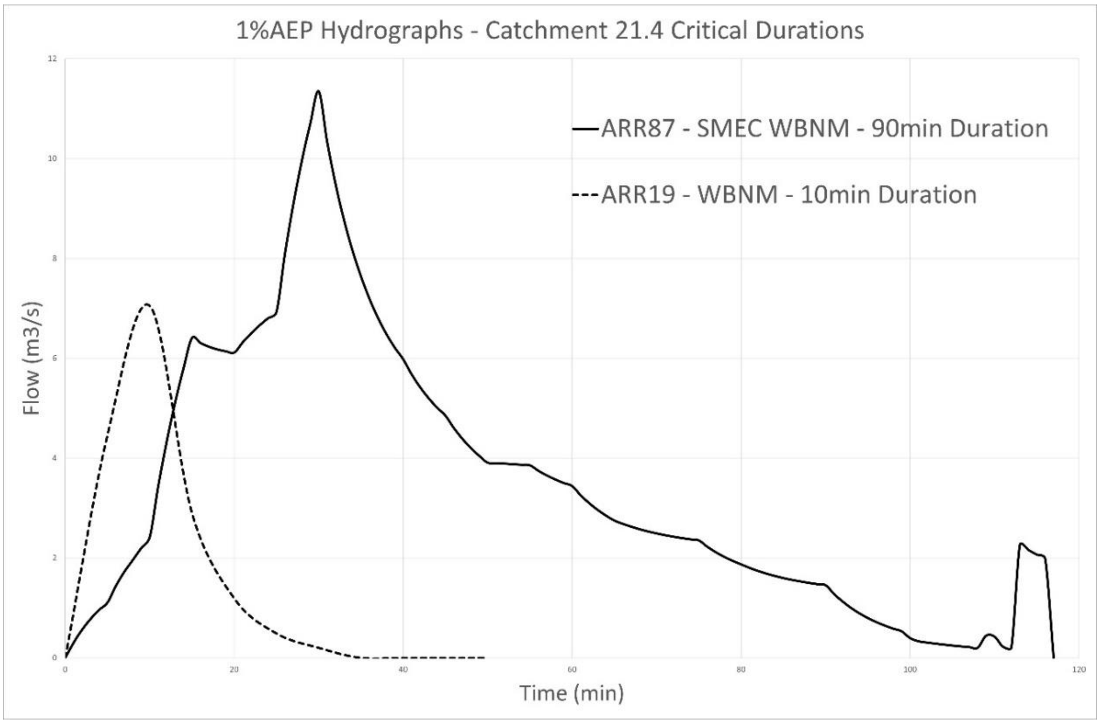


Figure 5-10 Peak Flow Hydrograph Comparison – ARR1987 vs ARR2019

5.2.2 ARR1987 to ARR2019 Hydraulic Comparison

Figure 5-11 and Figure 5-12 show the differences in results of the two investigations and ARR modelling methodologies for the 1% AEP event for the peak flood level and flood extent respectively. The 2019 Flood Study have used the ARR1987 modelling methodology and the updated modelling for this investigation has used the ARR2019 modelling methodology.

It is important to note the two investigations have different modelling extents and the 'Was Wet Now Dry' areas in Figure 5-11 on the northern end in Werri Lagoon, the eastern side upstream of Fern Street Gully Detention Basin and at the southern end upstream of Geering St are outside of the modelled extent for the ARR2019 modelling. The differences in modelling extent also explain the large flood extent differences at the same locations in Figure 5-12.

Figure 5-11 depicts the Afflux between the models and Figure 5-12 depicts the two flood extents, key points observed between the two models are listed below:

- There are minimal differences between the two models at the site location, within +/- 10 mm variance. The ARR2019 has adopted 100% blockage values on the culverts and pipe network beneath the holiday park whereas the ARR1987 modelling has adopted blockage factors between 10 – 50% suggesting the ARR1987 model is conveying more flow within the pipe network whereas the ARR2019 model is creating more overland flow resulting in comparable water surface levels at the site location between the two models;
- Downstream of the Werri Beach Holiday Park, the updated model produces water surface levels approximately 200mm lower, and a smaller flood extent. These features can be attributed to the lower peak flow as depicted in the hydrograph comparison in Figure 5-10;
- There are some differences at the houses along the northern side of Sandy Wha Road, which are no longer inundated, these can be attributed to the removal of the Werri Lagoon bathymetry data and the adoption of the 2011 LiDAR in this location;
- There is some variance at Werri Lagoon with the updated modelling produce water levels up to 400mm lower these can also be attributed to the removal of the bathymetry data;
- The park area upstream of the Holiday Park has lower water levels of up to 400mm in the updated modelling, which can be attributed to the smaller volume of flows as depicted in the hydrograph comparison in Figure 5-10.

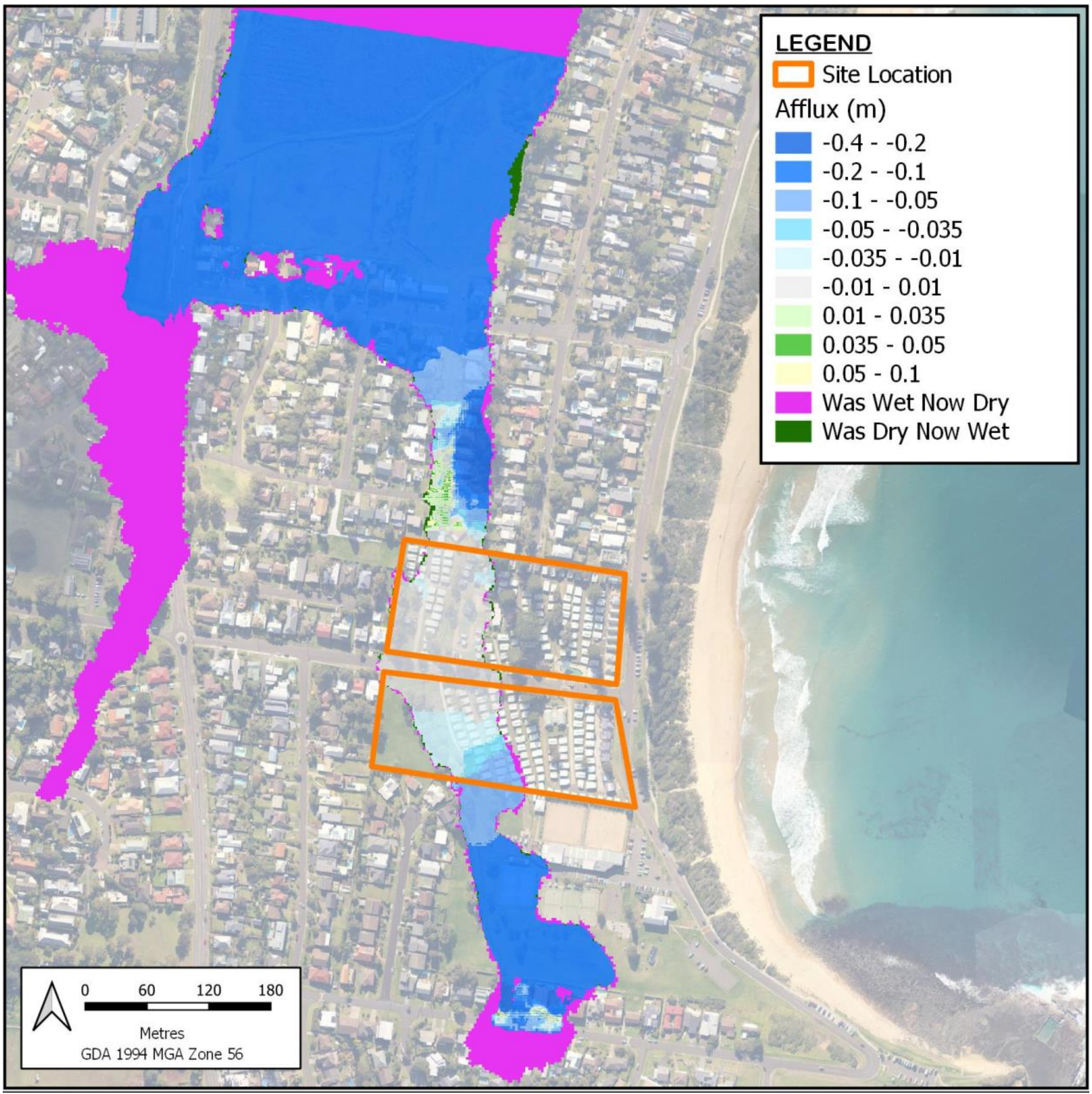


Figure 5-11 1% AEP Water Level Difference – Updated Model minus 2019 Flood Study

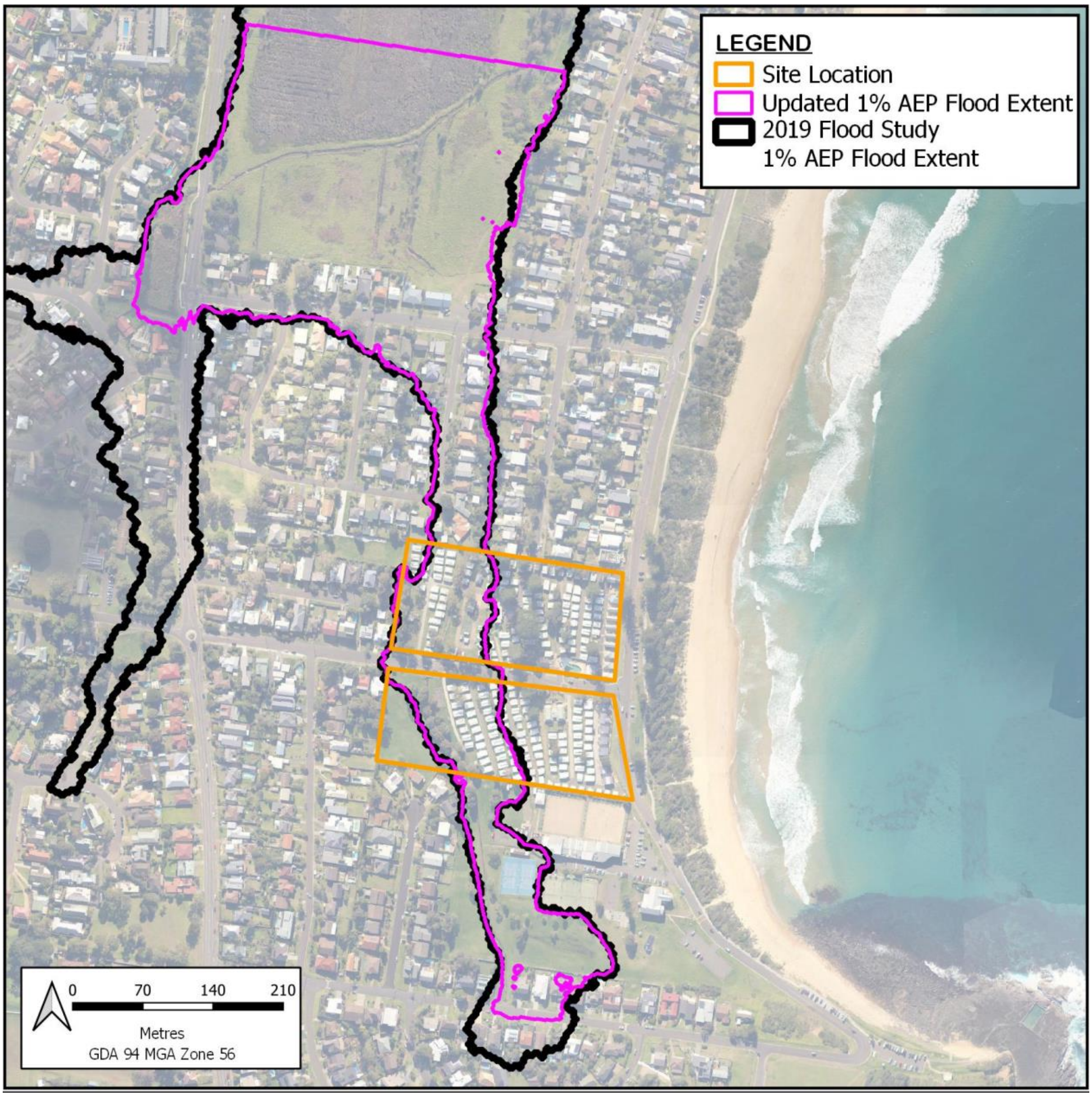


Figure 5-12 Peak Flood Extent Comparison – ARR1987 vs ARR2019

6 MITIGATION OPTIONS ANALYSIS

6.1 SCREENING ASSESSMENT

With Werri Lagoon forming a downstream control point, it is unlikely to be feasible to improve the rate at which flood waters can be drained from the site. This leaves Council with limited options – either to reduce the volume of flow entering the site (via upstream diversions and detention basins), addition of new drainage paths within the site (e.g. culverts draining to Werri Beach), or onsite works to improve channel conveyance and storage capacity. WMS and Dryside Engineering (DSE) have identified six potential options to consider further, shown in Table 6-1. Some options were not progressed according to mitigation discussion and project inception meeting.

Table 6-1 Preliminary Option Identification

ID	Option	Pros	Cons	Outcome
A	"Do nothing"	• Minimal cost, no new infrastructure or earthworks to be designed constructed	• Long term reduction in flood risk as caravans/cabins are renewed/redeveloped • No increase to total lettable area.	• Progressed – refer to Section 6.2.1
B	Setbacks through Werri Beach Holiday Park (Drainage Reserve) for 5% AEP Event	• Increased space for flood flows	• Loss of caravan/cabin space (i.e. reduced annual income)	• Not progressed • Potential community opposition to Werri Beach Holiday Park redraw & redevelopment of layout
C	Regrading Lot 1 DP 1075959 to direct overland flow towards beach	• Divert a portion of the flow path for the purpose of reducing peak flows through Werri Beach Holiday Park • Utilises currently vacant land, does not affect private property	• Increase flood risk across Bridges Road • Significant earthworks required to achieve fall through park, potentially including removal of coastal vegetation on the eastern side of Bridges Road, increase risk of berm erosion. • May worsen impacts during storm surge events where berm is overtopped	• Progressed – refer to Section 6.2.2
D	Detention basin in Lot 1 DP 1075959	• Reduce flood flows in Holiday Park • Add additional storage • Reduction of flood levels in residential area downstream of Werri Beach Holiday Park	• Acid sulphate soils may be an issue • Consider cost/benefit	• Progressed – refer to Section 6.2.3
E	New drainage pipe and outlet on Bridges Rd	• Divert a portion of flow eastwards before it reaches Werri Beach Holiday Park • Underground culvert reduces flood risk at ground level (compared to Option C)	• New pipe outlet to beach required, unlikely to be acceptable to community • Scour and environmental impacts at the outlet to be managed • Limited grade may affect effectiveness	• Not progressed • KMC advised that a new ocean outfall would likely be strongly opposed by community, particularly at the southern end of the beach which is popular with tourists

ID	Option	Pros	Cons	Outcome
F	Triangle cut and fill in southern Werri Beach Holiday Park site	• Reduce flood flows in Holiday Park • Reduction of flood levels in residential area downstream of Werri Beach Holiday Park	• Loss of caravan/cabin space	• Progressed – refer to Section 6.2.4

6.2 OPTION ASSESSMENT

6.2.1 Option 1 – "Do Nothing" - Apply long-term planning controls

6.2.1.1 Overview

This option does not include any structural measures, but rather considers the application of flood planning controls to achieve a reduction in flood risk to the Werri Beach Holiday Park in the long term. This approach is akin to how flood risk is generally managed in developed areas – that is, as dwellings (or caravans/cabins) are renewed or redeveloped, flood planning controls are applied to ensure the development is compatible with the flood risk at its site. The most common flood planning control is the application of a Flood Planning Level (FPL), typically the 1% AEP level plus 500 mm freeboard, which ensures dwellings are either outside the Flood Planning Area (the land covered by the FPL) or above the FPL.

6.2.1.2 Discussion and recommendation

The adoption of a suite of flood related development controls for the Holiday Park is recommended for implementation. Refer to Section 7 for further details.

6.2.2 Option 2 – Diversion Flowpath to Werri Beach

6.2.2.1 Overview

This option considers regrading Lot 1 DP 1075959 to divert overland flow towards Werri Beach, with the aim of reducing the peak flow through the Holiday Park. Following discussions with Council it was understood that a piped diversion culvert or defined channel through this site is unlikely to be acceptable to the community, however a shallow, subtle swale may be more palatable to park and beach users.

Features of the flowpath include:

- Approximate footprint of 1.14 ha, with majority of the works contained within Lot 1 DP 1075959;
- Regrading ground levels from 4 mAHD at the rear of the tennis courts to 3.8 mAHD at Pacific Avenue; and
- Removal of approximately 1,850 m^3 of spoil.

The long and cross sections of this flowpath are shown in Figure 6-1 and Figure 6-2.

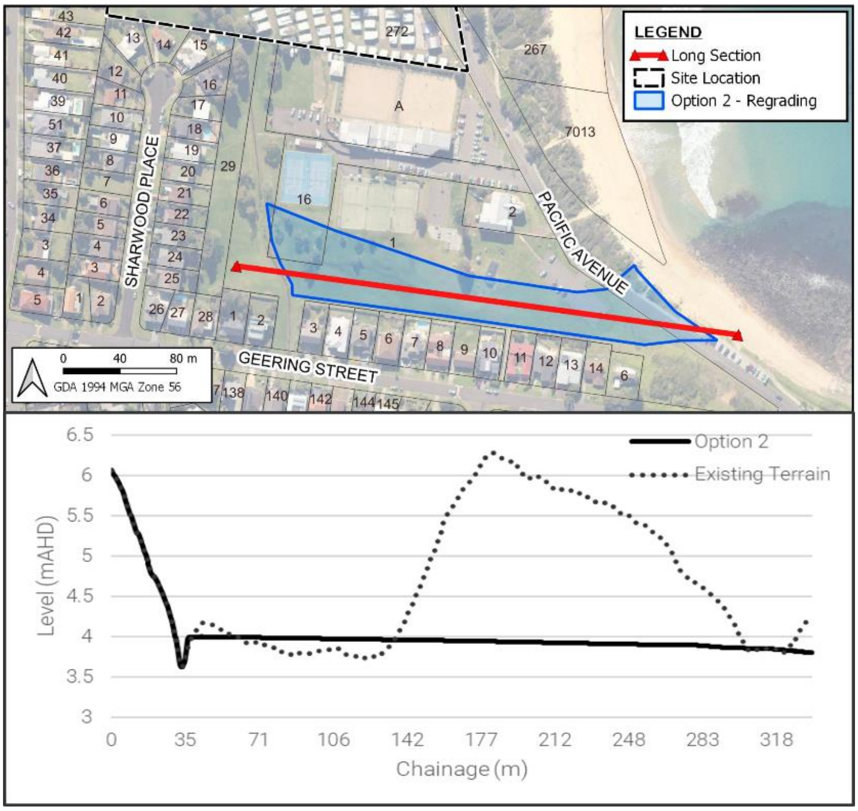


Figure 6-1 Long Section - Comparison Option 2 and Existing Terrain

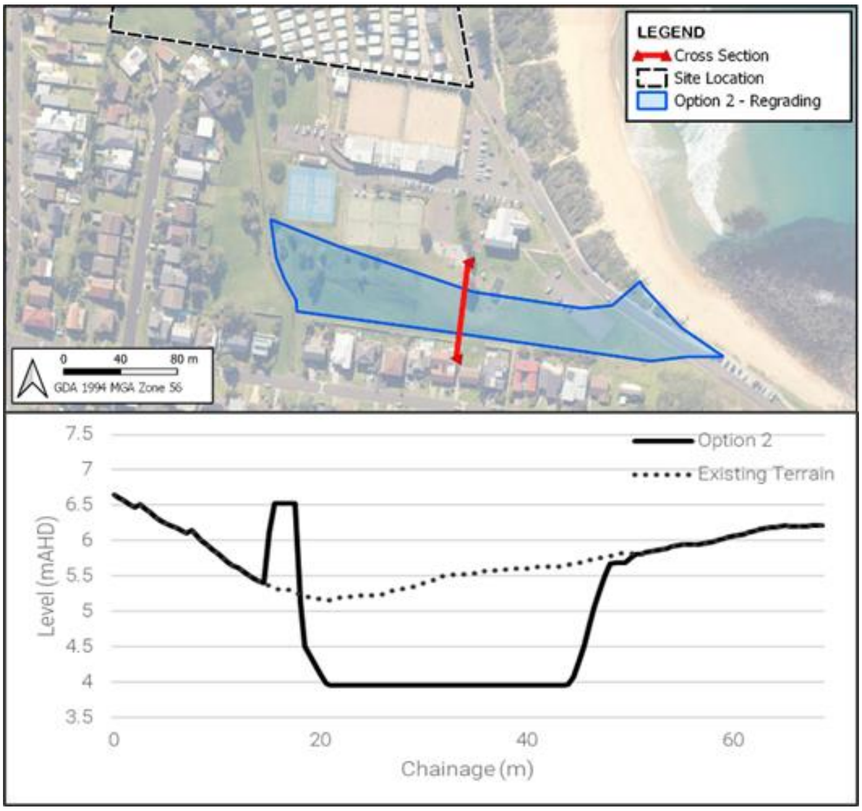


Figure 6-2 Cross Section - Comparison Option 2 and Existing Terrain

6.2.2.2 Impact

The diversion flowpath was modelled for the 1% AEP and 5% AEP events and compared to the corresponding existing conditions results to determine its effectiveness. The impacts are shown in Figure 6-3 and Figure 6-4 for the 1% AEP and 5% AEP events respectively.

In the 1% AEP event, the following observations are made:

- Peak flows entering the Holiday Park at the reporting line shown in Figure 6-3 are reduced from 6.72 m^3/s to 5.28 m^3/s;
- Peak flood levels within the site are not materially improved, with reductions in the order of 0.06 m;
- The flood extent is reduced by 5 m and 15 m on the eastern and western sides respectively; and
- Peak flood depths across Pacific Avenue would be in the order of 0.2 m, previously not subject to flood risk.

In the 5% AEP event:

- Peak flows entering the Holiday Park at the red line shown in Figure 6-4 are reduced from 3.30 m^3/s to 3.17 m^3/s;
- Peak flood levels within the site are reduced by 0.04 m;
- The flood extent is reduced by 3 m and 9 m on the eastern and western sides, respectively; and
- Pacific Avenue (currently not subject to flood risk) would be newly flooded to depths of 0.13 m.

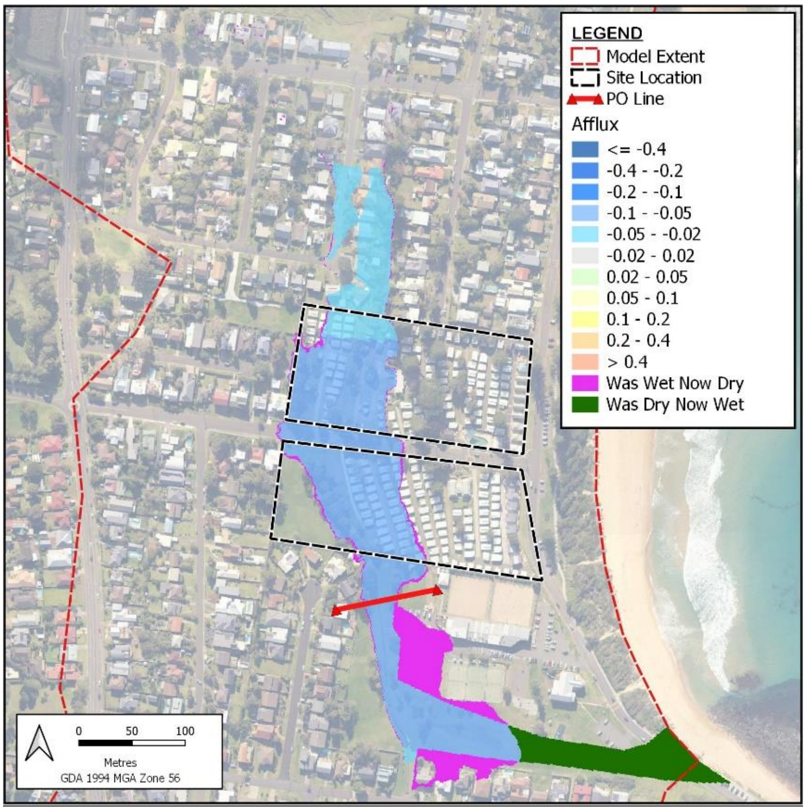


Figure 6-3 1% AEP Water Level Difference –Option 2 less existing conditions

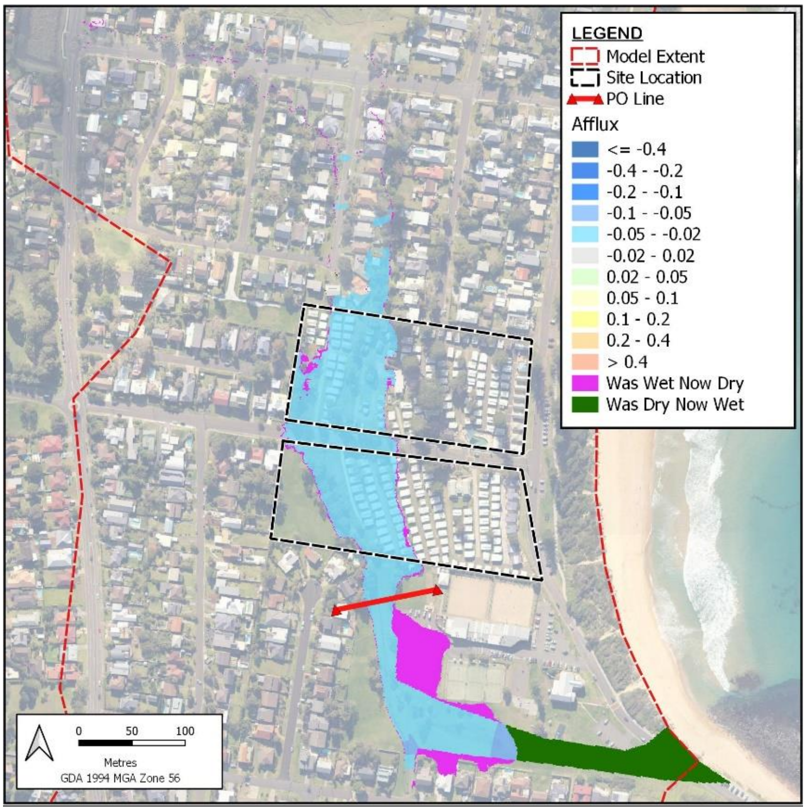


Figure 6-4 5% AEP Water Level Difference –Option 2 less existing conditions

6.2.2.3 Discussion and recommendation

Due to the higher ground at the eastern side of Pacific Avenue, there is not as much fall from the existing channel out to Werri Beach as first anticipated, making this option less feasible and less effective at reducing flood risk. The peak flood level reductions around the Holiday Park would not materially increase the net lettable area, nor reduce risk to patrons enough to warrant the excessive cut that would be required to achieve the flowpath bed slope.

In discussion with Council on the 25th of March, WMS and Council resolved not to pursue the diversion flowpath option further.

6.2.3 Option 3 – Detention Basin

6.2.3.1 Overview

This option shown in Figure 6-5 looks at excavating a detention basin in the vacant land upstream of the site, that is, Lot 1 DP 1075959. The purpose of the basin is to provide additional flood storage upstream of the caravan park, reducing the peak flows downstream to alleviate flood risk through the caravan park.

Features of the detention basin include:

- Approximate footprint of 1.22 ha;
- Storage capacity 10,700 m^3;
- Invert of 3.1 mAHD at the outlet to tie in with existing open channel;
- Embankments and retaining walls to provide a crest of at least 6 mAHD to tie in with levels at Geering Street; and
- Low flow outlet pipe (450 mm diameter assumed open for the 1% AEP event and 600 mm diameter assumed open for the 5% AEP event).

It is noted that for the purpose of this investigation the pipe outlet was sized to ensure flows did not overtop the basin walls, therefore different outlet configurations were adopted for the two AEP events. The volume of water upstream of the Werri Beach Holiday Park is greater in the 5% AEP event than in the 1% AEP event and therefore the 5% AEP event required a larger outlet pipe to ensure the detention basin walls were not overtopped.

Figure 6-5 demonstrates the terrain comparison between Option 3 and the existing scenario.

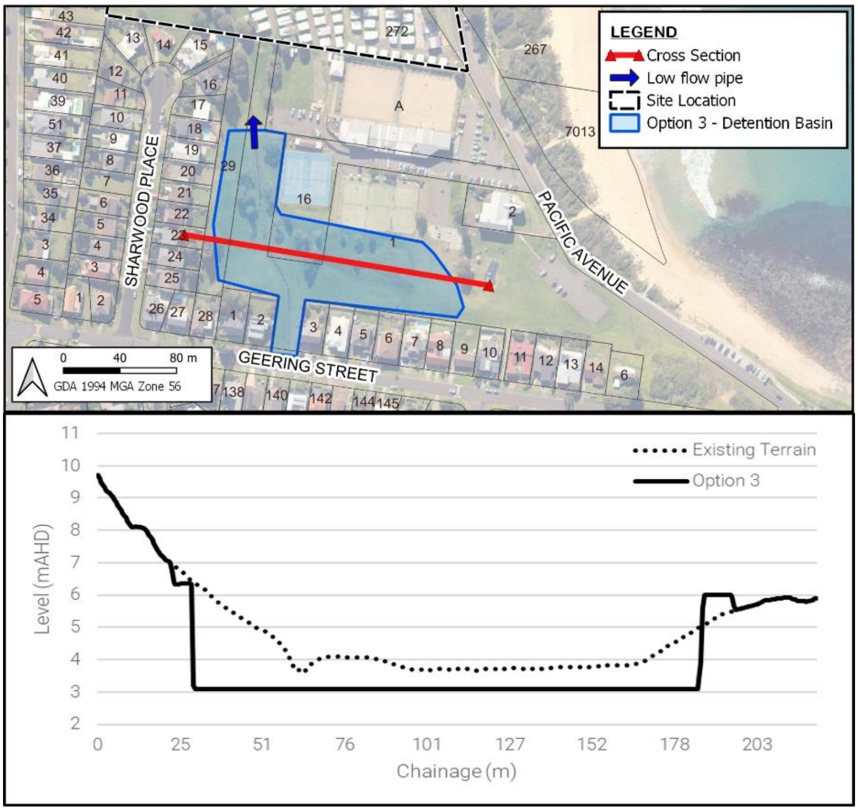


Figure 6-5 Cross Section - Comparison Option 3 and Existing Terrain

6.2.3.2 Impact

The basin was modelled for the 1% AEP and 5% AEP events, and compared to the corresponding existing scenario results to determine its effectiveness. The impacts are shown in Figure 6-6 and Figure 6-7 for the 1% AEP and 5% AEP events respectively.

In the 1% AEP event, the following observations are made:

- The basin top water level of 5.97 mAHD, maximum depth of 2.87 m, outlet pipe of 450mm;
- Peak flows entering the Holiday Park at the reporting line are reduced from 6.72 m^3/s to 0.54 m^3/s;
- Peak flood levels within the site are reduced by 0.03 m;
- The flood extent is reduced by 30 m and 40 m on the eastern and western sides, respectively; and
- Approximately 5521 m^2 of land around the Holiday Park would no longer be flooded.

In the 5% AEP event:

- The basin top water level is at 5.72 mAHD, maximum depth of 2.62 m, outlet pipe of 600mm;
- Peak flows entering the Holiday Park at the reporting line are reduced from 3.30 m^3/s to 0.96 m^3/s;
- Peak flood levels within the site are reduced by 0.02 m;
- The flood extent is reduced by 20 m and 25 m on the eastern and western sides, respectively; and
- Approximately 3085 m^2 of land around the Holiday Park would be no longer flooded.

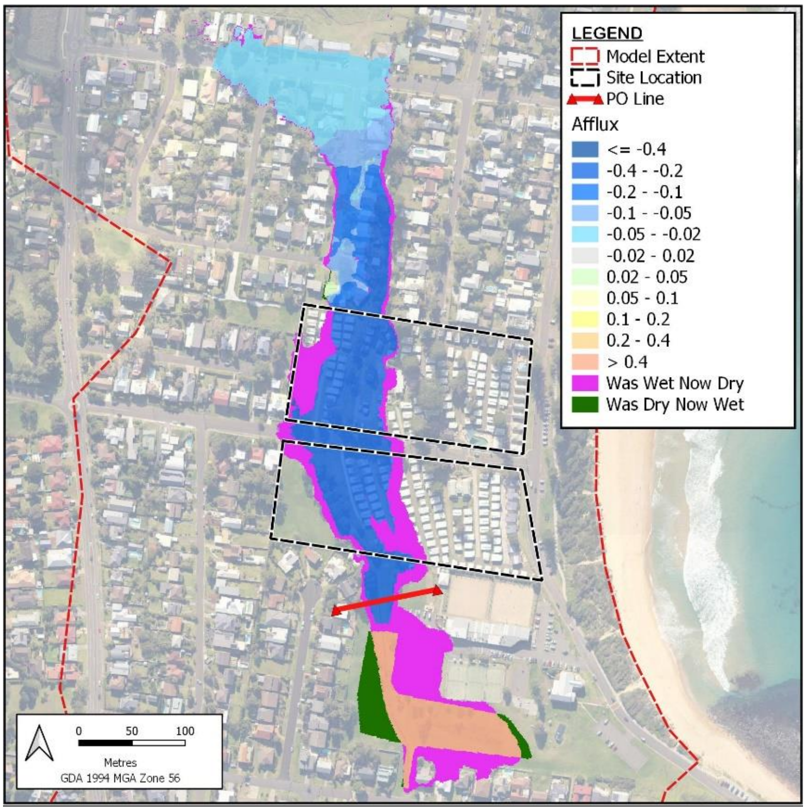


Figure 6-6 1% AEP Water Level Difference – Option 3 less existing conditions

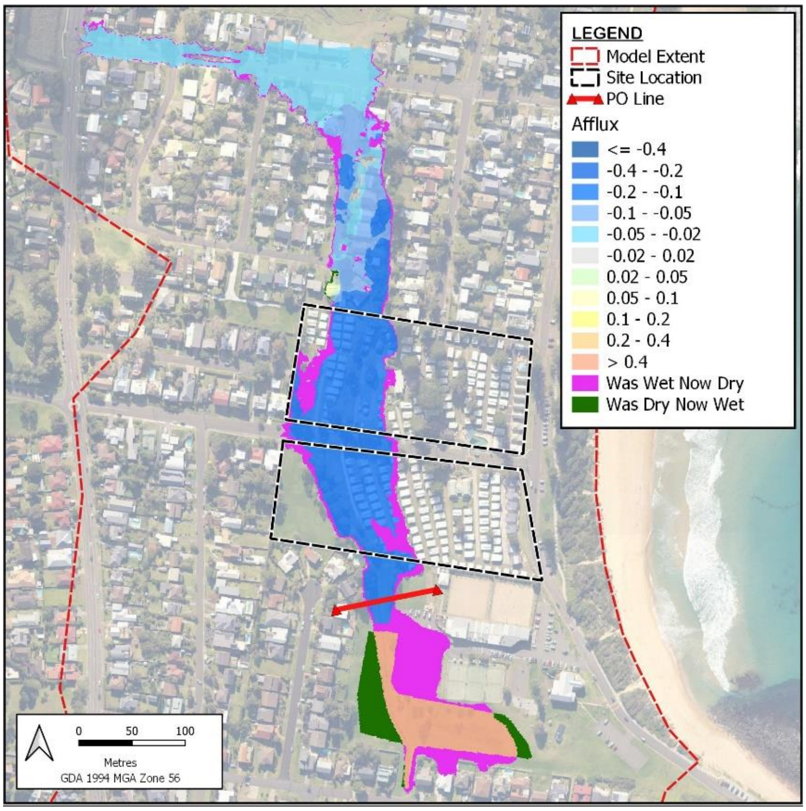


Figure 6-7 5% AEP Water Level Difference – Option 3 less existing conditions

6.2.3.3 Discussion and recommendation

While the basin appears to be the most effective option available, there are a range of concerns associated with the construction of a detention basin at this location relating to public safety, particularly the risk that children play in the deep ponded water. The outlet culvert would also require specific design consideration to ensure there is no risk to the public caused by the potential suction effect.

Construction of a raised bund along the rear of properties along Geering Street would also limit the ability of local runoff to drain northwards. A network of culverts would be required to service this need during minor events, with back-flow prevention valves fitted to ensure flooding is not worsened when levels in the basin rise.

Council has indicated that for 10,700 m^3 of cut to be excavated, removed and spoiled outside the floodplain would cost in the order of $3M, a capital cost unlikely to be offset by the limited benefits available.

In discussion with Council on the 25th of March WMS and Council resolved not to pursue the basin option further.

6.2.4 Option 4 – Increase Channel Capacity

6.2.4.1 Overview

This option shown in Figure 6-8 looks at increasing open channel capacity to the west of the Holiday Park in the southern portion of the site, with the aim of reducing the peak flows through the park. The ground levels in the southwestern corner rise quite quickly, so rather than considering a triangular shaped area cut in the southwest corner, broadening the whole channel was considered more technically feasible as significantly less cut would be required to produce the same amount of storage capacity.

Features of the increased channel include:

- Approximate footprint of 0.31 ha;
- Removal of approximately 2,400 m^3 of spoil; and
- Widening the base of the existing channel from 7 m to 20 m and grading the banks to meet the exiting ground surface level.

Figure 6-8 demonstrates the terrain comparison between Option 3 and the existing scenario.

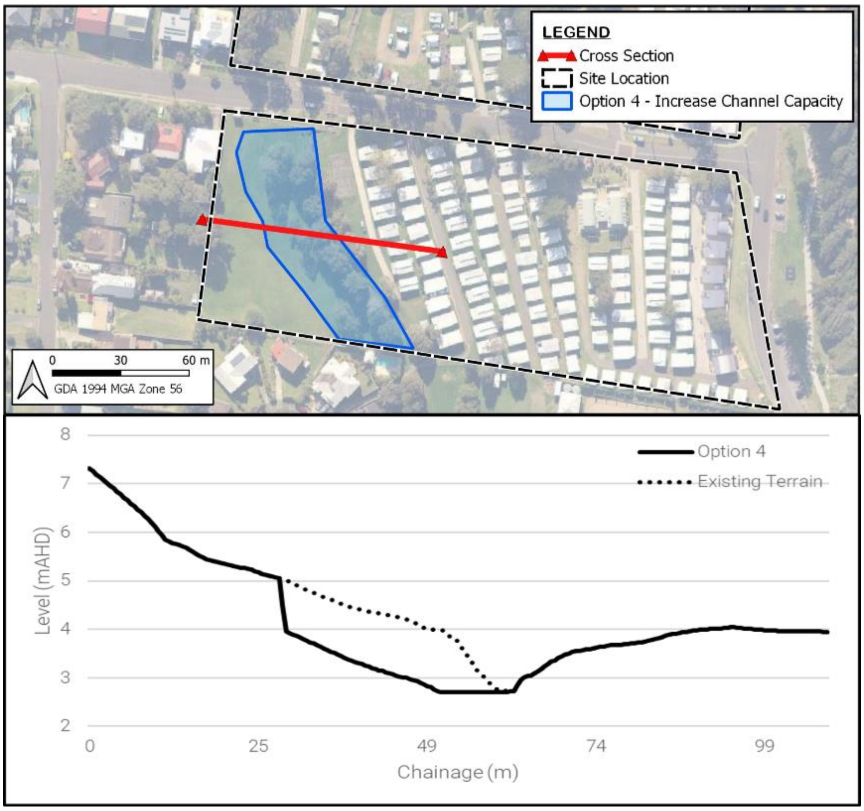


Figure 6-8 Cross Section - Comparison Option 4 and Existing Terrain

6.2.4.2 Impact

The widened open channel was modelled for the 1% AEP and 5% AEP events and compared to the corresponding existing scenario results to determine its effectiveness. The impacts are shown in Figure 6-9 and Figure 6-10 for the 1% AEP and 5% AEP events respectively.

In the 1% AEP event, the following observations are made:

- Peak flows entering the Holiday Park at the reporting line are reduced from 6.72 m^3/s to 6.35 m^3/s;
- Peak flood levels in the upstream of the site are reduced by 0.03 m;
- The flood extent is increased by 15 m on the western side; and
- Overall, there is a minimal impact on flood levels around the Holiday Park.

In the 5% AEP event:

- Peak flows entering the Holiday Park at the reporting line are reduced from 3.30 m^3/s to 3.25 m^3/s;
- Peak flood levels in the upstream of the site are reduced by 24 mm;
- The flood extent is increased by 15 m on the western side; and
- Overall, there is a minimal impact on flood levels around the Holiday Park.

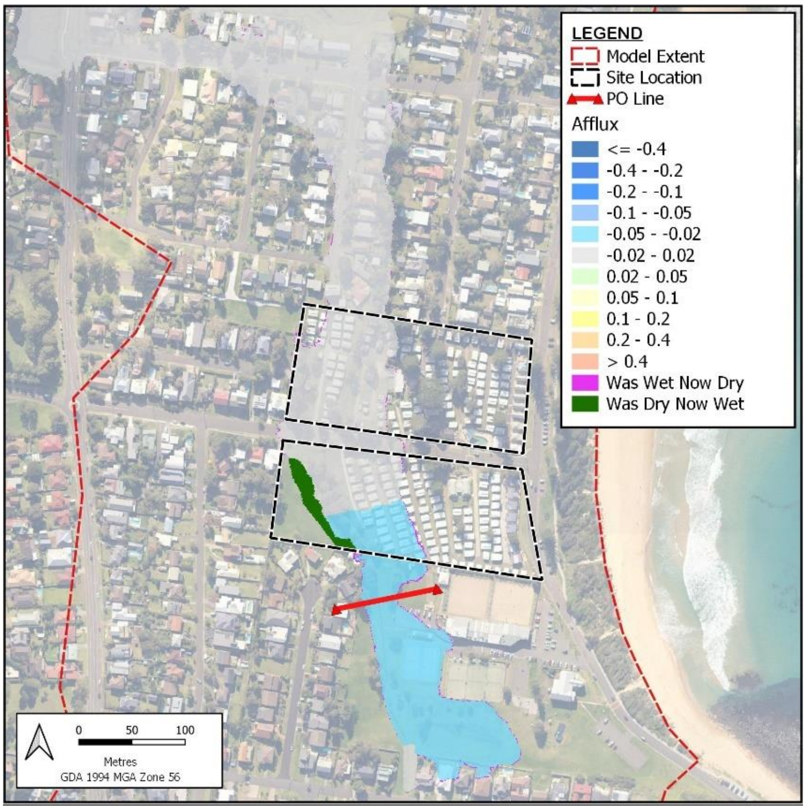


Figure 6-9 1% AEP Water Level Difference –Option 4 less existing conditions

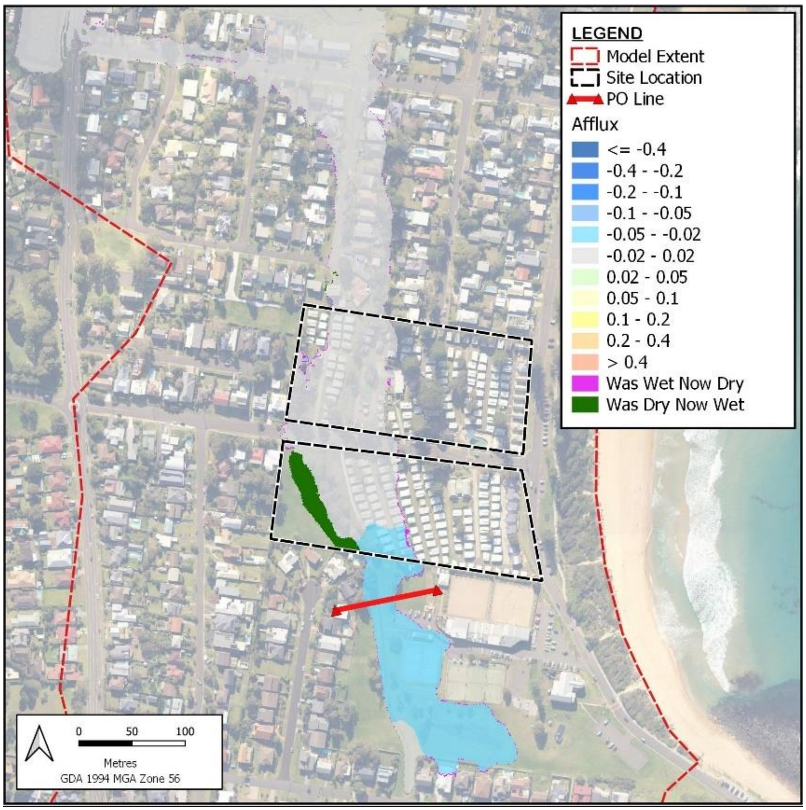


Figure 6-10 5% AEP Water Level Difference –Option 4 less existing conditions

6.2.4.3 Discussion and recommendation

The increased open channel provides additional storage, however does act to not reduce the flooding extent on the eastern side of the channel. This option reduced water levels upstream but has minimal impact on the flood levels within the Holiday Park site as flow would still enter the park as under the current regime. Without additional bunding to protect the park, additional storage is not considered worthwhile. Bunding around the park is not considered an appropriate solution as it would require moving a number of fragile caravans during construction, and would essentially create a levee at entry points that would not be suitable for caravans to traverse safely.

Construction of this option would also raise similar concerns as with Option 3 in regards to public safety with the creation of deep ponded water and the location of the large underground culvert directly downstream of the open channel.

In discussion with Council on the 31st of March, WMS and Council resolved not to pursue the option 4 further.

6.3 MITIGATION OPTION SUMMARY

The outcomes of the options assessment are summarised in Table 6-2 below and depth and hazard maps are available for options 2, 3 and 4 in Appendix E.

Table 6-2 Mitigation Options Outcomes

ID	Option	Outcome
1	"Do nothing"	No immediate actions to be taken, long term raising of dwellings above FPL and reduction of flood risk, see Section 7. Recommended
2	Regrading Lot 1 DP 1075959 to direct overland flow towards beach	Creation of diversion path would not materially increase net lettable area, decrease flood levels within the site or reduce risk to patrons enough to warrant excessive cut required to achieves the flowpath bed slope. Not Recommended
3	Detention basin in Lot 1 DP 1075959	The basin is the most effective option available however there are concerns in regards to public safety and the capital cost of construction would be unlikely to be offset by the limited benefits available. Not Recommended
4	Triangle cut and fill in southern Werri Beach Holiday Park site	Increasing the capacity of the open channel does not result in a significant reduction of flood levels and the deep ponded water creates public safety concerns Not Recommended

7 FLOOD RISK PRECINCTS

7.1 BACKGROUND

Flood Risk Precincts (FRPs) provide a means of classifying flood prone land (up to the PMF) extent based on the level of flood risk to which they are subject. FRPs are then commonly used to determine the flood related development controls that are suitable to be applied to manage flood risk to persons and property. Flood related development controls typically include considerations relating to flood compatible building materials, siting of new structures, management of flood impacts and adoption of minimum floor levels to reduce damage to properties.

Following discussion with KMC, WMS has completed a preliminary Flood Risk Precinct classification for the Werri Beach Holiday Park in line with the Shoalhaven DCP 2014 (Chapter G10, Caravan Parks in Flood Prone Areas).

7.2 FLOOD PLANNING LEVEL DEFINITION

For this investigation the FPL has been adopted at the 1% AEP flood level + 0.5m freeboard, in line with the definition from the 2020 Kiama DCP Section 2.5.2 (Kiama Municipal Council, 2020). A freeboard of 0.5m was added to the 1% AEP water surface level throughout the Werri Beach Holiday Park site. The 1% AEP flood extent was then extended to match the topography and represent the new flood planning extent with a 0.5 m increase to the 1% AEP flood levels. This Flood Planning Area extent was then used to determine the Flood Risk Precincts for the Werri Beach Holiday Park.

7.3 FLOOD RISK PRECINCT DEFINITION

The Flood Risk Precincts were defined using Figure 5 from the Shoalhaven DCP which uses flood affectation to determine the caravan park flood risk precinct, depicted in Figure 7-1. At present, there is insufficient information to determine the evacuation capability of land below the FPL as required by the Shoalhaven DCP (an excerpt is provided in Appendix G to this report). Therefore, as a conservative approach, all areas with the FPL flood extent have been categorised as 'High' for this assessment. Figure 7-2 depicts the flood risk precincts for the Werri Beach Holiday Park.

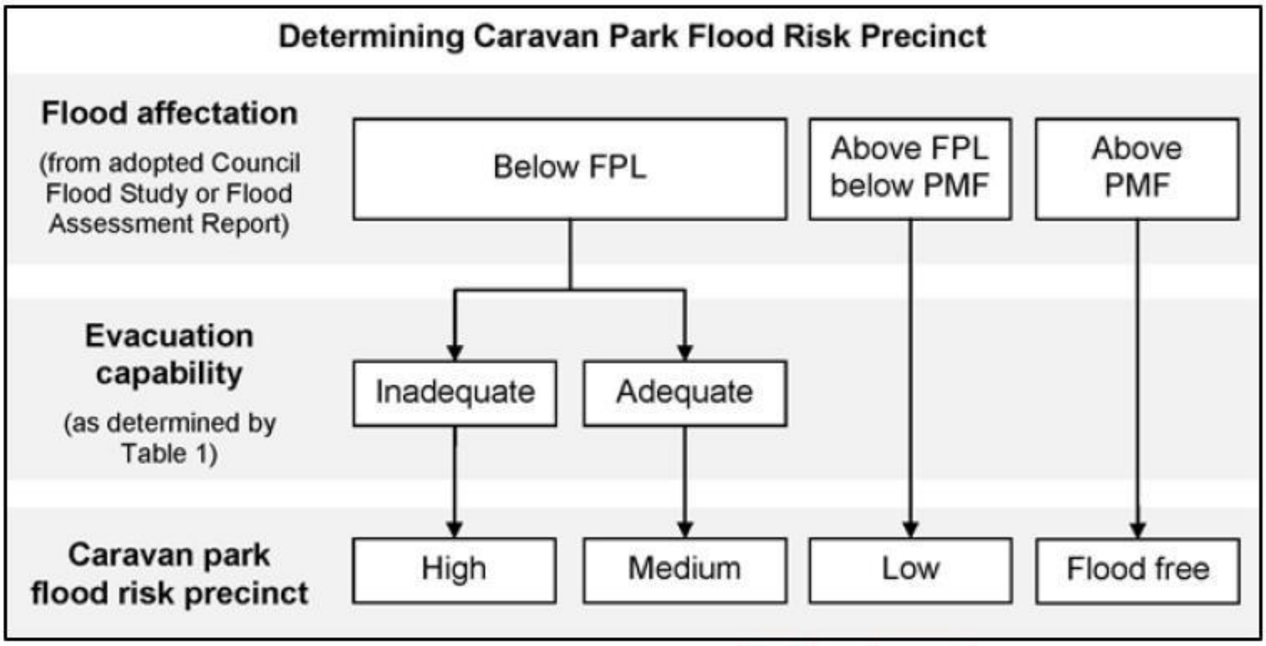


Figure 7-1 Determining Caravan Park Flood Risk Precincts (adapted form Caravan Park Flood Safety Study 2008) (Source: Figure 5, 2014 Shoalhaven DCP)

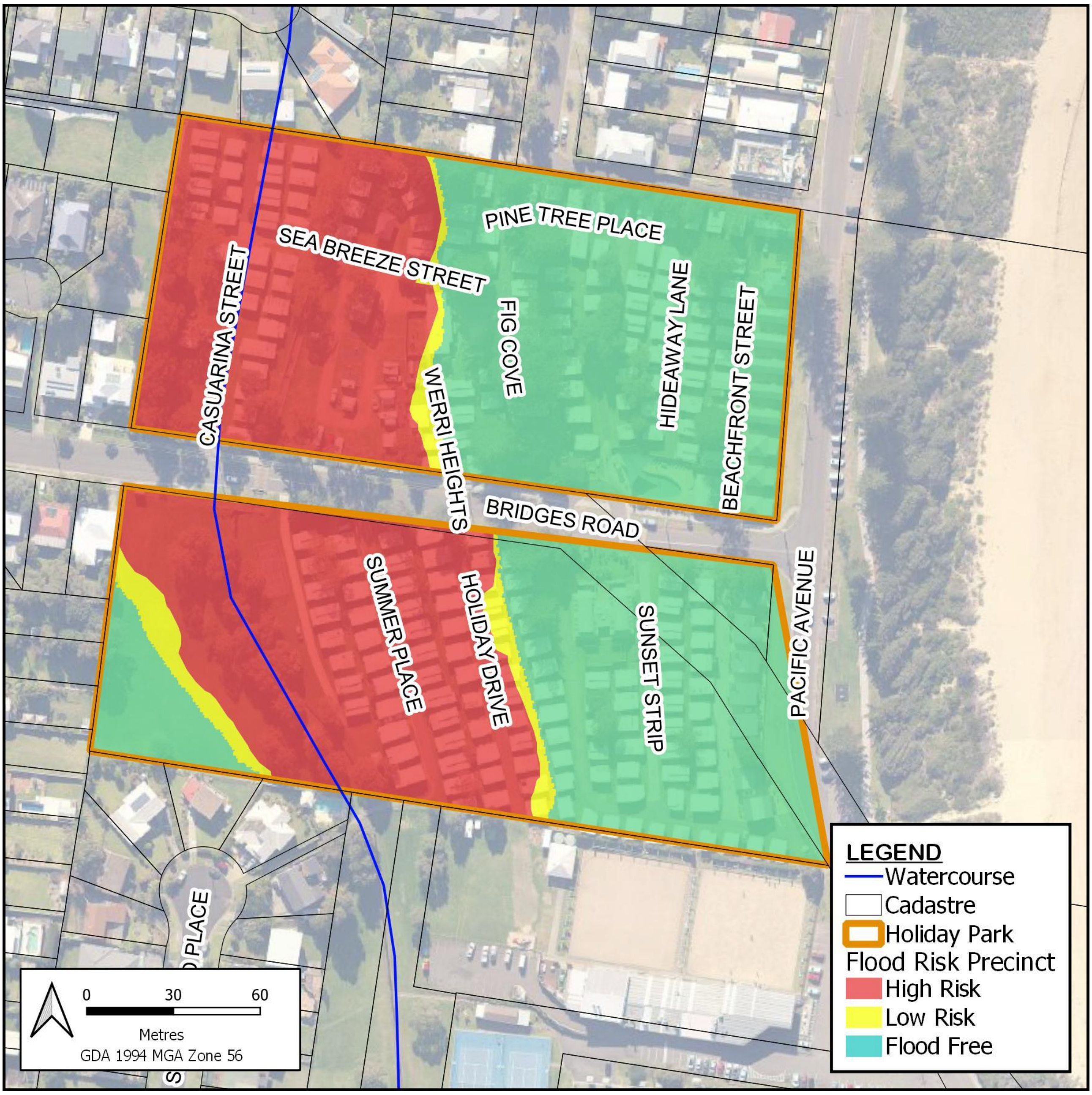


Figure 7-2 Flood Risk Precincts

7.4 NEXT STEPS

The Flood Risk Precincts correspond with Schedule 5 of the Shoalhaven DCP and determines the application of flood related development controls within the Holiday Park. The creation of these flood risk precincts is the first step in Option 1 to use flood planning controls to reduce the flood risk to patrons of the Werri Beach Holiday Park.

The following steps (outside the scope of this report) will need to be investigated further to be able to complete the determination of the flood planning controls for the site:

- Evacuation constraints are to be addressed, in accordance with the table provided in Appendix G, to determine the appropriate evacuation capability for the Werri Beach Holiday Park. This has the potential to reclassify the 'High Risk' Flood Risk Precincts to 'Medium Risk' and allow for a larger scope of redevelopment to occur.

- Development of a set of flood related controls for the Werri Beach Holiday Park based on the available guidance in Chapter G10, Caravan Parks in Flood Prone Areas from the 2014 Shoalhaven Development Control Plan, to assist in managing flood risk to future development and renewal within the Holiday Park.

8 SUMMARY AND CONCLUSIONS

Kiama Municipal Council (KMC) is planning to redevelop the northern area of the Werri Beach Holiday Park, located at 1A Bridges Road, Gerringong. The site is relatively flat, with a watercourse running along the western boundary. This proximity to the watercourse, limited gradient across the site and the hydraulic control of Werri Lagoon means that the site is subject to flood risk during storms and may take hours if not days to drain to the north.

A flood assessment was completed by WMS to inform the Council of construction constraints and mitigation options that may be available to reduce flood risk at the Werri Beach Holiday Park. Several mitigation options were investigated and assessed and the final four options are listed below:

- Option 1: "Do Nothing" and apply long-term planning controls
- Option 2: Diversion flowpath to Werri Beach
- Option 3: Detention basin
- Option 4: Increase channel capacity

Option 1 involves the application of flood planning controls (as outlined in Section 7) to be applied as dwellings (or caravans/cabins) are renewed or redeveloped to ensure the development continues to improve its compatibility with the flood risk at its site. This option would not require any immediate structural works; however it would require dwellings within the flood extent to be raised to above the FPL overtime to lower the flood risk, see Section 7. A preliminary set of Flood Risk Precinct classifications have been defined for the Holiday Park based on the methodology adopted in the Shoalhaven LGA. Further investigation of evacuation constraints may allow Council to downgrade areas currently classified as High Risk to Medium Risk, and potentially increase the area able to be safely developed within the site. Once the FRPs are confirmed, it is recommended that a suite of flood related development controls be adopted for the Holiday Park. This analysis is outside the scope of the current assessment.

The outcomes of the four options are summarised in Section 6 and, in conjunction with KMC, WMS conclude that Option 1 is recommended for implementation. The assessment confirmed that structural mitigation options including a detention basin, diversion swale and increased channel capacity do not effectively reduce flood risk within the site and are not recommended for further investigation.

9 REFERENCES

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors) (2016). Australian Rainfall and Runoff: A Guide to Flood Estimation, Commonwealth of Australia.

Smec (2019) The Ooaree Creek and Werri Lagoon Catchment Flood Study Report (Final), Prepared for Kiama Municipal Council, Ref No. 30011032, North Sydney NSW.

Catchment Simulation Solutions (2021) Gerringong & Jamberoo Flooding Investigation, Prepared for Kiama Municipal Council, Sydney NSW.

Cardno Lawson Treloar (2006) *Elliot Lake - LIttle Lake Flood Study,* Shellharbour City Council, Sydney NSW.

NSW State Emergency Service (2017) Illawarra Flood Emergency Sub-Plan, Volume 1, Wollongong NSW.

Kiama Municiple Council (2020) Kiama Development Control Plan 2020, Kiama NSW.

NSW Government (2021) Six Map Clip and Snip, NSW Department of Finance and Services, Bathurst, NSW, accessed at https://maps.six.nsw.gov.au/clipnship.html

Shoalhaven City Council (2014) *Sholhaven Development Control Plan - Chapter G10: Caravan Parks in Flood Prone Areas.* Shoalhaven: Shoalhaven City Council.

Wollongong City Council (2009) Wollongong Development Control Plan, Wollongong City Council, Wollongong NSW.

APPENDIX A

FLOOD MODEL DEVELOPMENT

A.1 HYDROLOGICAL MODELLING

A.1.1 Design Rainfall

Table A-1 Design Rainfall Intensities (location: -34.742,150.831)

Duration (min)	1% AEP (mm/hr)	5% AEP (mm/hr)
10	41.4	29.1
15	51.5	36.1
20	59.1	41.4
25	65.3	45.7
30	70.6	49.4
45	83.1	58.3
60	92.7	65.4
90	108	76.9
120	121	86.6
180	141	103
270	168	124
360	191	143
540	231	175
720	266	202
1080	325	248
1440	376	285

A.1.2 Critical Duration Selection

For the purposes of this study, the critical duration is defined as the length of storm that produces the highest peak flood level in our area of interest.

The temporal pattern selection was completed by finding the median of the 10 temporal patterns and adopting the Temporal Pattern which resulted in the one above the median, i.e. the 6th temporal pattern when sorted lowest to highest. The one above the median is adopted as a conservative approach, as typically the median peak flow will be between the 5th and 6th ranked temporal pattern. This was done for each duration and resulted in a duration and temporal pattern combination for each duration to use in the critical duration selection. The following table, Table A-2, provides an example of the temporal pattern selection, with the selected temporal pattern bolded.

Table A-2 WBNM Peak Flows Sub Catchment 24.1 – 1% AEP 15min storm

Temporal Pattern	Peak Flow (m^3/s)	Ranking (Low to High)
1	6.51	1st
2	6.55	2nd
3	6.62	3rd
4	6.69	5th
5	6.78	8th
6	6.73	7th

Temporal Pattern	Peak Flow (m^3/s)	Ranking (Low to High)
7	6.65	4th
8	6.70	6th
9	7.08	9th
10	7.16	10th

The peak flows at the site were then compared for all durations, and the maximum flow at the site was selected as the critical duration. This critical duration as well as three above and three below was then selected to be run in the hydraulic model. The decision to include three durations above and below the critical was due to the nature of the large underground pipe bypassing the site. The WBNM model captures the catchment as overland flow and does not take into account the pipe network system, therefore a larger envelope of durations will ensure if the critical durations changes between the hydrology and hydraulic model the peak flows are still captured in the hydraulic model. The following table, Table A-3, depicts the storms selected to run in the hydraulics model and the peak flows at the site associated with each storm.

Table A-3 WBNM Adopted Storms for Hydraulic Modelling

AEP (%)	Duration (min)	Adopted Temporal Pattern	Peak Flow at Site (m^3/s)
1	15	8	6.70
1	20	7	8.14
1	30	1	9.41
1	45	6	10.47
1	60	7	10.41
1	90	8	41.43
1	180	8	8.42
5	30	8	4.99
5	45	9	5.67
5	60	8	5.62
5	90	5	6.30
5	180	2	5.89
5	270	1	5.42
5	360	7	4.85

A.2 HYDRAULIC MODELLING

A.2.1 Hydraulic Roughness

The adopted hydraulic roughness (Manning's 'n') values for each land use are listed in Table A-4. The spatial distribution of roughness is shown in Table A-4.

Table A-4 Adopted Hydraulic Roughness Values

Land Use	Adopted Manning's 'n'
Urban Residential (excluding building footprints)	0.10
Building Footprints	1.00
Roads and Car Parks	0.025

Land Use	Adopted Manning's 'n'
Industrial	0.50
Open Spaces – Minimal Vegetation	0.03
Open Spaces – Moderate Vegetation	0.06
Open Spaces – Heavy Vegetation	0.10

Figure A-1 Updated TUFLOW Model Materials

A.3 BLOCKAGE FACTORS

A.3.1 Background

The drainage network running beneath the site has a large culvert opening at the upstream end and several open channels throughout the network. The culvert receives stormwater from the upstream residential catchment and some areas of the Werri Beach Holiday Park and the open channels run through the Holiday Park and are protected by wire fencing of an approximate height of 1.3 meters. There is the potential for these channels and culverts to be blocked by items in the surrounding Holiday Park such as camping equipment, children's toys, sports equipment such as balls and frisbees or other water sports equipment such as surfboards, boogie boards or kayaks, as well as debris from the upstream urban catchment. Considerations into the blockage factors used in the modelling to accurately represent the potential for the network to be blocked during design storms have been made based on the guidance provided by both surrounding local councils as well as ARR2019.

A.3.2 Industry Guidelines – ARR2019

ARR2019 provides a procedure in Chapter 6.4, Assessment of Design Blockage Levels, of Book 6 to calculate the design blockage of cross drainage structures such as culverts and bridges. The design blockage if the blockage condition that is most likely to occur during a given design storm and needs to be an average of all potential blockage conditions to ensure that the calculated design flood levels reflect the defined probability.

The blockage assessment form provided in Chapter 6.4 was completed and is available in Appendix D. The assessment was completed with extra consideration given to the Holiday Park occupants and items within the Holiday Park which have the potential to worsen the blockage of the hydraulic structures.

The outcomes of this blockage assessment calculated a 100% debris blockage factor and a 15% barrel blockage factor. As outlined in Chapter 6.4 the blockage mechanism creating the worse impact on flood behaviour should be used in design and therefore the 100% blockage factor has been adopted as the ARR2019 blockage factor and noted in Table A 5 below.

A.3.3 Review of Current Best Practice across neighbouring LGAs

Kiama Municipal Council

Review of the KMC documentation did not provide guidance on blockage factors. Discussion with council staff indicated blockage factors are to be calculated considering the objects in the Holiday Park, such as boogie boards, that have the potential to block the culvert openings and open channels. KMC also requested that advice be sought from nearby LGAs to ensure current best practice was applied in regards to blockage factors and public safety.

Wollongong City Council

The Wollongong DCP provides advice on blockage factors to be applied to major stormwater networks based on conduit dimensions and the Design AEP event. The outcomes of applying the Wollongong DCP to the stormwater network at Werri Beach is summarised in Table A-1 and the advice extracted directly from Section 5.2 of the Wollongong DCP is as follows.

2009 Wollongong Development Control Plan (DCP), Chapter E13 Floodplain Management, Section 5.2 Conduit Blockage (Wollongong City Council, 2009)

a) Applicability of this section

i) Blockage applies to all watercourses including creeks, floodways and other trunk drainage systems within the City of Wollongong with the exception of the minor system as defined in Chapter E14 of this DCP. It does not apply to pit blockage. Pit blockage considerations are set out in Section 6.2 of Chapter E14. It does not apply to pipes where the only upstream entry points are from kerb/gutter stormwater inlets (e.g. the minor system).

b) Conduit Blockage factors

i) The blockage factors in Table 1 are to be applied to structures across all watercourses and overland flow paths for all flood-modelling purposes.

c) Peak Flood Envelopes

i) Flooding and impacts are to be assessed using the following two scenarios:

- No Blockage; and

- Blockage factors.

ii) Scenarios requiring various combinations of blockage (e.g. no blockage at some culverts, partial blockage at others) are generally not required.

…

g) Blockage Factors

i) Culvert and bridge classifications are defined as follows:

- Class 1. Pipe 1.2m internal diameter or smaller. Box culverts or bridges with a diagonal opening less than 1.5m, and a width or height less than 0.9m.

- Class 2. Pipes greater than 1.2m internal diameter. Box culverts or bridges with a diagonal opening of more than or equal to 1.5m, less than 3m and minimum dimension of 0.9m for both width and height.

- Class 3. Box culverts or bridges with a diagonal opening of more than or equal to 3m, less than 6m, and a minimum dimension of 1.2m for both width and height.

iii) The blockage factors are to be applied as a reduction in the effective flow area of the unblocked waterway of the structure. The blockage is to be a consistent effective reduction of the total flow area across the entire cross-section (that is, not bottom-up, top-down, or other selective partial blockage of the waterway area). This will typically involve a consistent reduction of the cross-section width (1D hydraulic models) or computational cell width (2D or 3D hydraulic models) representing the structure.

iv) The blockage factors are to be applied to all bridges, culverts and other conduits in the catchment that have the potential to influence the flow behaviour at the point of interest.

Table 1 Blockage Factors

Design AEP	*Bridge/Culvert Classification*			
	Class 1	*Class 2*	*Class 3*	*Class 4*
20% AEP	*60%*	*50%*	*35%*	*5%*
Rarer than 20% and more frequent than 2% AEP (e.g. 10%, 5% AEP)	*75%*	*65%*	*50%*	*10%*
2% AEP or Greater (e.g. 2%, 1% AEP, PMF)	*95%*	*75%*	*60%*	*15%*

Shoalhaven City Council

Discussions with Shoalhaven City Council indicated no similar flood investigations had been undertaken in the Shoalhaven City Council area, however agreed that high blockage factors are to be considered when undertaking flood investigations of this nature. It was suggested to undertake ARR2019 blockage calculations considering scenarios where caravans and tents could be washed up against drainage structures as well as running a sensitivity test to understand the implications of 100% blockage on all drainage structures.

Shellharbour City Council

Discussions with Shellharbour City Council concluded with advice to consider the blockage scenarios modelled as part of the Elliot Lake - Little Lake Flood Study completed by Cardno Lawson Treloar in 2006 (Cardno Lawson Treloar, 2006). This Elliot Lake – Little Lake Flood Study assumed a 100% culvert blockage for sensitivity testing and conducted several sensitivity runs blocking individual culverts within the larger stormwater network. The reason for blocking individual culverts was due to uncertainty of culvert blockage in any given storm and the unpredictability of a single culvert or combinations of culverts becoming blocked. This Elliot Lake – Little Lake Flood Study looked at studies in the Wollongong area and conclude that the studies had indicated that blocked culvert combinations can lead to significantly higher water levels than if each culvert were to be blocked individually. Due to the large networks and number of permutations required to block each potential culvert combination it was the Elliot Lake – Little Lake Flood Study concluded to block individual culverts on a risk/consequence base approach.

The outcomes of Elliot Lake – Little Lake Flood Study concluded that culverts that are capable of carrying a large proportion of the total flow in the unblocked state will lead to the greatest increase in water levels when blocked. Those culverts that are already overtopped under blocked conditions will have a smaller impact on flood levels when blocked. An extent map was produced showing the extent increase in flooded area under blockage conditions and these results indicate that the extent of flooding is not modified appreciably for the culverts that have been investigated.

A.3.4 Ooaree Creek and Werri Lagoon Catchment Flood Study, SMEC, 2019

The 2019 Ooaree Creek and Werri Lagoon Catchment Flood Study calculated hydraulic blockages based on Project 11 'Blockage of Hydraulic Structures' of Australian Rainfall and Runoff ARR, which was the latest industry guidance at the time of the investigation. The blockage assessment considered the entire Ooaree Creek and Werri Lagoon Catchment and adopted the blockage factors listed Table A-5 below. The values are referred to as the 2019 Flood Study.

A.3.5 Adopted Blockage Configurations

A summary of all the potential blockage factors to be adopted in this investigation is depicted in Table A-1. As a conservative approach and to understand the impacts of culvert and pipe blockages 100% will be adopted for both the 1% AEP and the 5% AEP blockage factors for all pipe and culverts in the modelled drainage network.

Table A-5 Potential Blockage Factors

Pipe	1% AEP Blockage Factors			5% AEP Blockage Factors		
	Wollongong DCP	ARR19	2019 Flood Study	Wollongong DCP	ARR19	2019 Flood Study
C-SUR-1	95%	100%	10%	75%	100%	0%
C-SUR-4	95%	100%	10%	75%	100%	0%
C-SUR-7	95%	100%	50%	75%	100%	25%
C-SUR-8	95%	100%	50%	75%	100%	25%
C-EST-37	60%	100%	10%	50%	100%	0%
C-SUR-5	75%	100%	10%	65%	100%	0%
C-SUR-6	75%	100%	10%	65%	100%	0%

Two scenarios have been run as sensitivity tests on the modelling. Scenario 1 (S03) will have all pipes and culverts within the modelling extent blocked by the relevant blockage factors for the two events and scenario 2 (S04) will have only the two culverts that make up the underground pipe network blocked by the relevant blockage factors. Scenario 2 is based on the assumptions that the wire fences in place around the open channel will prevent items being washed into the open channel and related culverts, whereas the large opening to the underground culverts is exposed and directly downstream of areas of the Holiday Park, playgrounds and park area. Figure C-2 and Figure C-3 in Appendix C depict the Open Channel through the Holiday Park and the fencing surrounding it, and the opening to the underground culvert and culvert leading into the open channel respectively. The culvert beneath Fern Street will remain unblocked as it is located downstream and away from the site and is not expected to have any impacts on the water levels and flood extents at the Holiday Park. The two scenarios are summarised in Table A-6.

Table A-6 Updated TUFLOW Blockage Factors Sensitivity Test

Scenario	AEP (%)	Hydraulic Structures Blocked	Blockage Factor
S03	1%	All Culverts and Pipes	100%
S04	1%	Underground Culverts	100%
S03	5%	All Culverts and Pipes	100%
S04	5%	Underground Culverts	100%

APPENDIX B

FLOOD RESULTS

WATER MODELLING solutions

Appendix B - 1
Existing 1% AEP Peak Depth

LEGEND

- Site Location
- Cadastre
- 1% AEP Water Level Contour (m)

1% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

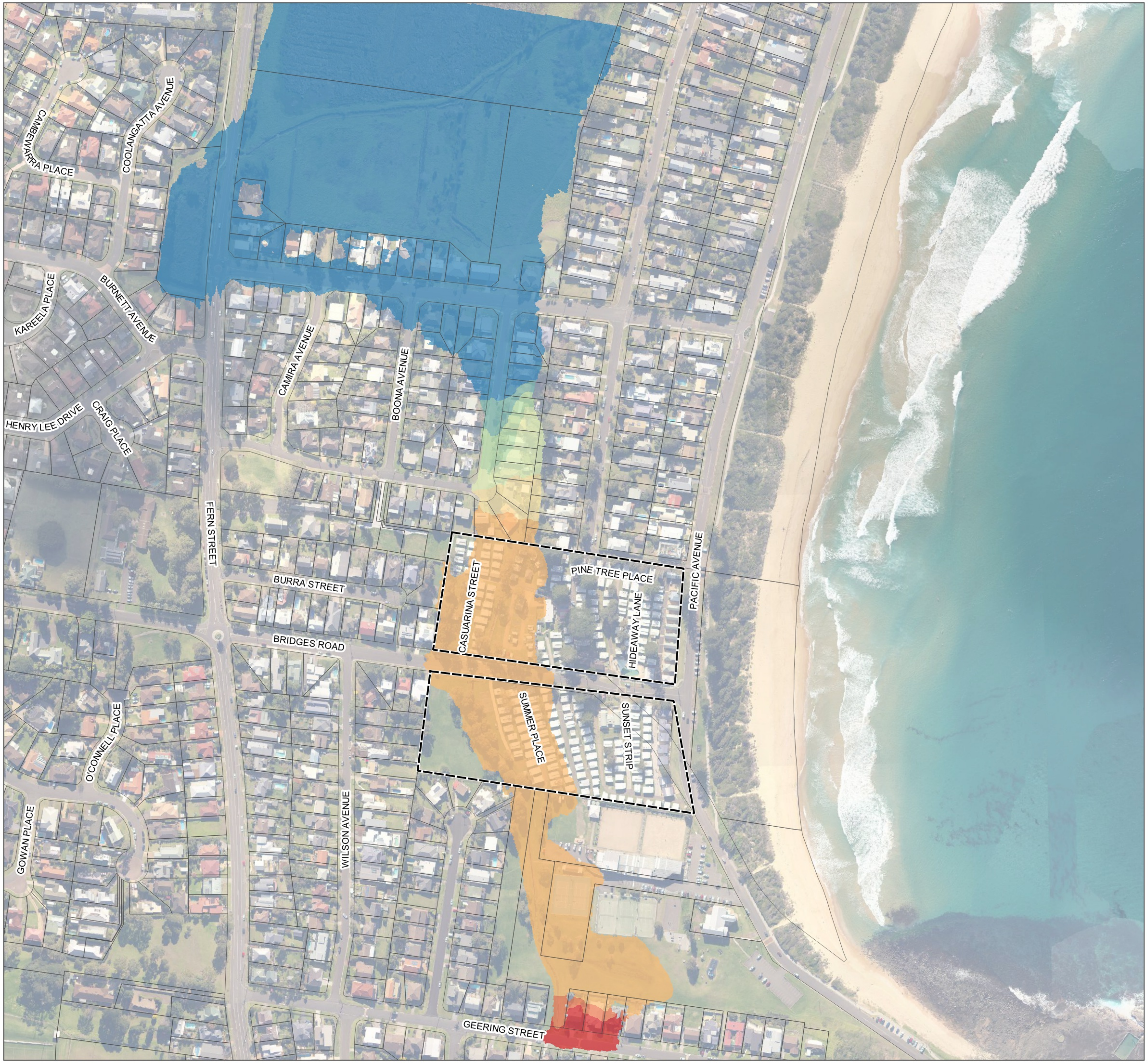
Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions
WATER MODELLING

Appendix B - 2
Existing 1% AEP Peak Level



LEGEND

- Site Location
- Cadastre

1% AEP Peak Height (mAHD)

- <= 3.25
- 3.25 - 3.50
- 3.50 - 3.75
- 3.75 - 4.00
- 4.00 - 4.25
- 4.25 - 4.50
- 4.50 - 4.75
- > 4.75

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix B - 3
Existing 1% AEP Peak Velocity

LEGEND

Site Location

Cadastre

1% AEP Peak Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003

Date: 27/04/2022

WATER MODELLING solutions

Appendix B - 4
Existing 1% AEP Peak Hazard

LEGEND

- Site Location
- Cadastre

1% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions
WATER MODELLING

Appendix B - 5
Existing 5% AEP Peak Depth

LEGEND

- Site Location
- Cadastre
- 5% AEP Water Level Contour (m)

5% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix B - 6
Existing 5% AEP Peak Level

LEGEND

- Site Location
- Cadastre

5% AEP Peak Height (mAHD)

- <= 3.25
- 3.25 - 3.50
- 3.50 - 3.75
- 3.75 - 4.00
- 4.00 - 4.25
- 4.25 - 4.50
- 4.50 - 4.75
- > 4.75

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix B - 7
Existing 5% AEP Peak Velocity

LEGEND

- Site Location
- Cadastre

5% AEP Peak Velocity (m/s)

- <= 0.25
- 0.25 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- 1.5 - 2.0
- > 2.0

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003

Date: 27/04/2022

WATER MODELLING solutions

Appendix B - 8
Existing 5% AEP Peak Hazard

LEGEND

- Site Location
- Cadastre

5% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

APPENDIX C

SITE VISIT PHOTOS

Figure C-2 Open Channel within Holiday Park looking north

Figure C-3 Bridge Road looking north, Underground Culvert (Left) and Open Channel (Right)

Figure C-4 Werri Gully open drain looking north, drawn in flow path of back flow into existing park detention

Figure C-5 Park detention area looking east towards beach, depicted significant elevation change to playground

Figure C-6 Pacific Avenue looking west towards park detention area, depicted significant elevation drop

Figure C-7 Pacific Avenue looking south-west, stormwater drainage kerb inlet

Figure C-8 Pacific Avenue looking north, stormwater drainage kerb inlet

APPENDIX D

BLOCKAGE ASSESSMENT FORM

BLOCKAGE ASSESMENT FORM

STRUCTURE :

OPENING WIDTH:......................m

Australian Rainfall & Runoff

DEBRIS TYPE/MATERIAL/L_{10}/SOURCE AREA - ***There may be more than one material type to consider!***

Debris Type/Material	L_{10}	Source Area	How Assessed

DEBRIS AVAILABILITY (HML) – ***for the selected debris type/size and its source area***

Availability	Typical Source Area Characteristics	Notes
High	• *Dense forest, thick vegetation, extensive canopy, difficult to walk through with considerable fallen limbs, leaves and high levels of floor litter.* • *Streams with boulder/cobble beds and steep bed slopes and banks showing signs of substantial past bed/bank movements.* • *Arid areas, where loose vegetation and exposed loose soils occur and vegetation is sparse.* • *Urban areas that are not well maintained and/or old paling fences, sheds, cars and/or stored loose material etc., are present on the floodplain close to the water course.*	
Medium	• *State forest areas with clear understory, grazing land with stands of trees* • *Source areas generally falling between the High and Low categories.*	
Low	• *Well maintained rural lands and paddocks, with minimal outbuildings* • *Streams with moderate to flat slopes and stable beds and banks.* • *Arid areas where vegetation is deep rooted and soils resistant to scour* • *Urban areas that are well maintained with limited debris present in the source area.*	

DEBRIS MOBILITY (HML) - ***for the selected debris type/size and its source area***

Mobility	Typical Source Area Characteristics	Notes
High	• *Steep source area with fast response times and high annual rainfall and/or storm intensities and/or source areas subject to high rainfall intensities with sparse vegetation cover.* • *Receiving streams that frequently overtop their banks.* • *Main debris source areas close to streams*	
Medium	• *Source areas generally falling between the High and Low categories.*	
Low	• *Low rainfall intensities and large, flat source areas.* • *Receiving streams that Infrequently overtop their banks.* • *Main source areas well away from streams*	

DEBRIS TRANSPORTABILITY (HML) - ***for the selected debris type/size and stream characteristics***

Transportability	Typical Transporting Stream Characteristics	Notes
High	• *Steep bed slopes (> 3%).and/or high stream velocity (V>2.5m/sec)* • *Deep stream relative to vertical debris dimension ($D>0.5L_{10}$)* • *Wide streams relative to horizontal debris dimension. ($W>L_{10}$)* • *Streams relatively straight and free of constrictions/snag points.* • *High temporal variability in maximum stream flows*	
Medium	• *Streams generally falling between High and Low categories*	
Low	• *Flat bed slopes (< 1%).and/or low stream velocity (V<1m/sec)* • *Shallow stream relative to vertical debris dimension ($D<0.5L_{10}$)* • *Narrow streams relative to horizontal debris dimension.($W<L_{10}$)* • *Streams meander with frequent constrictions/snag points.* • *Low temporal variability in maximum stream flows*	

BLOCKAGE ASSESMENT FORM

Australian Rainfall & Runoff

SITE BASED DEBRIS POTENTIAL 1%AEP (HML) - *for the selected debris type/size arriving at the site*

Debris Potential	Combinations of the Above (any order)	Notes
DP_{High}	HHH or HHM	
DP_{Medium}	MMM or HML or HMM or HLL	
DP_{Low}	LLL or MML or MLL	Eg. MML, therefore DP_{Low} selected

AEP ADJUSTED SITE DEBRIS POTENTIAL (HML) - *for the selected debris type/size*

Event AEP	At Site 1% AEP Debris Potential			AEP Adjusted At Site Debris potential
	DP_{High}	DP_{Medium}	DP_{Low}	
AEP > 5% *(frequent)*	**M**edium	**L**ow	**L**ow	Eg. Low
AEP 5% - AEP 0.5%	**H**igh	**M**edium	**L**ow	Eg. Low
AEP < 0.5% *(rare)*	**H**igh	**H**igh	**M**edium	Eg. Medium

Debris Blockage

MOST LIKELY DESIGN INLET BLOCKAGE LEVEL (B_{DES}%) *for the selected debris type/size*

Control Dimension Inlet Width W (m)	At-Site Debris Potential (Generally)		
	High	**M**edium	**L**ow
$W < L_{10}$	100%	50%	25%
$W \geq L_{10} \leq 3{*}L_{10}$	20%	10%	0%
$W > 3{*}L_{10}$	10%	0%	0%

Event AEP	Bdes %
AEP > 5% *(frequent)*	Eg. Low – 0%
AEP 5% - AEP 0.5%	100% (Eg. Low – 0%)
AEP < 0.5% *(rare)*	Eg. Medium – 10%

Refer Guideline if opening H<0.33W

BLOCKAGE ASSESMENT FORM

Australian Rainfall & Runoff

Barrel Blockage

<u>The following tables are only relevant to sites subject to a significant debris load of sediment. Where inlet blockage and barrel blockage are both likely, the blockage producing the greatest impact on flood behaviour should be used in design</u>.

LIKELIHOOD OF SEDIMENT BEING DEPOSITED IN THE BARREL OR WATERWAY (HML)

Peak Velocity Through Structure (m/sec)	Mean Sediment Size Present				
	Clay/Silt 0.001 to 0.04 mm	Sand 0.04 to 2 mm	Gravel 2 to 63 mm	Cobbles 63 to 200 mm	Boulders >200 mm
>= 3	L	L	L	L	M
1.0 to < 3.0	L	L	L	M	M
0.5 to < 1.0	L	L	L	M	H
0.1 to < 0.5	L	L	M	H	H
< 0.1	L	M	H	H	H

Likelihood of Sediment: Eg. Medium

MOST LIKELY DESIGN <u>BARREL</u> BLOCKAGE (Bdes%) ***for sediment of a particular mean size is then;***

Likelihood That Deposition Occurs	AEP Adjusted Sediment Potential		
	High	**M**edium	**L**ow
High	100%	60%	25%
Medium	60%	40%	15%
Low	25%	15%	0%

Event AEP	Bdes %
AEP > 5% (frequent)	Eg. Low – 15%
AEP 5% - AEP 0.5%	Eg. Low 15% – 15%
AEP < 0.5% *(rare)*	Eg. Medium – 40%

For modelling blockage mechanism (type, location and timing), refer to Guideline Table 8

APPENDIX E

MITIGATION OPTIONS RESULTS

WATER MODELLING solutions

Appendix E - 1
Option 2 1% AEP Peak Depth

LEGEND

- Model Extent
- Site Location
- Cadastre
- 1% AEP Water Level Contour (m)

1% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions WATER MODELLING

Appendix E - 2
Option 2 1% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

1% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions WATER MODELLING

Appendix E - 3
Option 2 5% AEP Peak Depth

LEGEND

- Model Extent
- Site Location
- Cadastre
- 5% AEP Water Level Contour (m)

5% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions
WATER MODELLING

Appendix E - 4
Option 2 5% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

5% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix E - 5
Option 3 1% AEP Peak Depth

LEGEND

- Model Extent
- Site Location
- Cadastre
- 1% AEP Water Level Contour (m)

1% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003

Date: 27/04/2022

solutions WATER MODELLING

Appendix E - 6
Option 3 1% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

1% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix E - 7
Option 3 5% AEP Peak Depth

LEGEND

- Model Extent
- Site Location
- Cadastre
- 5% AEP Water Level Contour (m)

5% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
Job No: 20003
Date: 27/04/2022

0 50 100 150 200 m

WATER MODELLING solutions

Appendix E - 8
Option 3 5% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

5% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003

Date: 27/04/2022

solutions
WATER MODELLING

Appendix E - 9
Option 4 1% AEP Peak Depth

LEGEND

Model Extent
Site Location
Cadastre
1% AEP Water Level Contour (m)

1% AEP Peak Depth (m)
- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions WATER MODELLING

Appendix E - 10
Option 4 1% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

1% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500

GDA 1994 / MGA Zone 56

0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

WATER MODELLING solutions

Appendix E - 11
Option 4 5% AEP Peak Depth

LEGEND

- Model Extent
- Site Location
- Cadastre
- 5% AEP Water Level Contour (m)

5% AEP Peak Depth (m)

- <= 0.15
- 0.15 - 0.30
- 0.30 - 0.50
- 0.50 - 1.00
- 1.00 - 1.50
- 1.50 - 2.00
- > 2.00

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

solutions WATER MODELLING

Appendix E - 12
Option 4 5% AEP Peak Hazard

LEGEND

- Model Extent
- Site Location
- Cadastre

5% AEP Peak Hazard

- H1 - No Restrictions
- H2 - Unsafe for Small Vehicles
- H3 - Unsafe for Vehicles, Children & Elderly
- H4 - Unsafe for People and Vehicles
- H5 - Unsafe for People or Vehicles. (Buildings Require Special Engineering Design and Construction)
- H6 - Not Suitable for People, Vehicles or Buildings

Werri Beach Flood Impact Assessment

A3 Scale: 1:3,500
GDA 1994 / MGA Zone 56
0 50 100 150 200 m

Job No: 20003
Date: 27/04/2022

APPENDIX F

DEVELOPMENT CONTROL MATRIX

Schedule 4 – Installation / Activity Types

The installation/activity types (IA types) listed in Table 2 below, are not exhaustive, they are indicative only. **Where an installation or activity does not fit within the IA types, assessment will be undertaken based on merit in accordance with the NSW Floodplain Development Manual provisions**. Council will determine, based on the documentation provided to Council, which IA type the proposal fits into.

Table 2 is to be used in conjunction with Schedule 5.

Table 2: Installation / Activity type description - IA types

Installation/Activity Type (abbreviation)	**Installation/Activity Type** (full description)
Long-term moveable dwelling or relocatable home	Long-term site in caravan park or dwelling site in manufactured home estate occupied by moveable dwelling. Sometimes described as "permanents".
Privately owned moveable dwelling – short term	Short-term site occupied by privately owned moveable dwelling. Sometimes described as "annuals" or "semipermanents". This may include manufactured homes.
Park owned moveable dwelling – short term	Short-term site occupied by moveable dwelling (other than a tent) owned by park and provided for tourist hire. This may include manufactured homes and safari tents.
Rigid annexe	Rigid annexe is an annexe that is not a flexible annexe as defined by the Local Government (Manufactured Home Estates, Caravan Parks, Camping Grounds and Moveable Dwellings) Regulation 2005.
Minor Associated structure	Associated structures such as a carport, small shed (<6m^2), pergola, veranda or similar
Large Associated structure	Garage or large shed (≥ 6m^2)

Schedule 5 – Development Control Matrix – Installations in existing/new complexes and extensions to existing complexes

Caravan Park Flood Risk Precinct	**HIGH**						**HIGH**						**MEDIUM**						**LOW**					
	Replacement of existing development already in a high caravan park flood risk precinct						**New development** in a high caravan park flood risk precinct						**New development** in a medium caravan park flood risk precinct						**New development** in a low caravan park flood risk precinct					
Installation / Activity Type	Long-term moveable dwelling or relocatable home	**Privately** owned moveable dwelling – short term	**Park** owned moveable dwelling – short term	Rigid annexe	Minor associated structure	Large associated structure	Long-term moveable dwelling or relocatable home	**Privately** owned moveable dwelling – short term	**Park** owned moveable dwelling – short term	Rigid annexe	Minor associated structure	Large associated structure	Long-term moveable dwelling or relocatable home	**Privately** owned moveable dwelling – short term	**Park** owned moveable dwelling – short term	Rigid annexe	Minor associated structure	Large associated structure	Long-term moveable dwelling or relocatable home	**Privately** owned moveable dwelling – short term	**Park** owned moveable dwelling – short term	Rigid annexe	Minor associated structure	Large associated structure
Minimum Floor Level		1*	3*						3*				1*	2*	3*									
Building components		1,2	1,2						1,2				1,2	1,2	1,2	1,2	1,2	1,2						
Design & Maintenance		1,3,4	1,3,4						1,3,4				1,3,4	1,3,4	1,3,4	2	2	1,4	4	4	4			
Hydraulic Impact		1,2	1,2						1,2				1,2	1,2	1,2	1	1	1,2						
Evacuation Access		1,2,3,4	1,2,3,4						1,2,3,4				1,2,3,4	1,2,3,4	1,2,3,4				1,2,3,4	1,2,3,4	1,2,3,4			
Management		1,2	1,2						1,2				1,2	1	1	1	1	1						

Legend on next page.

Key:
- (dark) Installation/Activity Type not permitted
- (green) No flood related development controls

Legend: Development Control Matrix – Installation in existing/new complexes and extensions to existing complexes

Minimum Floor Level

1. 2050 1% AEP flood level plus 0.5m freeboard*
2. 2050 5% AEP flood level plus 0.5m freeboard*
3. 2050 5% AEP flood level*

*Note: all development is to be built to the 2050 flood levels (above) or demonstrate that it can be relocated or elevated to the 2050 flood levels, if be directed by Council in the future to comply with future sea level rise conditions. Where 2050 flood levels are not used, the corresponding existing flood level is to be used.

Building Components

1. Any portion of the structure below the flood planning level to be built from materials that will minimise potential damage due to inundation.
2. Where practicable, electrical installations to be above the flood planning level. Otherwise, they must be able to be isolated in the event of flooding.

Design and Maintenance

1. Appropriate engineer's report to certify that the structure can withstand forces of flood-water, debris and buoyancy up to the 1% AEP flood.
2. Appropriate engineer's report to certify that the structure will not become floating debris during a 1% AEP flood.
3. Re-distribution of dwelling type sites within the complex should occur where existing location of structures poses substantial risk to occupants and property.
4. If required as a flood refuge, appropriate engineer's report to certify that the structure can withstand forces of flood-water, debris and buoyancy up to the PMF.

Hydraulic Impact

1. Applicant to demonstrate that the development will not increase flood effects elsewhere. Council may require this to be certified by an appropriate engineer.
2. Appropriate consulting engineer’s report for earthworks of volumes exceeding 250 cubic metres or with a length of more than 20m in high hazard areas.

Evacuation Access

1. Sufficient time/access must be available to evacuate pedestrians to an area of refuge (above at least the 1% AEP flood level but preferably above the PMF and with suitable community facilities).
2. Reliable access should be available for ambulance, SES, fire brigade, police and other emergency services up to a 1% AEP flood event.
3. Sufficient time and access should be available to evacuate vehicles and towable vans/dwellings/structures to an area above the 1% AEP flood level.
4. Applicant to ensure that the Caravan Park Flood Evacuation Plan is updated to include the new installation.

Management

1. Applicant to demonstrate that there is an area where hazardous and valuable goods can be stored above the 1% AEP level plus freeboard.

2. Applicant to demonstrate that there is an area where animals can find refuge above the 1% AEP level plus freeboard.

APPENDIX G

EVACUATION CAPABILITY TABLE

Table 1: Determining Evacuation Capability

DETERMINING EVACUATION CAPABILITY – ADEQUATE / INADEQUATE

If you answer Yes to all of the questions in Table 1, your caravan park has **adequate evacuation capability**.
If you answer No to any of the questions in Table 1, your caravan park has **inadequate evacuation capability**.
Detailed information and calculations are to be provided in the flood emergency management plan. This will be used to confirm the information provided below.

QUESTION	RESPONSE	NOTES
Q1. Is a warning system in place?	Yes/No (circle)	If a warning system is not in place one will need to be established prior to determining the evacuation capability for the caravan park.
Q2. What is the warning system?		Provide brief description (ie. Bureau of Meteorology weather warnings). Full details of the system and how it will be triggered are to be provided in flood emergency management plan (FEMP)
Q3. Warning time:	_____ hours	Provide source of information in FEMP
Q4. Number of people requiring evacuation:	______________ people	Calculate for peak season
Q5. Time/staff required to evacuate people:	_____ hours _____ staff	Use SES paper to calculate
Q6. 'Other actions' to be done during flood:		List (ie. Tie down structures, removal of structures/vans, relocation of hazardous goods)

Q7. Time/staff required to do 'other actions	_____ hours _____ staff	
Q8. Are the total number of staff (Q5 plus Q7) available to conduct evacuation and 'other actions'?	Yes/No (circle)	It is likely Q4 and Q6 will need to be conducted at the same time, therefore the number of staff identified in Q5 and Q7 need to be summed.
Q9. Is an evacuation site available?	Yes/No (circle)	Contact the SES to determine whether an evacuation site is already established for your area
Q10. What is the evacuation site?		i.e. SES identified evacuation site
Q11. If required, do you have permission to use this site?	Yes/No (circle)	If yes, provide written consent in the FEMP
Q12.1. Is there flood free access available to evacuate the site?	Yes (circle) Go to Q13 OR answer Q12.2 and Q12.3	
Q12.2. How long before access is cut by flooding?	_____ hours	Provide source of information in FEMP
Q12.3. Can all people requiring evacuation be evacuated before access is cut.	Yes/No (circle)	Only circle yes if time given in Q12.2. is greater than or the same as Q5.
Q13 Can both Q4 and Q6 be done prior to flood free access being cut?	Yes/No (circle)	Only circle yes if the time to conduct Q4 and Q6 concurrently is less than Q5 or Q12.2 if flood free access is not available. Calculations and timeline to be provided in FEMP.